– An international journal for New Concepts in Global Tectonics –

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New Concepts in Global Tectonics

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For donations, please feel free to contact the Research Director of the Geoplasma Research Institute, Mr. Bruce Leybourne, at leybourneb@iascc.org. For contact, correspondence, or inclusion of material in the NCGT Journal please use the following methods: *NEW CONCEPTS IN GLOBAL TECTONICS.* 1. E-mail: leybourneb@iascc.org (files in MS Word or ODT format, and figures in gif, bmp or tif format) as separate files; 3. Telephone, +61 402 509 420. *DISCLAIMER*: The opinions, observations and ideas published in this journal are the responsibility of the contributors and do not necessarily reflect those of the Editor and the Editorial Board. *NCGT Journal* is a refereed quarterly international online journal and appears in March, June, September and December. *ISSN number*; ISSN 2202-0039.

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EDITOR's CORNER: - Comments by Editor in Chief - Bruce Leybourne

"Earth and Space Weather" At the NCGT 2026 conference in Parma, Italy we discussed advanced tectonics and earthquake forecasting. The NCGT team reunited after fifteen years, for presentations on Earth model innovations and new scenarios to understand geophysical processes and space weather effects.

Prof. Valentino Straser
Earth and Space Weather Advanced Tectonics - Earthquake Forecasting

The Earth and Space Weather: NCGT 2026 International Scientific Conference, promoted in Parma (Italy) by the New Concepts in Global Tectonics -Journal, was created with the aim of promoting rigorous and interdisciplinary discussion on the possible interactions between processes affecting the lithosphere , the atmosphere , and the space environment , with particular attention to high-impact geophysical and geodynamic phenomena such as earthquakes, volcanism, extreme weather events, and other complex natural phenomena.

The meeting aims to foster discussion of interpretative models, experimental observations , and research results related to the potential mechanisms connecting the different environmental factors of the Earth system . While also considering the role of external factors , such as solar activity , geomagnetic variations, and the flux of cosmic rays. From this perspective, the conference aims to contribute to the development of an integrated research paradigm, oriented towards the study of the relationships between terrestrial processes and near-Earth space phenomena. Several elements suggest that seismicity is a planetary "pathology," whereby an earthquake occurs in a given location only when there is a large local accumulation of potential energy. We suspect the pathology may be related to solar magnetic field changes driving differential charge transfer between Earth's capacitance layers. And if so, is this a causal agent of accumulated potential energy linked to the interplay of space weather, lightning and earthquakes. And is this release of charge one causal agent of earthquakes? The "pathology" is simply the cause that triggers the release of local elastic potential energy. Therefore it is necessary to focus on monitoring the planetary "pathology " and its continental and regional implications. The next step is to monitor local crustal stresses in order to focus on the accumulation and propagation of such stresses during the precursor phase of an earthquake. Several contributions presented at this meeting focus on different aspects of this perspective, and we hope that the discussion will pave the way for new assessments and new approaches to addressing this major challenge.

Since its founding, NCGT Journal has been characterized by its focus on innovative perspectives and open scientific debate, founded on the principle of free discussion of ideas and experimental evidence. Born as a forum for debate on unconventional interpretations of tectonics and Earth's dynamics, the journal has progressively expanded its scope to include the study of electrical and electromagnetic phenomena associated with natural, physical, geophysical , and spatial processes . It is now well established—and has been argued for several decades—that plate tectonics is not easily applicable to the Mediterranean region. This area appears to behave differently, and we must seek a new approach that improves our understanding.

Consistent with the tradition of the NCGT Journal, the conference aims to provide a forum for dialogue between different disciplines , fostering encounters between geologists , geophysicists , atmospheric physicists, space physicists, volcanologists , meteorologists , and scholars of Earth and Universe sciences. The goal is to identify new research perspectives and working hypotheses through open, methodologically rigorous, and conceptually unbiased debate.

The scientific community involved hopes to promote an innovative and interdisciplinary vision of natural phenomena, encouraging the development of new avenues of inquiry capable of integrating knowledge from diverse fields and contributing to a broader understanding of the complexity of the Earth-Space system.

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Message from Our Sponsors

Parmafluid's participation in and support for the International Scientific Conference Earth & Space reflects our commitment to contributing to an initiative that brings researchers, scholars and expertise from different fields and countries to Parma, creating an opportunity for dialogue, exchange and the sharing of knowledge.

Parmafluid is an industrial company founded and based in Parma, operating for almost forty years in the highly technical field of hydraulics. Engineering, experimentation, collaboration across different areas of expertise and the development of hydraulic solutions are an integral part of our daily work. This corporate culture has shaped our belief that knowledge is one of the key drivers of innovation and development.

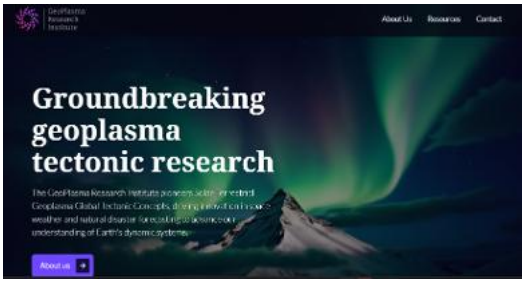
In this respect, there is a tangible connection between our field and the study and understanding of the Earth. Hydraulic technologies are widely used in machinery and systems designed to operate in complex environments, including drilling activities, geotechnical and subsurface investigations, and offshore operations. Scientific research studies interpret these environments, while technology and engineering develop the tools and systems that enable us to operate within them, explore them and understand them more deeply.

Our decision to support the conference is particularly meaningful because it takes place in Parma, the region where our company was founded and continues to grow. From the Apennines to the Po Valley, its geological, natural and environmental diversity represents a valuable heritage to be explored, studied and preserved. We believe that the industrial community also has an important role to play in supporting initiatives that connect the local area with universities, institutions and national and international scientific communities.

It is from this perspective that we have chosen to support Earth & Space Weather: NCGT 2026 International Conference to recognize the value of scientific exchange, critical discussion and research as processes through which knowledge can evolve.

We believe that scientific progress is built on the ability to ask questions, gather and verify evidence, compare different interpretations, and submit ideas and findings to the scrutiny of the scientific community, with full respect for the independence of scientific research.

It is in this spirit that we look to science: as a means of understanding and interpreting the world around us, but also as a driver of innovation and development, and as an essential resource for present and future generations.



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Conference Summary and Field Trip

The articles selected for this issue were submitted and ready before the conference include:

1.) **A potential relationship between luminous globes, tectonics and chemistry in the Taro Valley and the Po Plain Valley** by Valentino Straser.
2.) **On the possible shock action of the Earth's core** by Volodymyr Krasnoholovets.
3.) **The superrotation of the inner core (IC) and changes of its mean radius and shape** by Giovanni Pietro Gregori, Marco Marino, Alberto Incoronato, Bruce Allen Leybourne, Gabriele Paparo, and Maurizio Poscolieri.
4.) **Could high-energy neutrinos trigger earthquakes? The case of deep and simultaneous earthquakes** by Kazunori Miura, Valentino Straser.
5.) **A Geometrical Radial Evolution Model for Earth: (MGREM) model Investigating the Role of Variable Planetary Radius in Continental Separation** by Mojtaba Maleki.

This wide variety of intriguing papers cover a wide range of subject matter related to our general theme of tectonic models of the Earth and its core with a focus on observation of earthquake precursors and their possible forecasting capabilites. The venue was held at the VOCO Parma & Congressi featured here.

Three full days of presentations were given and a field trip into the local Apennine Mountains taken on the third day with some highlights below.

Photo Credit Leybourne

Stefan Ahmala at the Devil's Salti (Devil's Leap) is an ancient sedimentary conglomerate formation of the Cretaceous around 80 million years old. Their origins are traced back to an underwater landslide of pebbles and sand, producing these formations in a vast area stretching from the Monferrato to the Modern Apennines, outcropping in the Baganza Valley. Differential erosion over thousands of years of the resistant and compact stone have resisted erosion more than other sediments nearby which have washed away. Stratification of the conglomerate with decreasing grain size, is made up of a huge variety of mixed continental and oceanic rocks from the disintegration of ancient Alpine rocks. The upper and visible part is made up of a fine and compact sandstone. Legend from the medieval has it that the Devil's Leaps are footprints of the devil, chased away by a hermit who lived in Cassio. The devil tried to tempt him, but the hermit defended himself with a small crucifix left on the rocks sending Lucifer fleeing in an uncontrolled escape are the leaving enormous boulders and scratches clearly visible. A plasma tectonics and electric geology interpretation is warranted for the larger area, as the liquification melted appearance with vortex flow is apparent of the highly resistant rock and is possibly an electrically fused process explained by the Arc blast scenario. Stay tuned in for a reinterpretation of the plasma connection to the greater Alps and Apennine area. The vertical magnetic field ranged slightly higher than the horizontal magnetic field ranging from 0.3 - 0.5 Gauss.

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Other areas included ophiolite sequences of serpentine, peridotite, and basalts with strong magnetic signals from magnetite. Valentino Straser takes magnetic measurements below with a phone app. Strike Slip and normal fault contacts abound.

Photo Credits Leybourne

Landslide below along major fault scarp from regional earthquakes (church below) various conglomerate and flysch.

Photo Credits Leybourne

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And the Grand Finale has Giovanni Gregori reviewing his new book **"Universe out of the Box Worlds and Anti-worlds"**

A very sizable crowd attended, and the food was always exceptional!

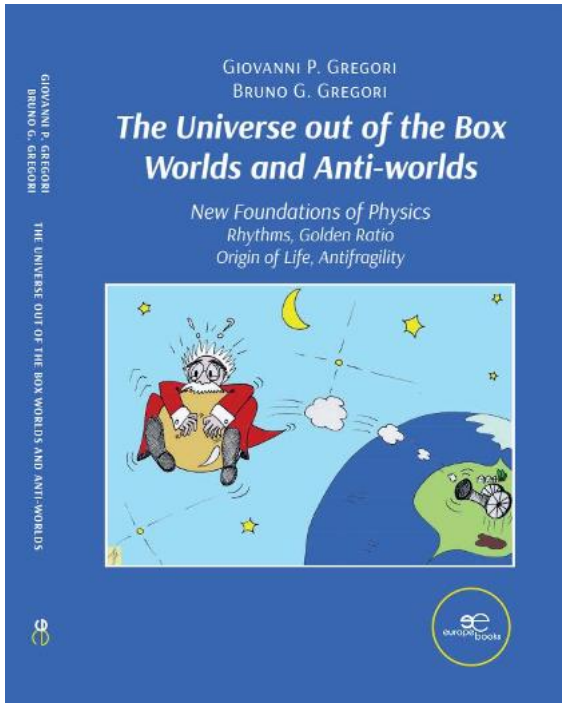

Photo Credits Leybourne

And some Ancient Roman Ruins of the Apennines

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A potential relationship between luminous globes, tectonics and chemistry in the Taro Valley and the Po Plain Valley

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Abstract: Taro River Valley in the northwestern Italian Apennines and the Po Valley represent a natural laboratory for studying the interactions between atmospheric light phenomena, electromagnetic fields, and earthquakes. The recurrent appearance of luminous spheres and seismic events in these areas of Northern Italy correspond to specific geodynamic conditions, generated in response to tectonic stresses caused by the ongoing evolution of the Apennine chain, which is extensional in the Taro Valley and compressional beneath the Po Valley. The transmission of crustal stresses in the Taro Valley is profoundly influenced by outcrops of the ophiolite sequence and clayey sediments, the latter of which can act as a vehicle for the propagation of deformations in the subsurface. Laboratory and field analyses have revealed that the silicate mineral content of clayey outcrops, especially in the surface layers, can trigger piezoelectric phenomena and cause variations in the static electromagnetic field. Further analyses carried out in the Po Valley area, on the chemical composition of luminous globes in the atmosphere, have shown a chemical variability that includes alkaline and alkaline earth elements, oxygen and hydrogen and silicon, peculiar to the soil.

Keywords: clay outcrops, light phenomena in the atmosphere, electromagnetic fields, seismic recurrences, earthquakes.

Introduction

Observed since ancient times and documented since the 18th century (Galli, 1910), anomalous atmospheric phenomena have attracted the scientific community since the second half of the 20th century, thanks also to studies in particularly recurring areas such as Marfa in Texas (Bunnell, 2003) and Hessdalen in Norway (Gori et al., 2001; Montebugnoli et al., 2002; Teodorani, 2004; Teodorani Strand, 2002). Studies carried out in particular in the Taro Valley date back to between the end of the 20th century and the beginning of the 21st century (Straser, 2021), while in the Po Valley experiments have been active for about thirty years by the 45GRU group (Straser, 2022). Research conducted in both the Taro Valley and the Po Valley (**Fig.1**)), which includes studies on microgravity (Straser, 2010), has focused on the potential relationship between anomalous atmospheric light phenomena and seismic activity, as well as the potential relationship between the presence of hydrocarbons, signaled by the recurrence of atmospheric light phenomena in correspondence with oil fields (Straser, 2019). These are transient events, sometimes recurrent, sometimes rare and short-lived, lasting on the order of a minute, which occur at various heights above the ground. Their color varies from red to yellow, from blue to green to bright white. Their recurring shape is spherical, but not always, and they can dissolve in place or undergo sudden accelerations until they disappear into the sky. Their passage or presence in the sky is silent and does not produce any noise. In this study, the possible trigger mechanism for the formation of plasmas(?) is neglected, but the possible relationship between geology and endogenous phenomena with the presence of anomalous light phenomena in the atmosphere is considered and discussed.

Earthquakes, Geology and Tectonic Stress

The relationship between light phenomena, accumulated tectonic stress in rocks and earthquakes has been known and studied for a long time in many parts of the world (Finkelstein and Powell, 1970; Lockner and Johnston, 1983; Derr, 1986; Ouellet, 1990; Tsukada, 1997; St-Laurent, 2000; St-Laurent et al., 2006 Terada, 1931), while in the seismic area of the Taro Valley the author has hypothesized a temporal correlation between light spheres and earthquakes. Luminous phenomena have been recorded not only in the Taro Valley but also in other parts of the Earth (Teodorani & Nobili, 2004; Bunnell, 2003; Strand, 1996-2003; Straser, 2009; Teodorani 2004-2005; Teodorani & Strand, 2001) and have been documented on many occasions with photographic evidence, as in the case of the Matsuhori earthquake in Japan, Mexico, and other parts of the world. A link between tectonic stress and luminous phenomena has already been hypothesized and explained, in the second half of the last century through the

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Fig. 1. Index Map. The circle with the number 1 inside indicates the area under study, and the one with the number 2 indicates the area of the Po Valley under comparison.

theory of piezoelectricity (Derr & Persinger, 1990; Derr, 1986; Finkelstein et al., 1973; Ouellet, 1990). According to this hypothesis, some silicate minerals, such as quartz, produce charged clouds and electric potential through the ionization of the air when subjected to mechanical deformation caused, for example, by crustal stress. The production of electric fields would in turn generate frequencies in the gamma band (Adams, 1990; Hayakawa et al., 2007, Serita et al., 2005, Gori, 2001; Warwick, 1990). Hypotheses about piezoelectricity dependent on mechanical deformation in rocks and the consequent production of electromagnetic fields have been confirmed in laboratory experiments (Brady and Rowell, 1986; Freund, 2002; Freund et al., 2006). The piezoelectric theory, however, has recently been questioned by some scientists who believe that electromagnetic fields would cancel the effects underground. "Charged clouds," argue Freund et al. (2006), would be produced as a result of tectonic activity. Regarding their genesis, it is also hypothesized that tensions due to the release of positive charges in siliceous minerals, according to the conduction modes of semiconductors (Freund, 2003), could trigger luminous phenomena. A fundamental role in this process could be played by the plasticity of clay materials containing quartz or other silicate minerals capable of triggering piezoelectric phenomena, amplified by the presence of water (Lockner et al., 1983). The connection in the Taro River Valley area between earthquakes and luminous events in the atmosphere is of particular interest because, together with periodic seismic activity, it allows us to investigate a possible cause-effect correlation between the two geophysical phenomena" (Straser, 2007). The EQL North Italy group is currently conducting an experiment to determine whether there is a relationship between the color of the luminous globe and a seismic source. Data collected over the past twenty years have shown the red- fuchsia color to be a potential seismic precursor, with sightings close to the ground, usually within 2 degrees, which predict a seismic event within a timeframe of approximately thirty days, but do not provide information on the magnitude and hypocenter of the earthquake (**Fig.2**).

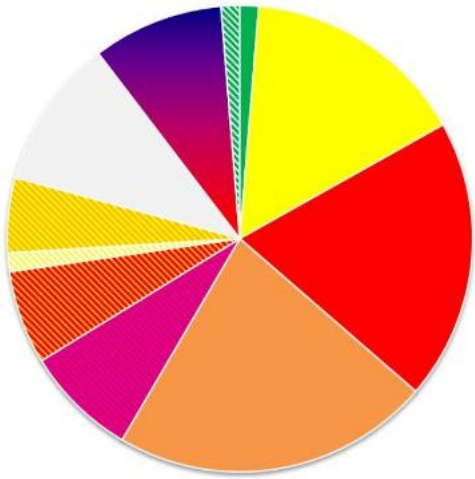

Fig. 2. The graph shows the percentage of color types of luminous globes analyzed over the last twenty years, where red predominates, considered in this research a potential pre-seismic candidate. (Courtesy of Jerry Ercolini and Giorgio De Luca)

Taro Valley

The Taro River valley is a natural laboratory for the study of the relationships between atmospheric light phenomena and earthquakes, both of which are infrequent during the year, in the seismic line of the Taro River (Petrucci et al., 1996, INGV database), which constitutes a corridor for the transfer of energy from the "stretching" Tyrrhenian zone to the "compressing" zone of the Po Valley (Bernini and Papani, 1987). The coincidence between the appearance of luminous spheres in the atmosphere, electromagnetic fields and earthquakes in the Taro River Valley (north-western Apennines, Italy) has been known for several decades, with the first reports dating back to the late 19th century (Baratta, 1891): "19 January 1850 in Borgo Taro an earthquake was felt at 10.30 pm, preceded by a rumbling and a flash of lightning; the sky was clear. 25 February 1850 in Borgo Taro a flash of lightning was seen during the shock that occurred at 9.30 pm." The sighting of small flames, sparks and luminous spheres, locally called "fires", in the Taro Valley (Fig. 1) occurs close to the ground, especially on the furrowed slopes of Solignano, along the valley of the Pessola and Rizzano streams, near

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Masereto and on Mount Sant'Antonio; They are often associated with the presence of gas in the subsoil (Rio & Villa, 1983; Zanzucchi, 1980; Fontana et al., 1994; Morlotti, 1988). Methane emissions in the Argille Scagliose of the Parma area had already been documented by Scicli (1972), Camerana and Galdi (1911) and Camerana (1926). In the locality of Bondi, near Solignano, methane emissions from the clayey soil gave rise to industrial activity, which continued until the 1940s, thanks to the Pietro Vicini company which drilled and extracted gas from a 103-metre-deep well. The first underground explorations date back to the early 1960s, when Agip Mineraria drilled a 3457-metre-deep well in Prelerna, near Solignano, to search for hydrocarbons. Luminous phenomena in the atmosphere have been regularly and accurately observed for years along the Taro River Valley, primarily in its central section. Their distinctive features are multicolored trails and spheres of light. They occur with appreciable but irregular frequency, alternating periods of activity with periods of quiescence. They occur near the ground or a few meters above the ground, usually preceding earthquakes by several weeks. They appear as spheroids or, more rarely, as luminous trails, bubbles, or "flash" effects, remaining suspended in the atmosphere for a few seconds or minutes. When moving, they are described as silent and possessing a certain velocity (**Fig.3**).

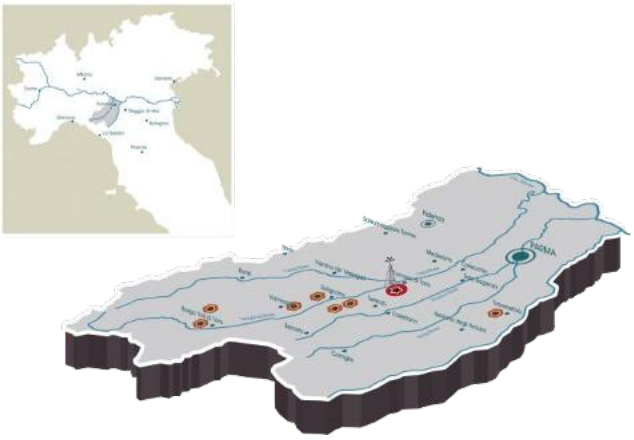

Fig. 3. The hexagonal symbols indicate the places of greatest appearance of the BL, thickened along the seismic line of the Taro River.

Geological context

The Taro Valley, in the northwestern Apennines, is the result of a series of orogenic phases involving the superposition of imbricated strata with a north-northeast polarity and a predominantly NW-SE orientation (Zanzucchi, 1980; Vescovi, 1994; Bernini & Vescovi 2002). The studied area is located in the central part of the Taro Valley and is mainly composed of Cretaceous-Eocene sedimentary rocks from the "Solignano" and "Monte Cassio" tectonic units (Fig. 5). The first is a sedimentary succession that, from bottom to top, consists of the Case Garola polychrome clays and the Solignano flysch, which can be interpreted as the result of seismic events (Mutti, Ricci Lucchi, and Zanzucchi, 1984), with thicknesses ranging from a few centimeters to a few meters. The second is composed, from bottom to top, of the Palombini shales of the Torrente Grontone, the Scabiazza sandstones, the Cassio polychrome clays, the Monte Cassio flysch, and the Viano clays. The tectonic relationships between the two units, where occasional ophiolitic components can be found, are still the subject of scientific debate. The construction of the Apennines responds to unique dynamics, such as "gravitational tectonics," which predicts differential sliding between the rock layers, explaining the presence of non-native rocks that originated in areas distant from their current location and then migrated toward the Taro and Ceno Valleys. The furrow carved by the Taro and Ceno rivers, which exposes the powerful sedimentary successions of Cretaceous Flysch (marine sedimentary rocks dating back to the Late Cretaceous period, such as the Solignano Flysch, consisting of cyclical alternations of sandstone, clay, or marl, generated during orogenic phases), partially reflects a key element in interpreting the seismicity of the Parma area: the seismic line of the Taro River.

The "Taro System," studied since the 1970s, consists of a tectonic alignment congruent with a left-lateral strike-slip kinematics and represents

a "tectonic boundary" because it separates two segments of the mountain range that have deformed differently. The seismicity of the Taro River valley, therefore, stems from a complex geostructural dynamic, and at the current state of research, earthquakes cannot be identified as being generated exclusively in this valley. Instead, these earthquakes occur with some frequency along the "Transversal" Taro System, defined as a tectonic lineament that, oriented southwest/northeast, from the Cento Croci Pass area, touches the middle Taro Valley, near Borgotaro, borders the Monte Molinatico relief to the north, then obliquely crosses the Val Baganza immediately east of Berceto and borders Monte Cervellino to the northwest. The "Taro System" extends across the lower Parma Valley, finally reaching the Po Valley margin at the mouth of the Enza Valley. The "Taro System" complex includes another lineament that largely coincides with the course of the Taro River, along the middle-lower valley. Molli et al. (2018) analyzed the Neogene structural architecture of the northwestern Apennines in this geodynamic context, focusing on the role of low-angle normal faults and thrust faults, sources of seismicity. Modern GPS sensing technologies can record ongoing horizontal and vertical movements of the Earth's surface; these movements are significantly different in the two Apennine blocks separated by the "Taro System."

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Method and Data

Research methods concerned the analysis of rock samples in the Taro Valley area where the railway tunnel is being bored, near Solignano. The survey is meant to find the presence and check the quantity of quartz in the rock formations (argillites, marls and sandstones) as well as other silicate minerals that can be related to the production of piezoelectric phenomena.
For this purpose, sample of clays have been collected and strain tests have been carried out in a laboratory to check both the percentage of volume reduction and the presence of electric and magnetic static fields generated while the samples were under compression.
Measurements were taken by means of a multifield static gauge model ESM-390, to display the variations of natural magnetic and electric fields. The portable instrument, which was also used for laboratory measurements, has the following technical specifications:

Viewer: analogic
Magnetic scale range: from 0 to 50 kHz - from 0 to 100 uT
Electric scale range: from 0 to 50 kHz - from 0 to 1000 V/m
Radiofrequency scale range: from 0.01 mW/cm² to 1 mW/cm² - from 100 kHz to 2.5 Ghz
Operational temperature: 0° C to +50° C

In the laboratory, I simulated the strain condition of a sedimentary rock, that is the multicolor clays of Case Garola which consist of silt clays and argillites of varied colors: red, wine-red, dark grey and greenish grey, often interspersed with thin layers of fine-medium grained, light grey, scaly micaceous arenites, to verify the property that some crystals, such as quartz, have of generating a difference in electric potential when subject to mechanical strain. When external pressure is applied to a crystal, opposite-sign electric charges develop on the opposite faces of that crystal: the variation of the mechanical strain generates an electric signal. Thus, the crystal acts as a condenser to which a difference of potential has been applied, therefore electric current is
generated between the opposite faces of the crystal.

Laboratory experiment specifications.
Volume of rock sample strained in laboratory:
Press cylinder: diameter = 65 mm
Press capacity: 200 bars
Cylinder containing rock: internal diameter = 74 mm; external diameter = 80 mm; height: 180 mm

Type of rock: Multicolour Clays of Case Garola: Calcite (6%), Quartz (12%), Plagioclase (10%), clorite (12%), Biotite (13%), Clayey Fraction (illite, montmorillonite, Kaolinite), 49%

Quantification of Crystalline Phases		
Phase	Weight %	Error %
Calcite	6	+/- 1
Quartz	12	+/- 1
Plagioclase	10	+/- 1
Chlorite	12	+/- 2
Biotite	13	+/- 2
Clay Fraction (Illite-Montmorillonite-Kaolinite)	49	+/- 5

Difrattometric test on clay collected at contact point between Solignano Flysh and Monte Cassio Flysh at Rio Orlando (thanks to Gian Luca Cavalli)

Discussion

Laboratory experiments have demonstrated a link between the production of electromagnetic fields and quartz-containing clay rocks when subjected to compression or, conversely, swelling (Bonini et al., 2002; Di Maio & Fanelli, 1997). The volume of the clay material was approximately 3,000 cm³ (2,930 cm³); it was compressed with the piston of a hydraulic press, first gradually, then abruptly, varying the pressure from 0 to 120 bar, never exceeding 120 bar. During the laboratory experiments, conducted at room temperature (15 °C), the static electric field and the static magnetic field were measured with a portable multi-field instrument, positioned approximately one meter away from the rock sample under pressure. During the simulations, the initial value of the static electric field, E = 2 V/m, remained unchanged until the applied pressure reached approximately 40 bar, while it increased to E = 10 V/m at a pressure of 120 bar. Once the pressure was removed from the rock sample (by operating the hydraulic press), the electric field also decreased almost immediately to its initial values. Throughout the experiment, the value of the static magnetic field varied between 0.2 and 1.0 UT. The experiment provided important information on the behavior of rocks under stress. The press experiments were conducted at pressures ranging from 0 to 120 bar, in an attempt to simulate the conditions of clays under the weight of overlying rock layers. Considering the cross-section shown in (Fig. 8), it is possible to calculate with reasonable accuracy the pressure exerted by the layered rocks on the underlying clay layers. Therefore, considering a density of approximately 2.45 g/cm³ for the marly shales and a thickness of over 200 meters above the clayey compounds, the pressure exerted by the flysch layers on the underlying clayey layers can be compared with the values obtained from the laboratory experiment.

The experiments demonstrated that clay minerals produce both electric and magnetic electrostatic fields when the pressure exceeds 40 bar and gradually increases up to 120 bar. The deformation of the clay was maintained under pressure, and it was observed that, after a few seconds, the static electric and magnetic field values returned to the

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same values recorded at the beginning of the experiment. The compression of the minerals in the clayey formations, which can expand freely under stress, can therefore generate static electric and magnetic fields as long as the piezoelectric minerals are subjected to pressure, while the previous electromagnetic effect disappears when the deformation is removed. Therefore, the presence of clay formations in the study area could be an important factor in the transfer of stress from the subsurface to the surface due to the compression of piezoelectric minerals such as quartz, and in the production of confined electromagnetic fields that, under certain conditions, can give rise to luminous phenomena in the atmosphere. If the appearance of luminous spheres depends on the presence of electromagnetic potentials, it is natural to assume that earthquakes and crustal stresses active in the subsurface could be the cause. The recurrence of almost regular intervals between the appearance of luminous spheres and the occurrence of earthquakes in the Taro Valley seismic zone indicates that stresses in the subsurface propagate with a certain regularity before reaching breaking loads and evolving into earthquakes.

Minerals and chemical elements in the Taro Valley area

Along the Taro Valley, peculiar plasma minerals are present in the area of Rovigo, due to the activity exerted by the clays (Straser, 2017). The chemical elements, associated with the plasmas of the Po Valley, in the collision zone of the Apennine Chain, derive from the analysis of the interaction between meteoric waters and the ultramaphite rocks of the area (Marroni et al., 2002). The results of the analyses, reported by Boschetti and Toscani (2008), indicate that the basalt sources are typically of the Ca–HCO_3 type, and the ultramaphite sources vary from Ca–HCO_3/Mg–HCO_3 to Na–OH/Na–SO_4. Bicarbonate waters, on the other hand, evolve into alkaline waters supersaturated in Ca-(Mg) carbonates, following the dissolution of serpentinite and the precipitation of minerals such as kaolinite, ferrihydrite, vermiculite, Fe_2^+–Mg_2^+ saponite, and poorly crystalline serpentine. Furthermore, the alkaline waters of the Taro–Ceno valleys differ from those of the Voltri Group (Liguria) due to very high B/Cl ratios and a different geochemical evolution (Boschetti and Toscani, 2008).

Potential relationship between chemistry and luminous globes

To attempt a comparison between the chemical elements detected in the investigated area, a spectrometric analysis of a luminous globe, photographed and analyzed in the Po Valley, in the Rovigo area (Italy), was used. The anomalous atmospheric phenomenon was observed by the 45 GRU, photographed by Jerry Ercolini, in the skies of Lendinara, or rather along the course of the Adige River (**Fig. 4**). The sighting of the fuchsia red globe, with orange variations, was made by the 45°GRU-Polesine UAP Research Group during a sky watch in the Barbuglio di Lendinara area (Italy), on July 3, 2026 at 10:26 PM (local time). The luminous phenomenon moved very slowly and appeared very low on the horizon, approximately 1° above the ground, in a direction of 275° west, for the entire duration of the luminous phenomenon, which lasted approximately 2 minutes.

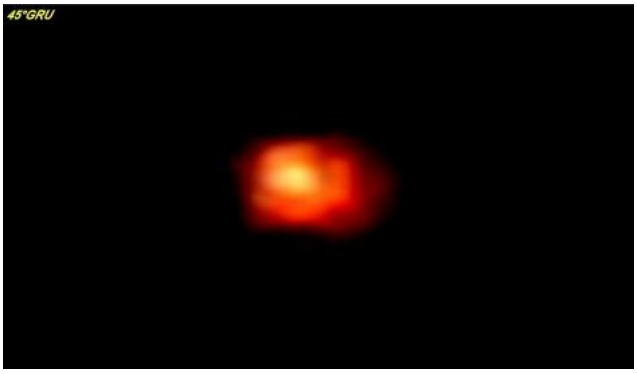

Fig. 4. A luminous globe photographed in the Lendinara area on July 3, 2026. (Courtesy Jerry Ercolini).

No particular trails were observed emitting from the luminous globe, nor any noise attributable to an aircraft, while its brightness was constant, without pulsation or intermittence, and consulting FlightRadar, there were no aircraft so low at that precise moment. It wasn't even a sky lantern or a fireworks/flare, because the research group has also been building a detailed database of known artificial lights for years. The globe was photographed with a 13MP Canon Ixus camera, the only one available at the time, with an exposure time of 0.25 seconds, ISO 4000, and F5.9. A light spectrum (albeit faint) was also detected with a Star Analyzer spectroscope. A few evenings earlier, on June 30th, the 45th GRU also noticed unusual discharges on the 400MHz and 130MHz radio frequencies during radio monitoring in the same area, orienting an antenna precisely towards 275° west. On June 28th, in the Rasa di Lendinara area, a luminous globe was observed and photographed. It appeared suddenly and remained suspended at a very low altitude for 10 minutes, before disappearing like an incandescent lamp. Subsequent spectrometric analyses, despite the globe's fuchsia-red light spectrum, recorded in the final moments before its disappearance, revealed that the composition of the fuchsia-red globe featured strong peaks of hydrogen, oxygen, and nitrogen (**Fig. 5**). An earthquake was recorded along the 400 MHz and 130 MHz radio frequency detection lines on July 24 (http/ingv.it), approximately twenty days after the appearance of the luminous orb.

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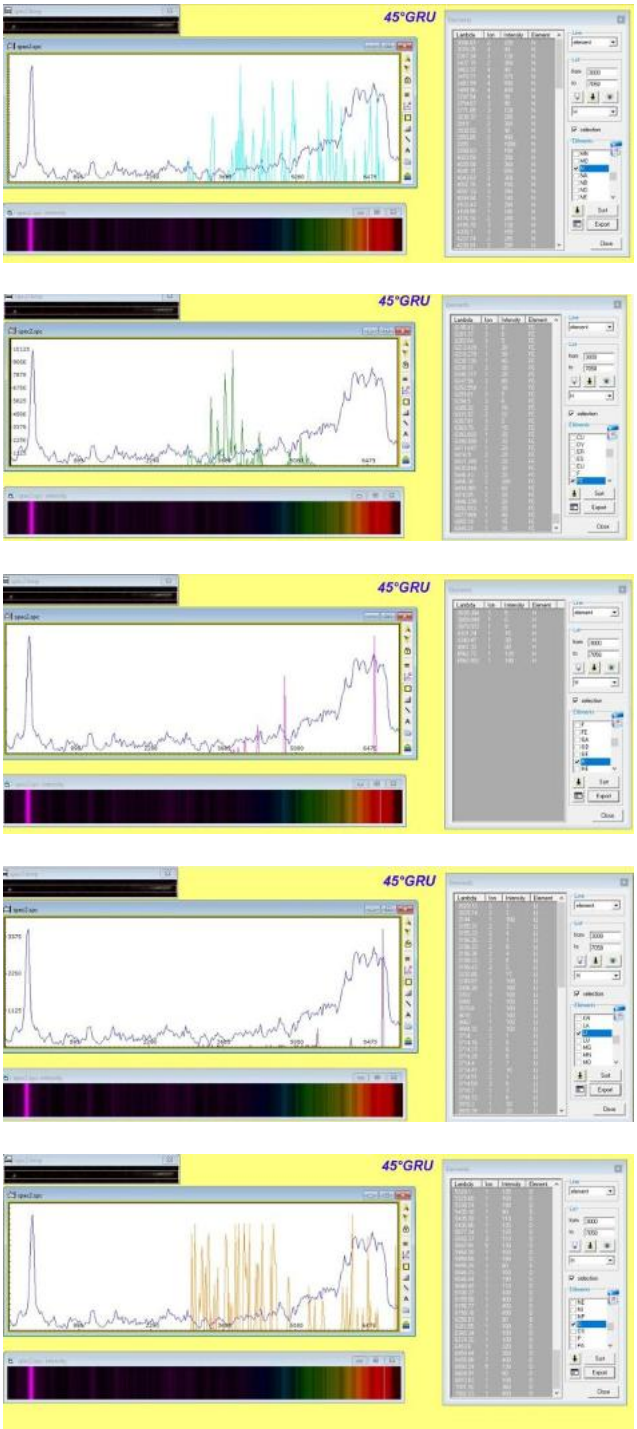
Day	hh:mm:ss (UTC)	Lat.	Long.	Deep (km)	ML	Zone
24-07-2026	21:27:27	45.0113	11.4230	10	2.5	Salara (RO)



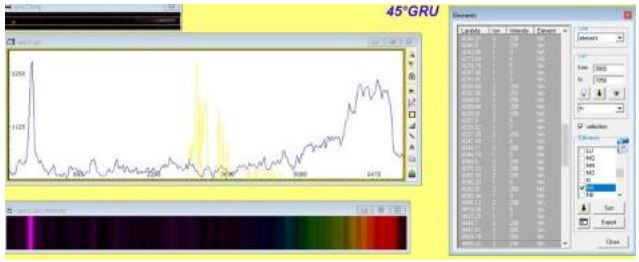


Fig. 5. Spectrometric analysis of the globe photographed on July 3, 2026 (Courtesy Jerry Ercolini)

Hypothesis of interaction between lithosphere and atmosphere

The phenomenon can be interpreted as follows:

1. Crustal stress propagates through the clay formations, which release charged clouds into the atmosphere and produce electromagnetic fields;

2. Piezoelectric minerals that experience pressure changes restore the electromagnetic field to its initial value;

3. The stress continues to propagate underground until it evolves into an earthquake, even many kilometers away from the area where the spheres of light appeared.

The time intervals observed between the occurrence of the two physical phenomena have been shown to be regular for the areas around the right and left banks of the river. The time intervals between the appearance of the sphere of light and the associated earthquake show a delay of several days in the two areas: approximately 55 days in the area around the left bank and approximately 50 days on the right bank (Straser, 2007).

The regularity of the deformation transfer is also confirmed by the relationship between the distance from the location where the light sphere appears and the epicentral area of the associated earthquake; in this case too, the distance varies from bank to bank: on average, about 35 km (area on the left bank of the Taro River) and about 10 km for the right bank.

Conclusion

It can be concluded that the clays present in the study area play a crucial role in the transfer of tectonic stresses, which propagate from the underlying rocks to the Earth's surface. The deformation of clays and piezoelectric minerals can release electrical charges upon contact with the atmosphere, especially in the surface regions.

Charged clouds present in the atmosphere can in turn generate electromagnetic fields, directly linked to the appearance of luminous spheres (Hauge, 2007;

Teodorani 2004-2005; Teodorani & Strand, 2001; Montebugnoli et al., 2002), such as those illustrated in Figures 9 and 10, which indicate the imminence of an earthquake (Straser, V. and Kokus, M., 2008), through the emission of radio frequencies or particular values of the static electric and magnetic field. The presence of chemical elements in the waters circulating in the peridotites and serpentinites of the Taro Valley, also common to the chemical elements present in the globes of the Po Valley area, suggests that the chemistry constituting the plasma is generated by the elements of the soil and in the waters (Mantovani, 2013).

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Ethics

There are no ethical issues associated with the document.

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On the possible shock action of the Earth's core

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Abstract: The starting point for this paper is the presence of a large ferromagnetic domain in the center of the Earth's inner solid core, which was theoretically substantiated by C. Teodorescu (2021, 2022) who coined the name 're-entrant ferromagnetism' for this case. This article considers the creation of a powerful shock wave when magnetostriction is triggered in the Earth's ferromagnetic domain, which is a new mechanism for ejecting material from the Earth's surface, in addition to the known volcanic eruptions, the mechanisms of which are activated in the Earth's crust and mantle. The idea of a shock wave originating in the inner solid core is used to explain the tragedy of an ancient, advanced civilization that perished in the Middle East (i.e., a modern transcontinental geopolitical region centered on Western Asia and Egypt in North Africa) about 12 thousand years ago. In addition, this shock wave, having colossal kinetic energy (maximum at the level of 10^{23} Joules), causes not only enormous destruction on the Earth's surface, but is also able to bring lethal doses of high-energy inerton radiation. Thus, the Earth core shock action appears to have been a major geological driver affecting Quaternary/Prehistoric environmental baselines, which created a physical reality that directly affected hominid and/or prehistoric settings.

Keywords: ancient civilization, ejection of mass, ferromagnetic domain, inertons, magnetostriction, shock wave

Introduction

The global Internet, mobile Wi-Fi, YouTube, and available messengers on mobile phones allow researchers to share their findings and discoveries with humanity. In particular, my attention was drawn to researchers of ancient history who visit ancient ruins and show their finds to the whole world. From watching such documentary videos, I, as a physicist interested in fundamental science, have identified the following global features of the ancient world:

- they were excellent at producing durable concrete/geopolymers (this indicates that they had deep knowledge of chemistry);
- they were perfectly able to cut and process natural stone of any strength weighing up to hundreds of tons using precise mechanisms, as if they were cutting and carving wood, and they did this sometimes in cramped conditions and on such a high-altitude platform that it was impossible to deliver any equipment to it (did they not have anti-gravity technology?);
- cities, settlements, and large areas at any altitude above sea level (up to 1600 m) are buried under a continuous cover of 6–20m fills of clay and mud with admixtures of silt, small stones, marble fragments, small minerals, ceramic and pottery shards, and bones, mostly human.

This last point is the subject of the article presented. Such terrible fills cover the territory of the Near East, Tunisia, and Cambodia – these are the places shown in the documentary videos "Forgotten Ruins" of Maksim Gaubets (2021-2026), as well as the Sahara Desert – where did so much sand come from? Almost 9 million square kilometers of sand; the sand layer is on average 10 meters thick, but there are also large embankments 50 meters thick. The few excavations in the Sahara show that under the sand lies agricultural soil; there are riverbeds, and there are solid stone buildings several stories high. That is, it looks like the Sahara is an area that suffered a terrible catastrophe; fertile lands were covered with sand from above in a short period of time, just like the territory of the Near East was covered with clay and mud mixed with debris. This scale of catastrophe, which generated a layer of sediment 10–20 meters thick, is a globally significant anomaly, and such an event requires an understanding of the geological and environmental mechanism of the end of the Younger Dryas (Sweatman, 2019; Powell, 2022).

When did those disasters happen? In his video Forgotten ruins (Gaubets, 2021-2026), the author indicates a possible date of about 11–12 thousand years

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ago, which is essentially prehistoric time (and this coincides with the start date of the Holocene, the era when global glacial melting began 11,7 thousand years ago). In addition, he also shows that fresher fills were placed on top of the first embankments, and that this occurred approximately 2,000 years ago. The fills have become overgrown with vegetation and are now home to modern humans, and people are farming on these fills.

Morphological Anomalies in Classical Stratigraphy

Figures 1–3 below demonstrate the presence of 10–20 m and higher fills, which are essentially a "Regional Chronostratigraphic Marker Bed." This thick layer physically seals and caps the late Palaeolithic/Epipaleolithic archaeological sites (such as the Natufian or early PPNA horizons in the Levant), explaining the sudden, absolute termination of their tool assemblages and settlements.

Gaubets [1] also noted that in the so-called ancient city of Troy, which is located at an altitude of around 200 m above sea level and is 4.5 km from the seacoast, he found many seashells in the backfills.

So, civilizations died, and in place of the destroyed ones came other, undeveloped ones, and started all over again. Gaubets (2021-2026) notes that he has observed three successive backfills – the first covered the developed proto-civilization, and the Greeks came in their place. But the Greeks suffered the catastrophe of the backfilling too. In their place came the Roman civilization, but it also died under the next backfilling.

This is where it would be appropriate to quote Plato (*Timaeus*) who in his dialog devoted to the origin and structure of the universe noted: "And when in turn gods purify the earth by flooding it with waters, then those who live in the mountains – herdsmen and shepherds – are saved, while those who live in the cities near you are swept into the sea by the rivers. But along this place here, neither then nor at any other time does water stream down on the fields from above, but it all tends by nature to come up from below. Hence, through these causes, the things preserved here are said to be the oldest… But it happens that at any given time your lands and those of other people have only just been equipped with writing and all the things that cities need; and after the usual span of years, the heavenly stream comes back again like a plague to sweep your people away, and leaves only the illiterate and uneducated among you, so that you become young, as it were, all over again from the beginning, knowing nothing either of things here or of whatever was in your own land in olden times. … you remember only one flooding of the earth, whereas many have come to pass before this."

Consequently, the ancients were aware of catastrophes that from time to time destroyed civilization. But can we then learn how these backfills of mixed clay, mud, and debris shown in Fig. 1–3, were formed?

Fig. 1. a: Carthage, Tunisia, traces of disaster. These wide "towers", are the remains of unexcavated embankments that once reached a height of 15 m (https://www.youtube.com/watch?v=qUbqXe-N6o0); b: Geraci (Jerash), Jordan, partially excavated marble columns (https://www.youtube.com/watch?v=xHksxZ_TqBk&t=330s); c: Sardis, Turkey, a high backfill (https://www.youtube.com/watch?v=YuX0yMk6pSI); d: Sardis, Turkey. These are not mountains; it is all backfill from the very bottom to the top (https://www.youtube.com/watch?v=zSHfySyTFjI).

The possibility of collisions between the Earth and space objects cannot be ruled out, because of which the Earth's surface became covered with solid stuff. Undoubtedly, all this massive material fell from the sky. For example, the Younger Dryas impact hypothesis (Sweatman, 2019; Powell, 2022) assumes that at the end of the Last Glacial Period, around 12,900 years ago was the result of some kind of cosmic event, although most researchers believe that it did not happen.

Fig. 2. Anomalous 6-meter sediment backfill obscuring classical street horizons at Laodicea, Turkey (37°50′N, 29°06′E). The altitude of Laodicea is about 1000 m above sea level; the mountains around are far away. There was nowhere to start the mudflow, but it passed here (https://www.youtube.com/watch?v=152GbhzJows).

Some researchers sometimes mention a collision with the hypothetical planet Phaethon/Phaeton (Wikipdia; James and van der Slujs, 2016) and exotic Nibiru. James and Slujs (2016) have examined the myth of Phaeton in detail and noted that the myth appears to be based on some unusual celestial event that was visible in the ancient Near East; Phaeton caused a solar eclipse and devastated the Earth. They derive the origin of the myth from Northern Syria. The stories of ancient people from Asia Minor about Silver (Hurrian), Fire (Hittite) and Erra (Babylonian) contain virtually all the essential motifs of the eventual later Greek version of the myth about Phaeton. These named territories include places shown in Figs. 1–3, i.e., eastern Anatolia, Mesopotamia and Iran.

The events demonstrated in this section happened much earlier than the powerful seismic upheavals that occurred around 2,200 BCE (4.2-kiloyear event). Sehaeffer (1948) also argued that areas of the major sites in the Aegean, Anatolia, the Caucasus, and Iran were levelled by earthquake and the flood, leading to the end of the Early Bronze Age and drought, but did not destroy the community living there.

Kugler (1927) suggested that the same meteor stream (3.4 km in diameter) passed over Ethiopia and the Aegean Sea, producing big fires there and then enormous flood waves in Lake Estonia, creating the Kaali crater field there (now it is dated to about 3,500 BCE). Nevertheless, that event did not bury any civilization.

James and Slujs (2016) have noted that the two possibilities of the original Phaethon being an impactor and a passing comet are not mutually exclusive, and a fireball collision in the Middle East (modern territories from Iran to Syria including Jordan) around 2,200 BCE can explain most of the defining elements of the classical story of Phaethon and its Eastern equivalents.

Tompson III (2017) held research and engineering positions at the former NASA Electronics Research Centre, the U.S. Department of Transportation, and several defense contractors. His avocational interest for over four decades has been in studying cosmic catastrophism affecting the Earth in ancient times. He has compiled an archive containing about 2,750 articles in which researchers,

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including astronauts, have presented evidence that our planet has experienced many more large-scale asteroid collisions than previously thought. Documents about cosmic catastrophes outside the Earth's environment are listed because they may have a bearing on the mechanisms causing catastrophes on Earth.

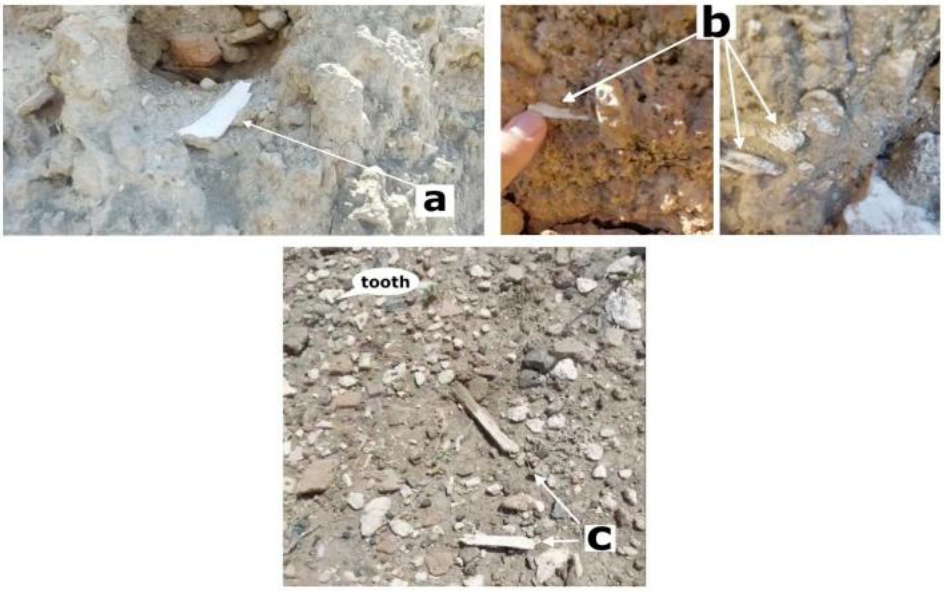

Fig. 3. Fragments of human bones in the backfills, which are almost completely decayed porous structures. Until now, these bone remains have not interested archaeologists in investigating their age and DNA. a: in the backfill wall. Laodicea, Turkey (https://www.youtube.com/watch?v=152GbhzJows); b: in the backfill wall. Elayussy Sebaste, Turkey (https://www.youtube.com/shorts/OH_FNbOJ9jo?app=desktop); c: on the surface of the land. Cybira, Turkey (https://www.youtube.com/shorts/dd7-gDqjcGw?app=desktop).

However, among the articles in Thompson's (2017) archive, we do not come across reports of the catastrophic destructive action of space objects of such force that could significantly distort a large area of the Earth's surface and destroy civilization.

Figures 1–4 reveal a very ancient, excavated civilization buried under a thick layer of an unusual material of the seabed and the Earth's surface. Therefore, the catastrophe is most likely not related to the collision of the Earth with a celestial body but has a purely terrestrial origin.

Gaubets (2021-2026) emphasizes that, apparently, the entire prehistoric highly developed civilization completely perished. The Hellenes, Iranians, and Romans came later to the lands of the lost civilization and to a large extent used and appropriated the excavated buildings and cultural achievements of the lost advanced civilization. But the second civilization also suffered a catastrophe similar to the previous one; in the younger fill that covered the Hellenic and Roman civilizations, modern people often find numerous gold ornaments.

The article is further organized as follows. Section "Materials and Methods" gives an overview of earthquakes and volcanic eruptions, which have been traced back to prehistoric times, and mentions their classification. Section "Results" represents the mechanisms of generation of the Earth's magnetic field and highlights one of them, which alone can explain the physical cause of the large-scale disasters that occurred in prehistoric times. Section "Discussion" provides an analysis of the results. The presented work is largely based on both the author's previous discoveries in fundamental physics (Krasnoholovets and Byckov, 2000; Krasnoholovets and Gandzha, 2012; Krasnoholovets, 2014, 2017; Litinas et al., 2020) and the findings of other researchers focused on studying the mechanism of generation of the Earth's magnetic field (Okonkwo, 2025; Landeau et al., 2022; Aubert et al., 2017; Dumberry et al., 2025; Dormy, 2025; Sens, 2023; Gordienko, 2024; Teodorescu, 2021; Teodorescu and Hușanu, 2022; Lowes and Wilkinson, 1963; Olson, 2011; Verhile et al., 2010; Stoner, 1938), Sens, 2023; Gordienko, 2024; Teodorescu, 2021; Teodorescu and Hușanu, 2022; Lowes and Wilkinson, 1963; Olson, 2011; Verhile et al., 2010; Stoner, 1938), relying on knowledge of the structure and properties of the Earth's core.

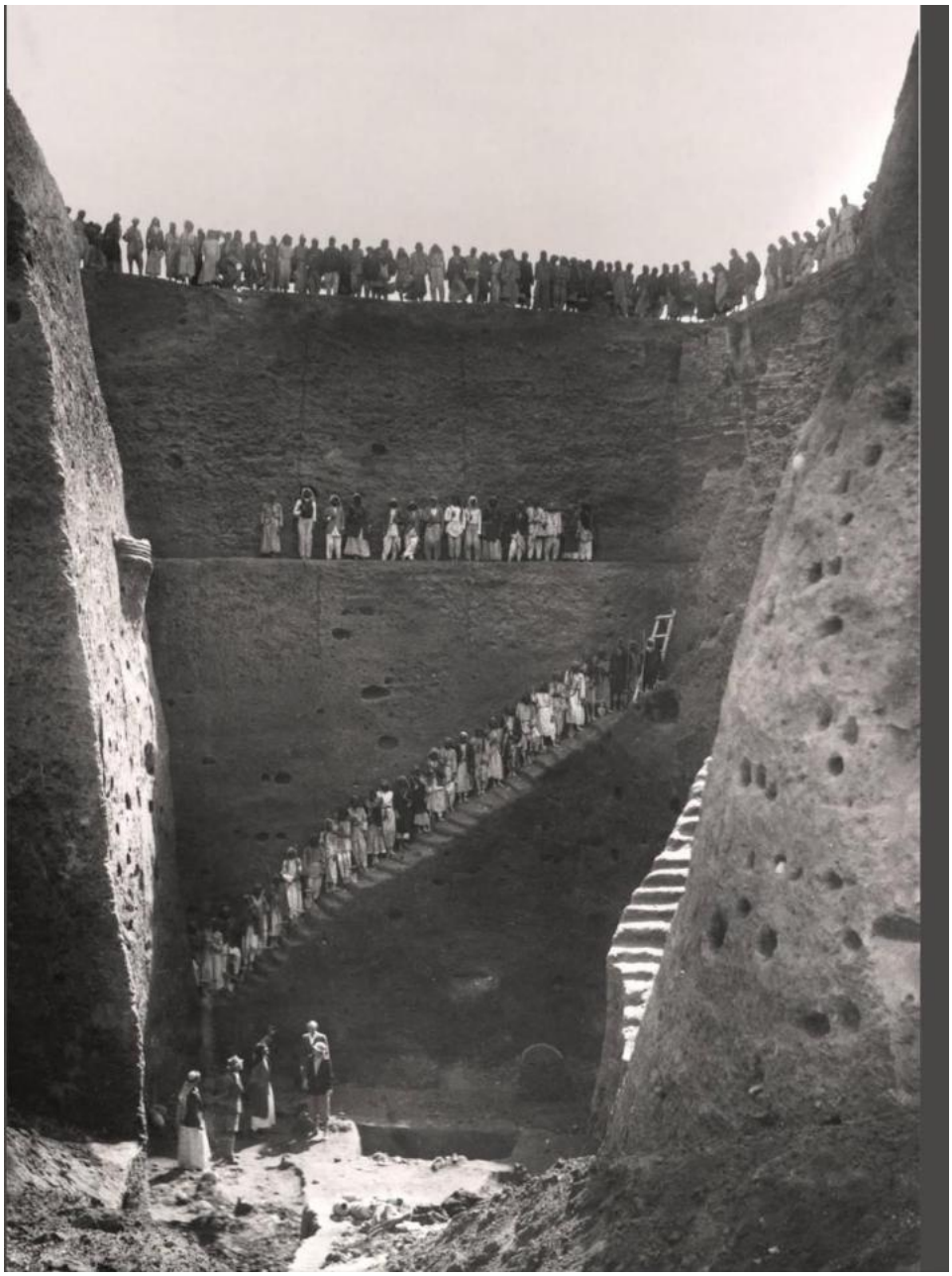

Fig. 4. During excavations at the ancient Sumerian city of Ur in the 1920s, archaeologist Leonard Woolley uncovered a massive layer of clean silt. The deposit was so deep that it had to be completely removed before older structures could be reached below. Beneath this layer, Woolley discovered remains of an earlier culture with different pottery styles, showing a clear break in occupation. This was not the result of seasonal flooding, but a large-scale event that deposited meters of material at once. Woolley himself described it as "a flood of a magnitude unparalleled in the history of the site." If a catastrophic flood buried Ur this deep 5,000 years ago, how many older layers of history remain undiscovered beneath the ground? (This photo was taken from facebook.com by my colleagues many years ago. Courtesy of Heatherly and Timothy Hookers.)

Materials and Methods

Stratigraphic Site Selection and Visual Analysis

To evaluate anomalous macro-sedimentation events across the Near East and Mediterranean basins, a morphological survey has been conducted across key archaeological complexes, including Carthage (Tunisia), Laodicea, Sardis, Cybira (Turkey), and Persepolis (Iran). Initial site cross-examinations were compiled using high-resolution video documentation and field surveys (Gaubets, 2021-2026). Stratigraphic metrics were assessed based on the vertical depth of unexcavated

sterile clay, silt, and matrix backfills overlying established architectural horizons.

Evaluation of Catastrophic Deposition Models

The physical parameters required to deposit 6 and much more meters of continuous, poorly sorted matrix (mud, clay, marine shell debris, shards of pottery and marble, and fragments of human bones) over terrestrial urban centers up to 1,000 meters above sea level (e.g., Laodicea) have been evaluated against three distinct catastrophic models:

- *Localized Fluvial/Alluvial Mudflows*: Assessing regional topography to determine upstream catchment basins capable of generating macro-scale colluvial flows.
- *Cosmic Impactor Hypotheses*: Evaluating regional databases, including the Thompson (2017) archive for evidence of localized meteoric airbursts or crater fields matching the chronological constraints.
- *Terrestrial Endogenous Dynamics*: Modelling the kinetic energy thresholds (10^{23} Joules) required to lift marine and lithospheric sediments via core-generated magnetostriction shock waves. This is a completely new view of the nature of Earth's cataclysms, which stands apart from volcanic eruptions and earthquakes.

Historical and Mythological Textual Concordance

To cross-reference physical stratigraphic data with ancient historical memory, comparative textual analyses have been conducted of classical and Near Eastern accounts of catastrophism. This framework evaluates the structural parallels between Hellenic accounts (Plato's Timaeus, the Phaethon myth (Wikipedia; James and Slujs, 2016) and equivalent Bronze Age scripts from Northern Syria, Anatolia, and Mesopotamia (Hurrian Silver, Hittite Fire, and Babylonian Era traditions) regarding sudden aerial soil and thermal depositions.

Analysis of the Capabilities of Known Destructive Sources

Extreme atmospheric events, such as category-5 hurricanes, are hydrodynamically incapable of fracturing multi-ton megalithic structures or depositing thousands of cubic kilometers of poorly sorted sterile sediment over inland elevations.

Could a seismic wave produce effects described in subsection *Morphological Anomalies*? Probably not because its propagation is coming outward from the hypocenters in all directions, like ripples on a pond, and hence the power of such a wave is distributed into a spherical angle of about 2π, which weakens the impact force of the wave front, and such a wave does not carry material with which it can cover huge areas ten meters thick from above. Standard earthquakes lose energy rapidly due to geometric spreading and anelastic attenuation as body waves (*P*-waves and *S*-waves) move through the heterogeneous crust.

Could the physical mechanism of a volcanic eruption lead to the filling of large areas with material that is not present in the eruption, i.e., mud, clay, and small minerals? The list of large volcanic eruptions in the present Holocene time (List of large volcanic eruptions. Wikipedia) occurred in the Near East and South Europe region mentions only one event with a volcanic explosivity index (VEI) of about 7, namely, the Minoan eruption of Thera (Greece), which took place around 1610 BCE (Minoan eruption. Wikipedia). The ejected mass devastated Minoan settlements on the island of Thera and in the surrounding areas of the Aegean and Mediterranean Seas with subsequent earthquakes and tsunamis, and its effects were felt throughout the Mediterranean and the Middle East. The ejection of ≤ 41 km^3 of dense-rock equivalent was one of the largest volcanic events in human history (Karstens et al., 2023), and its profile falls orders of magnitude short of the 1,000 km^3 thresholds required for the macro-sedimentary backfills documented in subsection *Morphological Anomalies*. Furthermore, no magmatic VEI 8 events are chronologically supported in the region's recent archaeological strata.

Nevertheless, atypical eruptions are known to exist. In 1980, tragedy struck: Mount St. Helens in the United States captured the world's attention with a powerful volcanic eruption that sent waves over 600 feet (182 meters) high into Spirit Lake and unleashed an avalanche of water, uprooted thousands of trees, and millions of tons of soil, ultimately radically changing the surrounding landscape (Dzurisin et al., 1980). The volcanic explosivity index (VEI) of the 1980 Mount St. Helens event was a VEI 5 (discharging ~1 km^3 of material).

This tragedy points to the possibility of a similar scenario in ancient times, namely, a very strong jolt from beneath the ground, much more powerful than the one that occurred in 1980, tore apart the deposited soil mixed with seawater and threw this huge mass high into the atmosphere. No volcanic eruption, just a jolt. Then this ordinary mass fell, scattering back to the ground, and having high kinetic energy, stirred everything that was on the surface, covering a large area with a thick layer of mud, clay rubble, and other debris, burying all living things.

If such an event is theoretically possible, then there must be a mechanism in the Earth's interior that can tear a large mass of Earth's matter from its surface. The presence of volcanoes and earthquakes is associated with geophysical phenomena occurring in the mantle and crust of the Earth. These phenomena are quite well studied, and the boundaries of their action are outlined in different regions of the globe; therefore, a possible new mechanism seems to lie outside the known concepts.

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Results

In this section, we are to investigate a mechanism capable of severely damaging the Earth's surface.

Core Ferromagnetism and Limits of the Geodynamo Framework

Beneath the silicate mantle lies a multi-phase core composed of a liquid outer layer and a solid, high-density inner core. While minor radioactive decay configurations exist within these layers, the concentration of unstable heavy nuclei is insufficient to induce critical fission or sustained fusion dynamics. Consequently, sudden energy releases must stem from alternative electromagnetic or structural transitions.

Traditional geodynamo models attribute the Earth's magnetic field to convective fluid loops within the outer core (Okonkwo, 2025; Landeau et al., 2022; Aubert et al, 2017; Dumberry et al., 2025; Dormy, 2025). However, standard thermal convection models struggle to maintain a physical basis without a continuous, mechanically forced seed input, as confirmed by rotating liquid metal container experiments (Lowes and Wilkinson, 1953; Olson, 2011; Verhille et al., 2010).

The major scientific community considers the generation of the Earth's magnetic field because of the movement of fluid in the outer core, which is called the geodynamo (Okonkwo, 2025; Landeau et al., 2022; Aubert et al, 2017; Dumberry et al., 2025; Dormy, 2025). However, even some researchers working within the framework of the geodynamo concept note that there is no physical justification for such a strange mechanism. The proposed carrier is thermal convection in the Earth's liquid core. It is difficult to determine unequivocally what energy supports heat and mass transfer and how it leads to the specific properties of the magnetic field source. Sens (2023) considered a hypothesis in which the magnetism of the Earth is generated by the motion of the solid central core with charges rather than a current of charged ions and electrons. Gordienko (2022) proposed, as an alternative, to treat convective flows in the global asthenosphere caused by the influence of active processes in the tectonosphere.

Laboratory experiments involving rotating liquid metals have successfully generated magnetic fields through mechanically forced flows, sometimes with the addition of an external seed magnetic field (Lowest and Wilkinson, 1963; Olson, 2011; Verhille et al., 2010), however, none have yet created a self-sustaining magnetic field from purely thermal convection in a rotating container. But it is convection flows that should contribute to the generation of the Earth's magnetic field in the geodynamo model.

Interesting theoretical and experimental studies of iron under high pressure and temperature were conducted by Cristian Teodorescu and collaborators, which are presented in a concentrated form in papers (Teodorescu, 2021; Teodorescu and Hușanu, 2022). Teodorescu notes that although the temperature in the Earth's core (roughly 5500 K) is close to the melting point of iron under the Earth's pressure of 360 GPa, it is nevertheless possible to reproduce ferromagnetism in the solid core, which he calls 're-entrant ferromagnetism'. This means that traditional Born-Oppenheimer lattice approximations break down due to pronounced thermal lattice vibrations (Teodorescu and Hușanu, 2022). By incorporating these perturbations directly into Fermi-Dirac statistics, the classic Stoner (1938) criterion is modified to define a new stability limit for spin-asymmetry in the absence of thermal effects:

$$g'_0(\varepsilon_F) \cdot \int_0^{\varepsilon_F} g_0(\varepsilon)\, d\varepsilon \geq g_0^2(\varepsilon_F), \qquad (1)$$

where ε_F is the Fermi level, $g_0(\varepsilon)$ is the paramagnetic single-electron density of states (DOS) in the absence of spin splitting, g'_0 is its first derivative with respect to state energy (Teodorescu and Hușanu, 2022). The temperature dependence is introduced using the Fermi-Dirac function, and ultimately this is what allows one to increase the critical Curie temperature for *bcc* Fe phase and *hcp* Co phase to about 5500 K (which is beyond the capabilities of the Stoner (1938) model).

When the derivative of the DOS at the Fermi level is negative ($g'_0 < 0$), the zero-asymmetry state becomes inherently unstable (Teodorescu and Hușanu, 2022): the electronic population shifts toward maximum spin asymmetry, establishing a stable, high-temperature **re-entrant ferromagnetism** within the solid hcp iron phase. Incorporating a magnetostriction coefficient of $\alpha \sim 10^{-5}$, Teodorescu and Hușanu evaluated the associated magnetic ordering enthalpy at $\epsilon = 0.16$ meV per iron atom, bounding a core ferromagnetic domain radius R_{domen} between 188 km and 201 km located at the Earth's centre. They also estimated the maximum magnetic induction at the Earth's surface to be $B_{\text{surf}} \approx 65$ μT, which is consistent with the measured value.

Quantitative Energetics of Core Magnetostriction Activity

Structural transitions, chemical diffusion anomalies, or external mechanical stresses from the outer core boundary can destabilize the magnetic ordering enthalpy, inducing a rapid, first-order magneto-structural phase transition. When this occurs, a rapid loss of magnetization triggers sudden volume magnetostriction. After that, the core's ferromagnetic order gradually renovates its magnetization, i.e. the magnetic moment **M**.

To quantify the potential kinetic output of this core engine, the physical properties of the inner core domain are modelled using a baseline radius $R_{\text{domen}} = 2 \times 10^5$ m. The corresponding domain volume is $V_{\text{domen}} = 4\pi R_{\text{domen}}^3/3 = 3.351 \times 10^{16}$ m^3. Utilizing a localized inner-core iron

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density $\rho_{\mathrm{Fe}} = 1.29 \times 10^4$ kg·m^{-3}, the mass of the ferromagnetic domain is $m = \rho_{\mathrm{Fe}} V_{\mathrm{domen}} = 4.323 \times 10^{20}$ kg. Given the molar mass of iron (55.845 g·mol^{-1}) and Avogadro's number ($N_{\mathrm{A}} = 6.022 \times 10^{23}$ mol^{-1}), the total constituent atomic population (N) within the domain volume is

$$N = \frac{m}{\text{molar mass of Fe}} \times N_{\mathrm{A}} = 4.66 \times 10^{45} \text{ atoms.} \quad (2)$$

When a sharp drop in regional magnetization destabilizes this domain, the conversion of magnetic ordering enthalpy ($\epsilon = 0.16$ meV $\approx 2.563 \times 10^{-23}$ J per atom) yields a cumulative instantaneous kinetic energy release

$$E = \epsilon N = 2.563 \times 10^{-23} \text{ J} \times 4.66 \times 10^{45} = 1.194 \times 10^{23} \text{ J.} \quad (3)$$

This immense energy E is mechanically stored via volume magnetostriction, governed by the relation $E \approx \alpha P \delta V$, where $\alpha \approx 10^{-5}$ represents the magnetostriction coefficient, $P \approx 350$ GPa defines the ambient inner-core hydrostatic pressure, and δV indicates the net volumetric distortion of the core domain during the phase transition.

Shock Wave Propagation and Lithospheric Coupling Mechanics

The instantaneous liberation of volume magnetostriction energy $E \sim 10^{23}$ J induces a localized mechanical collapse within the core domain. Because the macroscopic structural shifts associated with magnetic domain boundaries occur on millisecond scales, the rapid phase transition generates a highly directional, longitudinal shock wave. The propagation vector of this wavefront is governed by the structural elongation axes of the *hcp* Fe crystals during spin relaxation, focusing the kinetic energy into a collimated propagation cone that minimizes global spherical attenuation.

As this supersonic longitudinal front approaches the upper lithosphere, it encounters structural discontinuities at major tectonic boundaries – specifically the crustal material transitions dividing low-density continental granite from dense oceanic basaltic plates. Upon breaching these fault matrices (e.g., the Levant margin, Mediterranean coastlines, or the North African continental shelf), the wavefront partitions into coupled geomechanically components: primary *P* waves ($4.8 - 8$ km·s^{-1}), secondary *S* shear waves ($3.2 - 4.8$ km·s^{-1}), destructive surface configurations (Rayleigh and Love waves), and global atmospheric Lamb waves.

Ballistic Mass Ejection and Regional Sedimentation Footprints

To evaluate the volume of terrestrial and marine substrate displaced by the arrival of the core shockwave front, the mechanical work required to launch the surface mass against gravitational acceleration must be quantified. Assuming an empirical coupling efficiency (η) wherein a fraction of the total shock energy ($E = 1.194 \times 10^{23}$ J) translates directly into vertical kinetic displacement, the mass (Δm) of the detached lithospheric and marine substance is bounded by the change in gravitational potential energy:

$$E_{\mathrm{shock}} = G \frac{M \, \Delta m}{R + H} \quad (4)$$

where $G = 6.674 \times 10^{-11}$ m^3·kg^{-1}·s^{-2} is the gravitational constant, and $M = 5.972 \times 10^{24}$ kg and $R = 6.371 \times 10^{24}$ m are the mass and mean radius of the Earth, respectively, and H is the height to which the detached material is ejected, which can be neglected. Solving for the accelerated mass yields

$$\Delta m = \frac{E_{\mathrm{shock}} \cdot R}{G \cdot M} \approx 1.6 \times 10^{15} \text{ kg.} \quad (5)$$

Given a mean bulk density $\rho = 1{,}600$ kg·m^{-3} for a saturated marine matrix consisting of water, benthic silt, and alluvial clay, the total volume of the ejected material is derived as

$$V = \Delta m / \rho = 10^{12} \text{ m}^3 = 1{,}000 \text{ km}^3. \quad (6)$$

Structurally, this volume corresponds to an initial sub-marine or coastal excavation trench measuring approximately 200 m in depth across a localized 50 km × 100 km pull-apart zone. Following sub-orbital atmospheric trajectory arcs, this immense mass of wet slurry is driven laterally by coupled surface and Lamb atmospheric waves before collapsing back to the surface.

The resulting aerial deposition blankets a macro-regional footprint

$$S = (500 \text{ km}) \times (134 \text{ km}) \quad (7)$$

mapping a dense, non-uniform stratigraphical layer averaging 15 metres in thickness. The high kinetic energy of this descending matrix would catastrophically shear, crush, and hermetically seal any existing Epi-Paleolithic or early Neolithic settlements within the distribution zone, providing a mechanical explanation for the sudden architectural and cultural terminations documented across the Near East.

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Discussion

The physical framework proposed by Teodorescu (2021), and Teodorescu and Hușanu (2022) provides a natural mechanism wherein a sudden magnetostrictive collapse within the inner solid core's ferromagnetic domain generates a collimated shock wave. However, to account for the recurrent macro-catastrophes observed throughout human prehistory and history, this core engine must be modelled as a dynamical, non-linear system.

While a permanent ferromagnetic phase dominates the inner solid core, fluid motion within the outer liquid core generates a transient magnetic field via traditional geodynamo mechanics (Landeau et al., 2022; Aubert et al., 2017; Dumberry et al., 2025; Dormy, 2025). Probably, the primordial magnetization $\mathbf{M}$ of the solid inner core acts as a continuous seed field, initiating and stabilising the outer core's convective magnetic vector $\mathbf{M}_{\text{out}}$. Consequently, a complex, coupled $\mathbf{M} - \mathbf{M}_{\text{out}}$ oscillatory regime can become established.

Fig. 5. Paris, France (1973): restoration of the original appearance of the Les Halles building. The city of Shelbyville, Illinois, USA; the city was founded in 1827, which means that the mudflow of unknown origin occurred much later (screenshot from video (Burau of Ruins, b, 2226)). Kyiv, Podil district, Ukraine. Kazan', Muscovy.

Under specific thermodynamic thresholds, this coupling can trigger a cascading series of successive magnetostrictive events (5, 10, 20, …) within the inner domain. Rather than a singular isolated event, the core can discharge a rapid succession of shock waves along a shared anisotropic axis over brief temporal windows (minutes to hours). This multi-shock sequence effectively amplifies the cumulative kinetic energy, expanding the regional deposition footprint (S) by orders of magnitude. Depending on the initial core-alignment angles, these events can blanket massive continental expanses, providing a physical explanation for sudden regional desertification sequences, such as those that formed the modern Sahara Desert or the arid basins of the Near East.

The limits of conventional uniformitarian volcanic models become apparent when analyzing historical multi-meter sedimentary anomalies. For example, the severe climatic anomalies of the "Year Without a Summer" (1816–

1819) are classically attributed to the April 1815 eruption of Mount Tambora in Indonesia (VEI 7, discharging about 41 km^3 of dense-rock equivalent) (List of volcanic eruptions. Wikipedia; Minoan eruption. Wikipedia; Stothers, 1984). While stratospheric transport via the Brewer-Dobson circulation distributes light volcanic aerosols globally, it cannot mechanically account for the massive, localized clay backfills and non-uniform sediment accumulations documented across Western Europe, the Eurasian plain, and the United States during this exact window.

The mass balance of regional clay deposits suggests that these sedimentary blankets did not descend from long-lived stratospheric sulphate aerosols but were instead injected directly into the troposphere ($8-15$ km altitude) via localized, low-altitude terrestrial ejections. This strongly implies that sub-colloquial regional flooding and clay backfills – such as those observed in early 19th-century municipal foundations – stem from lower-magnitude, core-generated magnetostriction shock waves breaching vulnerable continental interior faults.

Physical footprints of these endogenous kinetic pulses remain visible across the modern landscape. Independent historical and geological surveys indicate that anomalous, rapid soil burial events actively impacted urban architectures globally well into the mid-19th century, Fig. 6 (Kungurov, 2017; Bureau of Ruins, a & b, 2026; Quantum of Supermind, 2024).

These localized, high-energy mud ejections correlate spatially with expansive networks of anomalous round and oval lake formations stretching from the Tver region across the Ural Mountains and into the Tyumen depression (Fig. 6). The loose, poorly sorted soil matrices surrounding these circular depressions lack typical glacial or standard fluvial features. Instead, they closely resemble the geomorphology of explosive crater

Fig. 6. Top row: Round lakes northwest and northeast of Moscow. Bottom row, left: the Lena River; right: oval-shaped depressions, the USA (screenshot from video (GeologyHub, 2024)).

This mechanical framework is highly consistent with the formation of kimberlite pipes – such as those found within the Lena River basin in Yakutia – where deep-seated mantle material was violently forced to the surface from depths of $150-200$ km (Fig. 6). Because the formation of diamonds within these pipes demands ultra-high-pressure configurations that exceed typical tectonic or volcanic stresses, they stand as physical evidence of hyper-accelerated, vertical kinetic shock fronts propagated directly from the Earth's core.

Stratigraphic and field investigations conducted by an international team – including Dr. Dallas Abbott and D. Breger (Lamont-Doherty Earth Observatory), Dr. P. McCafferty, and Prof. V. Guzyakov (Siberian Branch of the Russian Academy of Sciences) – revealed an internal basin morphology incompatible with simple karst collapse (Karabelnikov, 2013). The lake floor exhibits crushed,

highly shocked lithic materials displaying horn-like conchoidal fractures, indicating the passage of a high-velocity mechanical shock front. While the presence of microspheres has been used to support a stony meteorite impact scenario that could have happened about 2,000 years ago, the total absence of macroscale meteoritic fragments points toward an endogenous shock vector originating from the deep lithosphere.

Similar non-karst deep basins emerge globally, notably Kingsley Lake in Florida, USA. This morpho-stratigraphic footprint matches thousands of shallow, oval depressions clustered across the Atlantic Coastal Plain, universally designated as the Carolina Bays (spanning North and South Carolina, and Georgia; see Fig. 6). Gravity and magnetic anomalies across these bays reveal older, deep-seated circular subterranean fractures beneath the surficial sand rims.

Rather than invoking highly speculative, uniformitarian cosmic-shower grids, these geometries can be modelled as surface venting fields where core-propagated acoustic-gravitational solitons breach fluid-saturated sediment layers. This expansive out-venting mechanism accounts for the uniform alignment of the rims and maps directly to equivalent high-density subterranean shock-vent structures, such as the network of over 60,000 limestone cenotes cross-cutting the Yucatán Peninsula.

Macroscopic evidence for an endogenous, radiative shock mechanism is preserved in the unique stratigraphy of historic urban ruins and coastal marker beds. In locations such as Bray, Ireland, massive, poorly sorted sediment backfills composed of intermixed clay and un-eroded marine clasts have physically buried classical architectural ground floors, transforming them into sub-surface basements.

Mechanically, these events correlate with the extensive fields of unique, surface-vitrified impactite pebbles distributed within and around 19th-century geomorphic crater fields [35, 36]. Independent attempts to replicate these structures via conventional thermal conduction, furnace baking, or localized combustible heat treatments have consistently failed. The pebbles exhibit a pristine, hyper-localized glassy surface layer measuring precisely $\delta \approx 0.2$ mm in thickness, while the inner lithic core remains entirely unaltered.

Thermodynamically, a purely mechanical kinetic collision or hydrothermal mudflow cannot restrict a high temperature $T \approx 1{,}600$ °C and high-pressure ($P \geq 2$ GPa) phase change exclusively to a 0.2 mm boundary layer across thousands of independent clasts simultaneously. Standard kinetic impacts release energy via bulk thermal dissipation and mechanical vaporization.

The worldwide distribution of surface vitrification anomalies and compact crater grids introduces profound thermodynamic contradictions for uniformitarian impact geology. The Libyan Desert craterless glass sheets cover thousands of square kilometers of the Sahara (Koeberl, 2007). They demand formation temperatures exceeding $T \approx 1{,}700$ °C. Yet, they lack any associated cosmic impact craters or meteoric mass distribution beds.

Unexplained high-energy signatures recur throughout human history, including the Iron Age vitrified forts of Scotland (e.g., (Craig Phadrig)) and the Bronze Age structural ruins of Arkaim (Bureau of Ruins, a & b, 2026) in the southern Urals. These stone walls exhibit localized, non-uniform point-melting and spot-sintering, which cannot be replicated by conventional tribal warfare fires, wood-fueled kiln temperatures, or localized lightning strikes.

In China, extensive fields of tektites and impact glass debris exhibit peak structural preservation and soil stratigraphy limits that anchor their deposition to the late 18th and early 19th centuries, directly challenging millions-of-years impact models.

All this fits into a single scheme: {Core Magnetostriction: 10^{23} J} $\Longrightarrow$ {Wavefront Fragmentation} $\Longrightarrow$ {Localized Pulses: 10^{16} J (=10 megaton of TNT)} $\Longrightarrow$ {Reverse-Side Spallation}.

To account for these compact, non-random crater networks (Fig. 6), alternative historical researchers frequently invoke the hypothesis of a global, prehistoric nuclear war utilizing 5 to 10 megaton trinitrotoluene (TNT) equivalent detonations. One ton of TNT releases exactly 4.184×10^9 J of energy. A 10-megaton detonation translates to a localized kinetic and radiative output of 4.184×10^{16} J.

While an anthropogenic nuclear model satisfies the basic localized thermodynamic melting thresholds, it fails to explain the global geological orchestration, the deep-seated gravitational anomalies under the basins, or the macro-scale sediment displacement (1,000 km^3) documented in Introduction.

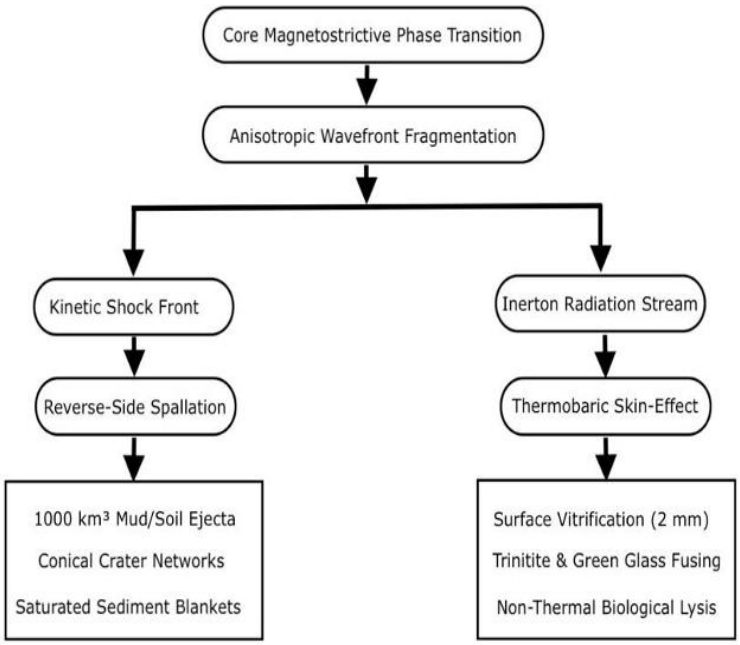
The endogenous core engine resolved in Eq. (3) yields a cumulative potential of $E = 1.194 \times 10^{23}$ J – a threshold exactly seven orders of magnitude higher than an isolated 10-megaton blast. As this colossal wavefront propagates outward through the anisotropic *hcp* iron lattice and mantle boundary faults, the primary wave collapses and undergoes geometric fragmentation. The main energy front breaks apart into a coherent cluster of dense, localized shock channels, each carrying an individual kinetic budget on the order of 10^{16} J.

When these high-energy seismic-acoustic solitons strike the rigid lithospheric surface *from the rear side*, they trigger a classic mechanical phenomenon known as reverse-side spallation. When a compressive shock wave hits a free boundary, it reflects back as an intense tensile wave. If the tensile stress exceeds the structural yield strength of the rock or soil matrix, the material fractures instantly. The surface layer is violently torn out and ejected forward in a conical trajectory.

The incorporation of the submicroscopic inerton field framework (Krasnoholovets, 2014; 2017) resolves a critical explanatory gap that has forced alternative historians to rely on anthropic nuclear strike models and

mainstream geologists to invoke unproven meteoric events. Mechanically, both nuclear detonations and core-generated magnetostrictive ejections utilize identical underlying submicroscopic energy carriers: dense, high-energy streams of mass-carrying inertons.

When a fragmented core shock wavefront ($E_{\text{local}} \sim 10^{16}$ J) breaches the surface, it functions as a highly collimated mass-radiation beam. This intense bombardment induces a rapid submicroscopic compression of surface electron-nuclear clouds within the target lithosphere. This quantum phase coupling generates a catastrophic, localized thermobaric skin-effect – yielding melting temperatures $1{,}500 - 2{,}000$ °C and gigapascal pressures – while simultaneously releasing destructive ionizing field radiation. This dual mechanism accounts for the uniform patterns of destruction documented across highly disparate geographical and chronological boundaries:



Let us mention some important results examined by different research groups.

At the high-altitude 4,000 m Andean plateau of Puma Punku, Bolivia, the structural ruins display a distinctive vertical kinetic disruption (Project Chronos, 2026). Multi-ton andesite megaliths were violently lifted, sheared, and overturned in mid-air, with a 400-ton monolith left displaced at a 45-degree angle. Rather than indicating an aerial kinetic blast, the presence of swollen, structurally ruptured soil beneath the blocks – combined with highly localized, short-term thermobaric surface vitrification – points directly to a sub-surface mechanical jolt. The upward propagation of the core-generated shock wave induced a massive, backside spallation front directly beneath the complex.

Multidisciplinary stratigraphical analyses of the Dead Sea settlement of Tall el-Hammam ~ 3,700 BP) reveal an instantaneous 2,000 °C destruction layer containing molten ceramics, diamond-like carbon, and melted noble metals (Bunch et al., 2021). While standard models invoke a cosmic airburst, this hypothesis fails to account for a critical geomorphological feature: a continuous, centimeters-thick layer of salt blanketing 200 km^2 footprint around the site. The endogenous core shock wave model resolves this paradox. A highly collimated energy channel from the inner core breached the hyper-saline Dead Sea basin from beneath, instantly vaporizing and ejecting thousands of cubic meters of brine and benthic mud into the lower atmosphere. The resulting regional tropospheric vortex deposited the thick saline layer alongside an explicit secondary energy beam that struck the urban center, inducing instantaneous material sintering and elemental transmutation.

The physical signature of a core-generated inerton flux is chemically preserved within the archaeological strata of Mesopotamia. At Eridu, Iraq, excavations within a 12,000-year-old horizon uncovered green, glassy trinitite fragments at a depth of 10 meters (FACTS HUB, 2026). Quantitative cross-examinations conducted by geophysicist John Olson demonstrate that the vitreous chemical composition of these Eridu trinitite fractions is identical across seven diagnostic elemental components to the 3,700 year-old melted fractions retrieved from Tall el-Hammam. The fact that two distinct geographical centers separated by 1,200 km and a chronological expanse of 8,000 years exhibit identical vitrification signatures confirms a recurrent, non-anthropogenic planetary engine. Furthermore, cuneiform accounts from the city of Ur (2,000 BCE) describe the physiological footprint of this event: an invisible, non-thermal “evil wind” that caused citizens to collapse in the

streets without external wounds, leaving bodies that resisted standard organic decomposition and assumed a clay-like rigidity while corrupting regional canal waters. This represents a classic, highly documented clinical manifestation of acute, high-energy mass radiation exposure induced by severe, non-classical inerton flux density.

This core-breakthrough dynamic explains the structural layout documented by Davenport and Vincenti (1979) at the ancient Indus Valley complex of Mohenjo-Daro (~3,750 BP). Their field mapping reveals a highly defined, 50-meter-wide central epicentral zone where all brickwork was completely crystallized, vitrified, or melted at temperatures exceeding $1{,}600 - 2{,}000$ °C, with structural damage decreasing systematically toward the periphery along three concentric shock wave vectors. The unilateral melting patterns observed on the inward-facing surfaces of building blocks up to 60 meters from the epicenter demonstrate a directed, bottom-up radiative energy flash. The complete absence of human skeletal remains within this central zone indicates instantaneous material vaporization. This thermal signature matches the descriptive accounts preserved within ancient Sanskrit epics detailing the discharge of an intense, smokeless thermal weapon that induced rapid atmospheric pressure drops, localized cyclonic reversals, and boiling aquatic environments. The systemic marginalization of these rigorous Italian and international mineralogical analyses by uniformitarian academia has obscured the true cyclical nature of these geodisasters.

The macro-scale geological consequences of these core-generated pulses are captured in the extensive datasets compiled by Immanuel Velikovsky (1955), who documented massive, global bone-cave complexes where remains are packed into deep rock fissures. These chaotic, high-density bone breccias – coupled with erratic boulder displacements and instantaneous coal formation tracks – indicate sudden mass transport and burial by immense, high-velocity mud matrices falling from sub-orbital trajectories.

The rapid, localized nature of this energy deposition is further validated by contemporary discoveries. For instance, during a 1999 infrastructure project in Andhra Pradesh, India, engineers exposed a continuous underground layer of completely molten vitrified quartz covering an area of 50 m² and 30-40 cm thick at a depth of 2 meters. The formation of pure fused quartz demands an instantaneous thermal input of 1,600 °C directly within the shallow alluvial soil matrix, confirming the passage of a high-density, upward-directed endogenous inerton radiation channel.

The convergence of historical data establishes that macro-sedimentary backfilling and high-energy inerton field releases did not cease in prehistory. Instead, they recurred well into the historical era, with a major planetary activation threshold occurring between 1815 and the late 1860s (Kungurov, 2017; Bureau of Ruins, a & b, 2026; Quantum of Supermind, 2024). Stratigraphic anomalies across global urban centers indicate that municipal foundations built in the early 19th century were retroactively buried under meters of sterile clay, silt, and mud matrix (Fig. 5). In cities like London and Tomsk, original ground-floor windows and entryways were hermetically sealed by sudden regional deposition sequences, forcing their conversion into modern semi-basements.

Fig. 7. Aspendos, Turkey. This screenshot shows how a stone slab experienced plastic deformation due to an unknown mechanism (https://www.youtube.com/watch?v=ocVplh2dvqM).

This mid-19th-century activation provides a concrete physical explanation for the sudden geopolitical collapse and erasure of the Tartary civilization across the Siberian plain before its systematic annexation by the Muscovite administration. The primary urban centers of Tartary did not fall to standard military campaigns. They were depopulated by localized, tropospheric mud-ejecta blankets accompanied by highly lethal, invisible doses of high-energy inerton field radiation. The destruction of regional infrastructure allowed subsequent waves of uneducated commoners to reinhabit the pristine, abandoned high-quality stone architectures starting in the 1860s, while surviving structural documentation was systematically destroyed by imperial censors to obscure the cyclical timeline of the disaster.

Standard structural geology assumes that crystalline rock matrices can only undergo ductile, plastic deformation under millions of years of lithostatic pressure or high-ancient anomalies, temperature magmatic melting. However, field surveys of ancient architectural complexes reveal anomalous, fluid- like warping of structural stone slabs that completely lack brittle micro-fractures. A primary example is preserved within the ruins of Aspendos, Turkey (Fig. 7), where heavy, load-bearing limestone and marble blocks display smooth, sinusoidal plastic bending load-bearing limestone and marble blocks display smooth, sinusoidal plastic bending.

This non-thermal crystalline warping cannot be replicated via traditional mechanical stress. Within the framework of submicroscopic mechanics formulated on a real space tessellattice with a Planck-scale cell size (10^{-35} m), the space between overlapping atomic real wave functions (ψ-functions) in a condensed medium is densely saturated with the atoms' inertons [14]. When localized magnetostriction occurs along subterranean plate interfaces or core boundaries, a massive volume contraction (δV) fires a highly dense flux of inertons outward along spiral karst conduits (Krasnoholovets, 2017; Krasnoholovets and Gandzha, 2012).

Because inertons function as the physical sub-structural carriers of the field of inertia and particle mass waves, this high-density stream directly modulates the local inertial and gravitational tensor properties of the material it passes through (Krasnoholovets, 2017). On a macroscopic scale, this mass-radiation flux acts as an ultra-potent field catalyst. It accelerates standard submicroscopic mass-transfer reactions by orders of magnitude (Litinas et al., 2020), temporarily loosening the rigid Coulomb barriers of the stone lattice into a hyper-plastic, clay-like state without requiring macroscopic magmatic temperatures (Krasnoholovets and Gandzha, 2012; Krasnoholovets, 2017). This explains the transient, non-destructive deformation of the Aspendos steps, just as lower-intensity subterranean inerton leaks induce localized cellular swelling in the basal stems of agricultural fields during the generation of complex crop circles; such a behavior of plant rhizomes was demonstrated by Levengood (1994).

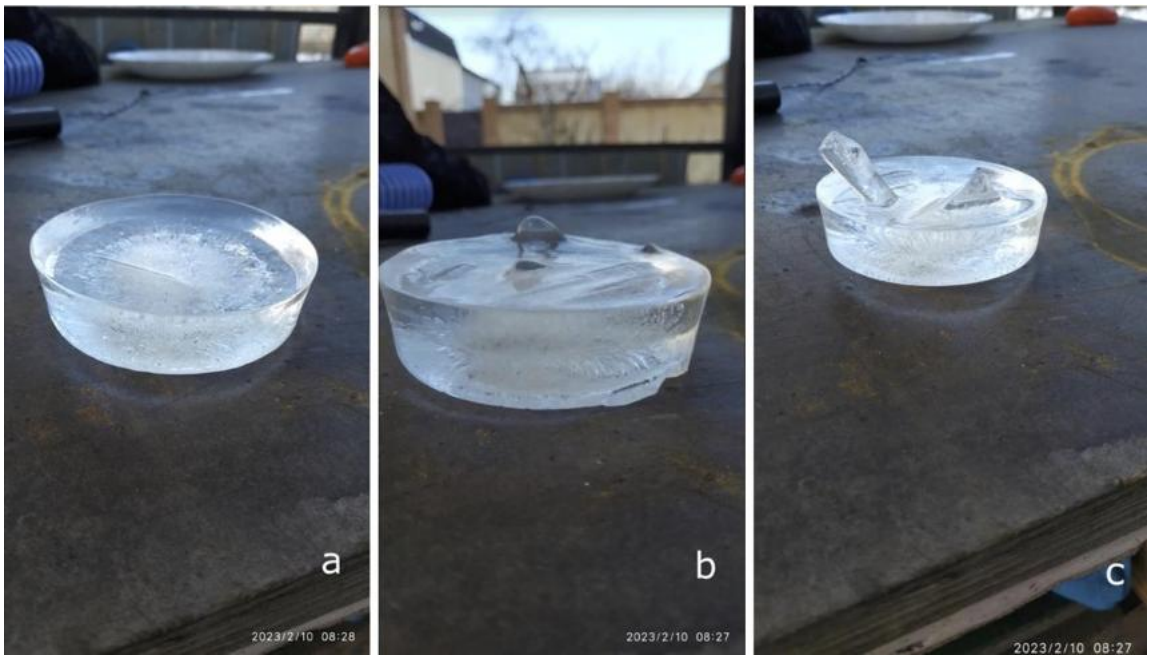


Fig. 8. Ice taken from a saucer placed under a corresponding pyramid overnight. All three saucers are identical. a – ice removed from under the first pyramid (unordered); b – ice removed from under the second pyramid (North-South orientation), and here traces of stalagmites are visible; c – ice removed from under the third pyramid (East-West orientation), and here it is clearly visible that two stalagmites grew overnight.

The behavior of these submicroscopic massotension fields can be measured and replicated using macro-scale geometric resonators. Because the Earth's orbital and rotational trajectories generate continuous, background inerton waves along a primary East-West vector, a geometric pyramid oriented precisely to the cardinal points functions as a passive resonant cavity for the massotension, or inerton field (Krasnoholovets, 2014; 2017).

The physical reality of this coupling was demonstrated in February 2023 during the catastrophic Turkey-Syria lithospheric ruptures. While conventional electromagnetic and standard seismic monitoring arrays failed to register pre-seismic gravitational variations, small, 30 cm plywood model pyramids deployed in Kyiv, Ukraine, successfully captured the anomalous core-flux propagation (Fig. 8). Saucers of water allowed to freeze overnight beneath an East-West resonant pyramid during the active earthquake sequence displayed highly pronounced, vertical acoustic-gravitational stalagmites (Fig. 8c). This morphology indicates that the local molecular bonds of the water were subjected to a strong, upward-directed vertical kinetic draw field as it underwent its phase change. Following the stabilization of the Turkey-Syria fault junctions, the stalagmite formations ceased entirely, proving that earthquakes are preceded and accompanied by deep-seated, high-flux inerton waves that can be measured using proper massotension instrumentation [13, 14].

Conclusion

This paper presents a novel theoretical framework to explain the catastrophic disruption of an advanced prehistoric civilization roughly 12 millennia ago. During that civilization, not only stone structures and quarries have survived to the present, but also Vedic culture, according to which people's behavior is connected to Space, a subtle matter capable of influencing and controlling the behavior of the human community (the so-called autopilot mode). The current civilization broke the connection with Space, calling it a void (vacuum), and its behavior resembles a manual control mode.

Ethics

This article is original and contains unpublished material. The author declares that there are no ethical issues and no conflicts of interest that may arise after the publication of this manuscript.

The integration of Teodorescu's re-entrant ferromagnetism equations confirms the presence of a stable, 200 km radius permanent magnetic domain within the Earth's solid inner core, establishing a highly dynamic $\mathbf{M} - \mathbf{M}_{\text{out}}$ oscillatory relationship with the liquid geodynamo.

Sudden, first-order magneto-structural phase transitions within this central domain yield a cumulative volume magnetostriction energy release of $E \approx 1.194 \times 10^{23}$ J, providing a self-consistent physical engine capable of launching over $1{,}000\,\text{km}^3$ of surface and marine sediment into sub-orbital trajectories via reverse-side spallation. This endogenous, fragmented shockwave mechanism perfectly explains the simultaneous occurrence of macroregional mud-sediment blankets, circular sagamorphic crater networks, and 0.2 mm skin-effect impactite vitrification's across disparate sites (Puma Punku, Tall elHammam, Mohenjo-Daro, Svetloyar, and Siberia) without requiring unproven meteoric impacts or speculative ancient nuclear conflicts.

The empirical evidence tracking these core-generated inerton pulses down to the mid-19th century demands an immediate reassessment of uniformitarian chrono stratigraphy. Mainstream geophysics and archaeology must implement non-classical inerton-gravitational tension sensors to map the ongoing, cyclical phase transitions of the internal planetary core engine.

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The superrotation of the inner core (IC) and changes of its mean radius and shape

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Abstract: The *IC superrotation*, as it is presently reported in the literature is shown to be the result of a misunderstanding of observational data that must be interpreted as a change of the mean radius of the *IC*, consequent to the "battery" operation of the Earth. Three distinct problems are considered: the *IC superrotation*, the time variation of the radius R_{ICB} of the *IC*, and the non-spherical shape of the *IC*.

The exact mean *IC superrotation* can be computed by considering a stroboscopic effect between the unknown rotation speed of the *IC* and the time-averaged geomagnetic field. This average is usually computed over $1\ year$ (yearly values), but this time lag can be either shorter or longer than $1\ year$. The stroboscopic effect envisages an *IC* that spins faster than Earth's surface (apparent period of $\sim 369.75 \pm 0.5$ rotations during one solar year of 365.25 days). The *IC* spins faster than Earth's surface by $\sim 370/365.25 \cong 1.01$, or by $\sim 1\%$. A reasonable final value is $\sim 370 \pm 0.3$ rotations in 1 year, or one rotation period of $\sim 0.9872 \pm 0.0008$ days $\cong 23.69 \pm 0.02$ hours . The standard reported observed *WD* of $\sim 0.2°\ \text{year}^{-1}$ is a beat due to the arbitrary reference to annual mean values computed over ~ 365.25 days. Conversely the *IC* experiences a *WD* of $\sim [4.5 \pm 0.5] \times 360°/365.25\ \text{year}^{-1} \cong [4°.4 \pm 0.5]\ \text{year}^{-1}$. That is, the stroboscopic evidence is ~ 22 times larger than the expected $\sim 0.2°\ \text{year}^{-1}$ (or, $\sim 0.24°\ \text{year}^{-1}$). Upon a closer inspection on the data set by better algorithms than visual inspection, it is found a *WD* of $0.287°\ \text{year}^{-1}$, in closer agreement with $\sim 0.24°\ \text{year}^{-1}$. Details are given in Gregori et al. (2025y).

The *IC superrotation* reported in the literature relies, rather, on Richards (2000), who used seismic ray paths, from a source in the South Sandwich Islands to an observatory in Alaska. They considered records collected over $28\ years$. The time difference between arrivals of ray paths crossing, or not, through the *IC* increases over these decades by $\sim 0.3\ sec$. Richards (2000) explains this by a variation of the speed rate of the *IC*. However, subsequent investigations disputed, sometimes confirmed, sometimes denied, this. The correct interpretation of observation is, however, in terms of a time variation of R_{ICB} consequent to the battery behavior of the Earth, according to an independent estimate of the variation of R_{ICB} based on models of the geomagnetic field from 1400 AD through present.

A more correct approach is, rather, to consider the shape of the *IC* that can explain the *mysterious response* of pole motion and of changes of the *l.o.d.* (length of the day), which *sometimes appears conspicuous* and *sometimes negligible* even for strong earthquakes. The unique available explanation seems to be in terms of a "*sail*" effect acting on upheavals, or bumps, of the *IC* - compared to an ideal spherical figure.

Finally, we outline a strategy for the investigation of the structure of deep Earth, relying on different monitoring devices, and we show how a planetary

network of comparatively less expensive *AE* (acoustic emission) recording stations can provide an instant information on the propagation of crustal stress with a twofold perspective: monitoring local and regional geodynamics, and a significant treatment of seismic precursors for mitigating the seismic hazard.

Keywords: Paradigms and viewpoints - time variation of the average radii of the *ICB, CMB,* and *ALB* - *superrotation* of the *IC* computed by a beat effect - the claimed *superrotation* of the *IC* – conflicting evidences - Earthquakes and perturbations of pole motion and *l.o.d.* -the figure of the *IC* - geomagnetism and gravity - geomagnetic evidence alone - *WD* of the geomagnetic *SV* - latitudinal drift of *SV*, and its correlation with pole motion and/or *l.o.d.* variation - correlation between geomagnetism and *l.o.d.* - Earth's rotation anomalies and the "*French Revolution*" jerk - measuring and monitoring the *IC* - dualism e.m. induction *vs.* P-wave pressure - strategy to investigate the deep structure of the Earth - high-precision gravimetry – *AE* arrays - Earth's tides - variation of *l.o.d*. – earthquakes - volcanism; - loading tide and Antarctica - gravity changes and volcanic activity

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Introduction – Paradigms and viewpoints

We must warn for a few basic misconceptions that bias several, even authoritative, present studies.

Firstly, a subconscious - tacitly agreed even though undeclared - assumption imagines a former hot and fluid Earth, which is cooling on the Ga time scale. This reminds, in some respect, about the old classical feeling of "floating" continents over some fluid ocean (Gregori, 2006e, 2009). This is similar also to the old-fashioned Buffon's experiment, who studied the analogy of the Earth with the cooling of bronze cannon balls. Georges-Louis Leclerc, Comte de Buffon (1707–1788) is the famous French naturalist, mathematician, and cosmologist, who was intendant (director) at the *Jardin du Roi*, now called the *Jardin des Plantes*. We briefly call *tout court* "*Buffon model*" this subconscious assumption.

Secondly, a generally agreed "myth" deals with the assumption of the "*solid*" state of the *IC* (inner core). They claim that this assumption is supported by the crossing of S waves through the *IC*. However, according to the present assessed knowledge of solid-state physics, this assumption is just nonsensical. In addition, owing to the density of iron meteorites, it is generally believed that the *IC* is composed mainly of iron.

An alternative to this untenable model derives from a realistic consideration of the state of matter inside deep Earth (Gregori et al., 2025w; Gregori and Gregori, 2025; and references therein). Consider that temperature increases *vs.* depth due to the transformation of potential gravitational energy into kinetic energy. Crystalline bonds progressively break, while the state-of-matter becomes more plastic. In the *OC*, the state-of-matter is fluid. According to a term used by planetologists for the interior of the giant outer gaseous planets, they claim that the state is "*metallic*", due to the large availability of free conduction charges (electrons). We can state that the *OC* is "*metallic*", with a higher electrical conductivity in deeper layers.

The ever-increasing temperature makes an ever-increasing number of electrons to be stripped from their atomic orbitals, until all atoms eventually lose all their orbiting electrons, and are "naked". What is the interaction between "naked" atoms?

They are positively charged; hence, they experience electrostatic repulsion, even though they are subjected to a strong gravitational compression. On the other hand, owing to the Hamilton's variation principle (Gregori et al., 2025e), the free electrons expand as much as possible. Hence, the "naked" atoms – strongly compressed by gravitation - interact through their respective nuclear magnetic moments. They compose therefore a state-of-matter characterized by all magnetic moments closely and strongly packed altogether, all of them parallel one another, into some kind of "fibrous" structure. In fact, this is what happens inside the *IC* of the Earth and of other sufficiently large planetary

objects. We call "*magpol*" state this stare-of-matter (acronym for "*magnetic polarization*"),

The observational evidence is given by the mainly dipolar nature of the geomagnetic field. In addition, note that S waves can cross a *magpol* object, due to the extremely strong coupling between nuclear magnetic moment, by which every displacement of nuclei that is perpendicular to the "fibrous" structure is forbidden.

One must stress that we live in a comparatively "cool" part of the universe, where the temperature permits the existence of ions, atoms, molecules that are the primary ingredients for chemistry and biology, hence for life. On the other hand, the largest fraction of matter in the universe is very hot, and "naked" nuclei are the most common occurrence. However, "naked" nuclei cannot release photon. They are invisible in terms of standard photons, they are "*dark matter*", and their existence can be assessed – at most- only by means of indirect evidence.

Thirdly, this leads to the next misconception. Following the successful 1919-1920 Larmor's hypothesis of a stellar dynamo to explain the magnetic field of the Sun and of stars, Elsasser, later supported by Bullard, envisaged an extension of the same mechanism to the Earth. The proposal was reasonable, relying on fluid motions inside the "metallic" *IC*. This is the still fashionable Elsasser-Bullard dynamo, and a huge literature is available of attempts to compute a numerical model, analogous to stellar dynamo models.

Gregori (2002) – but see also Gregori and Leybourne (2025n) – analyzed critically all assumptions and showed that every Elsasser-Bullard dynamo must end into a blocking ("*Biermann blocking*").

The argument can be explained by a simple example, i.e. a dynamo constructed by engineers for a hydroelectric power plant. It is well-known that, depending on the power absorption by the user network, the operator must modulate the water flux, which is allowed to impinge on the turbines. The purpose of the power-plant operator is to ensure an approximately steady power supply to the network, and to balance the fluctuations of the user network absorption.

Now, suppose that no user network is connected to the dynamo, that is powered by the turbine - and suppose that Joule dispersion is negligible inside the circuit where the e.m. (electromagnetic) induction occurs, which produces the dynamo action. The induced currents inside the dynamo circuits must continue to increase up to infinity, as no energy-sink whatsoever exists, while a steady and uninterrupted energy input is supplied to the system. Therefore, the forces always increase *vs.* time that attract to each other the different dynamo components, as these forces are originated by the ever increasing $\boldsymbol{B}$.

The result is that all mechanical components of the dynamo are firmly locked with one another. No relative movement can anymore occur. The eventual addition of water flux - even with some very large kinetic energy - will be strictly incapable to move the turbine. This is the "*Biermann's blocking*". The dynamo thus unavoidably stops, and it no longer produces electric current.

This is in fact what happens to an Elsasser-Bullard's dynamo. The Biermann's blocking, however, has no effect inside a star, because the star interior is dominated by thermonuclear reactions. If the star is blocked by the *MHD* Larmor's dynamo due to the Biermann's blocking mechanism, the star cannot release its endogenous energy. A star would thus be a very efficient "*plasma bottle*"[1] that contains and confines plasma by means of the very intense and ever-increasing fields $\boldsymbol{B}$. No expansion can occur of the stellar corona. No photosphere can exist. Maybe, the star cannot be even visible. This would be just a paradoxical condition. Hence, it can satisfy no energy balance. Therefore, a star is dominated by the primary physical requirement of its thermodynamic energy balance, rather than by the e.m. interaction, which is, rather, a secondary effect. A star must be in a continuous state of steady thermonuclear explosion, just in order to ensure the energy balance, and in this way the Biermann's blocking is continuously broken. Differently stated, the Larmor's dynamo exists inside a star only as a transient phenomenon, being continuously disrupted as soon as the $\boldsymbol{B}$ of the star is generated, because the newly born $\boldsymbol{B}$ rapidly leads to a blocking condition. Hence, in general the $\boldsymbol{B}$ of the Sun or of a star can display no "regular" dipole field, which is, rather, typical of much smaller objects where no thermonuclear reactions occur and a *magpol IC* can exist.

Indeed, all numerical models of the Elsasser-Bullard dynamo end into a blocking and applied mathematicians attempt to manage the paradox by means of perturbations terms, introduced by suitable mathematics.

The problem is physical, not mathematical, and it is unrealistic to speculate about intricate fluid motions inside the *OC* (outer core). There is, however, a slow, though steady relative motion of different component parts of the Earth caused by a differential tidal action by Moon and Sun. Since all parts are more or less ionized, this is a true dynamo powered by the tidal interaction. This is the *TD* (tide driven) -*dynamo*, which is active inside the Earth and several other planetary objects, and responsible for the release of huge amounts of endogenous energy (Gregori et al. 2026a).

For future reference, there is sometimes some confusion about terms used for referring to internal Earth's structure. We adopt the names indicated in Fig. 1. We call *malicrust* the ensemble of mantle, lithosphere, and crust. This figure is illustrated by Gregori et al. (2026a). as follows. "*For additional details refer to Gregori and Leybourne (2021) or, e.g., to Reimink et al. (2023).The Moho is tentatively defined by a transition between a lower-to-higher speed of the seismic waves, consistently (perhaps) with a different water concentration in ground.*

The asthenosphere is the upper layer of the mantle, and can be associated to - or identified with - the serpentosphere, i.e., the layer of unknown thickness where water penetrates through dehydrated rocks (see Gregori and Hovland, 2025). An explosive chemical reaction, i.e.,

[1] A star is a "*monad*". See Gregori et al. (2025w) and Gregori and Gregori (2025).

serpentinization, produces hydration and high fracturing of rocks, embedded in supercritical water (ScriW). Hence, the lithosphere drifts over the asthenosphere, which is a layer lubricated by ScriW. The asthenosphere has a high electrical conductivity σ *. Moreover, owing to the Hamilton's variation principle (see Gregori et al., 2025e), every electric current* $\boldsymbol{j}$ *originated deep inside the Earth tends to expand as much as possible. Hence, the currents* $\boldsymbol{j}$ *that leak off from the* CMB *(core mantle boundary) expand as much as possible, i.e., up to the upper boundary of the serpentosphere where they decay, and contribute to increase the local* σ.

*Owing to the increasing gravitational compression, temperature increases vs. depth through the mantle. Higher temperatures produce greater ionization, i.e., free electrons are available extracted from progressively deeper atomic shells. Electrons are stripped from their respective nucleus. The state-of-matter is no more solid – unlike what happens in the crust - because crystalline bonds no more exist. The large availability of electrons makes the medium highly conductive - i.e., a state occurs that, inside a large planet such as Jupiter, is conventionally called "*metallic*". The Earth's mantle is therefore a fluid of decreasing viscosity vs. depth, being in a state that, more correctly, must be said to be "*metallic*".*

*The outer core (*OC*) is basically completely fluid, or metallic - and S waves cannot propagate through it. In any case, the electrical conductivity* σ *in the deep Earth's interior can be estimated only with large error-bars, by means of computations of induced e.m. currents of very low frequency (see Fig. 4 of Gregori and Leybourne, 2021, and also Gregori, 2002, and references therein).*

When the atomic nuclei are completely stripped of their electrons, the "naked" nuclei interact through their nuclear magnetic moments (see Gregori et al., 2025w, Gregori and Gregori, 2025). On the other hand, the present theoretical physics has several uncertainties concerning the detailed mechanism. The state-of-matter is, however, compact - because magnetic cohesion forces exist that are much stronger than crystalline bonds. Owing to the complete absence of electrons, the electrical conductivity σ *is null. At the same time, nuclei experience a strong electrostatic repulsion, which is opposed by gravitational compression, while attraction by nuclear magnetic moments overwhelms Coulomb's repulsion. Call "*magpol*" such a state-of-matter, being acronym for "magnetic-polarized state". Owing to the close alignment of all magnetic moments, all nuclear magnetic moments are compacted into some kind of "fibrous" pattern, In addition, the magpol state releases no photons, i.e., it is "dark matter". Several different subtle meanings are associated to the term "dark matter". "Dark matter" here simply denotes absence of photons, hence, we cannot directly observe it. The general feeling is that the largest fraction of matter in the universe ought to be "dark matter*".

In addition, the overall balance of the Earth is controlled by three engines, a physical engine (*TD*-dynamo), a chemical engine (serpentinization), and a biological engine (biosphere). See Fig. 2.

Inside the Earth, we can deal with three basic surfaces, at the *ICB (*inner core boundary), *CMB*, and *ALB*, (asthenosphere-lithosphere boundary), respectively (some details are given, e.g., in Gregori et al., 2025k, 2025l,, 2025m,, 2025n,, 2025o), briefly denoted as spherical surfaces (ss) even though they are not necessarily spherical, The *magpol IC* has no free conduction charges (electrons), hence, its electrical conductivity σ is null. Conversely, a rapid drop of σ characterizes both *ICB*, *CMB*. Owing to Hamilton's (Gregori et al., 2025e), all currents generated inside the *OC* and mantle must expand as much as possible, until they decay by Joule heat.

The timing of the transport of endogenous energy to Earth's surface originates the Earth's *electrocardiogram* (Gregori and Dong, 1996) pattern that is clearly displayed by the output of the Hawai'i hotspot recorded on the Pacific Ocean floor (Gregori et al. 2026a and references therein). A key feature is the *sea-urchin* pattern of the deep Earth interior, always determined by Hamilton's (Gregori et al. 2026a).

All computations deal basically with energy balance, and this leads to the important mechanism of the Earth's battery, which is refilled by the *TD*-dynamo, while the efficiency of the *TD*-dynamo is modulated by long-period changes of solar activity, through the e.m. field transported by the solar wind,

In contrast, the energy loss of the battery is determined by the energy loss off the Earth's surface, i.e. by the efficiency of the "channel" through which the deep energy can be transported up to Earth's surface. That is, this efficiency is determined by the available sea-urchin spikes. Sea-urchin spikes evolve and develop, taking a time lag in the order of $\sim 28\ Ma$, thus causing the typical pattern of the Earth's *electrocardiogram*. At present, we are going across a *heartbeat*, which causes a violent climate change. The ongoing *heartbeat* can be called the *Iceland heartbeat*, as $\sim 2\ Ma$ ago Iceland did not exist.

Suppose that, at some given time, the stage of the Earth's evolution is through an epoch when the *OC* is warming, i.e. the battery is recharging, because the sea-urchin spikes transport less energy than the energy refilled by the *TD*-dynamo.

A warmer *OC* causes a more effective "erosion" of the *IC*. Indeed, if the kinetic energy of the ions of the *OC* is larger than the bonds between the magnetic moments of the fully ionized nuclei that compose the *magpol IC*, the *OC* ions can scatter and take off from their *magpol* state some fully ionized nuclei. Note that this is independent of the Feynman graphs argument of nuclear physics etc. That is, a warmer *OC* causes a reduction of the size of the *IC* and an increase of the volume of the *OC*.

Conversely, an increase of the volume of the *OC* determines a greater efficiency of the *TD*-dynamo, because a larger volume is available of freely moving conductive matter. Hence, a more efficient *TD*-dynamo causes an additional increase of the *OC* temperature, etc. Therefore, the result is self-amplifying.

On the other hand, a warmer *OC* altogether with a more efficient *TD*-dynamo speeds up the process of penetration

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of the sea-urchin spikes. Therefore, at some suitable subsequent time, the ”channel” is almost abruptly improved for the outward release of endogenous energy. Differently stated, the former ”positive” energy balance of the battery (i.e. greater energy production than release), is reversed into a ”negative” balance (i.e. greater release than energy production).

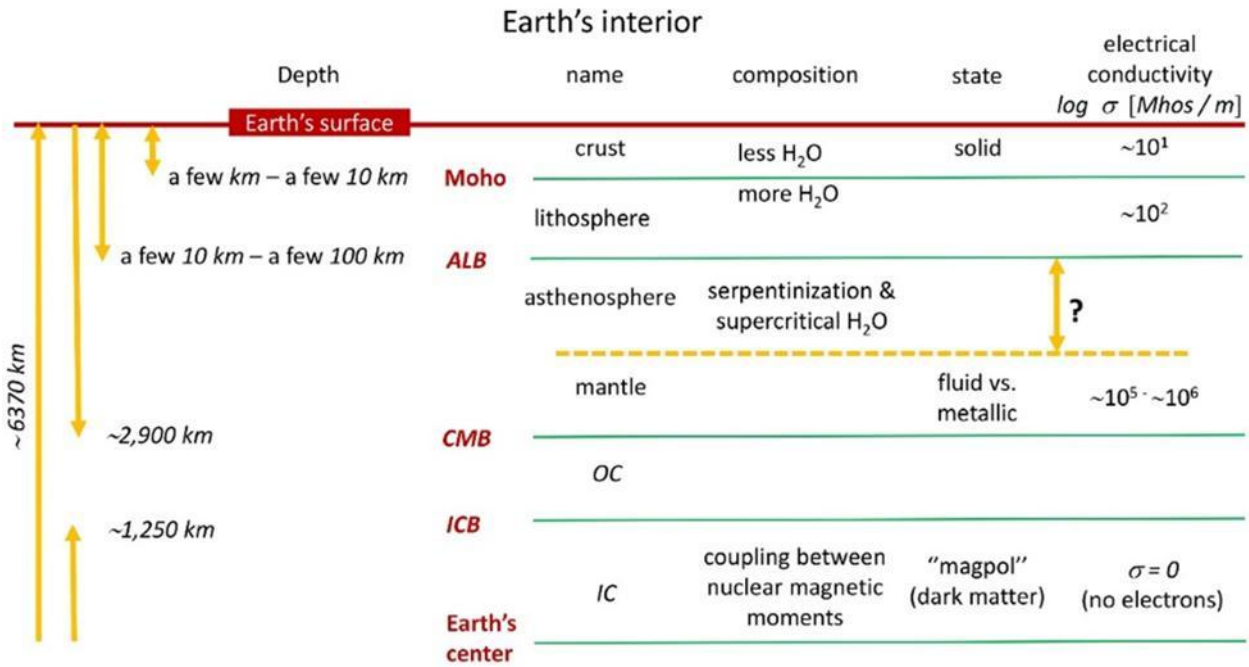

Fig. 1 – Conventional structure and names that are here adopted of the components of solid Earth. After Gregori et al. (2026a). With kind permission of *New Concepts in Global Tectonics, Journal*.

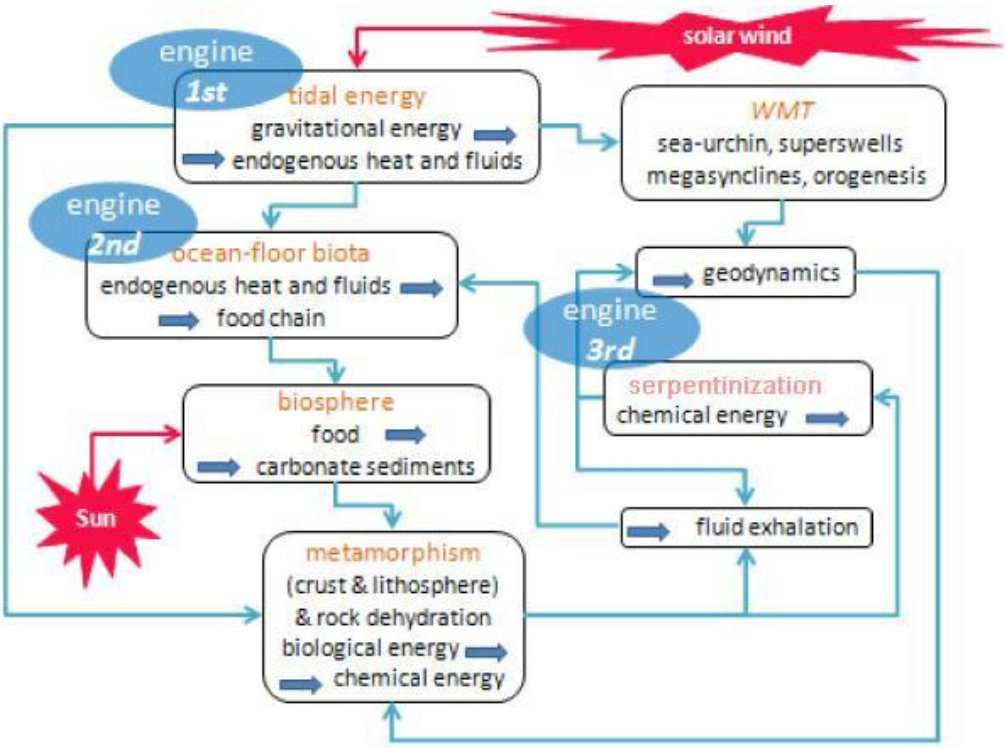

Fig. 2 – *"The leading drivers of 'climate' are three engines. The Sun modulates - by means of the solar wind - the efficiency of the physical engine (i.e. the* TD *geodynamo). In addition, concerning the food-chain and the production of biomass, the solar irradiance amplifies the role of fluids and energy that are exhaled from soil. Biomass finally returns carbon into ground in the form of organic sediments."* Figure and captions after Gregori (2015b), also in Gregori and Hovland (2025). With kind permission of *New Concepts in Global Tectonics, Journal*.

In general, a battery stores energy to be released at a second time. The best-known batteries rely on chemical reactions (such as a car battery). Other batteries can rely on huge capacitors. Other batteries can rely on a change of the state-of-matter. This is the case of the Earth.

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Time variation of the average radii of the *ICB*, *CMB*, and *ALB*

An unexpected and interesting inference deals with the time variation of the average radii of the *ICB*, *CMB*, and *ALB*, respectively (see details, e.g., in Gregori et al., 2025k).

The observational database is the ensemble of the several *SHE* (spherical harmonic expansion) models for the geomagnetic potential available in the literature, which were computed for different epochs, since the former first historical analysis by Gauss. At present, also several historical models are available that range back until the 15th century, computed by means of the logs of the historical voyages across different oceans.

Concerning these very old observations, they measured the geomagnetic declination and inclination, not the field strength, not the Z component. Therefore, their corresponding *SHE* model can be computed apart an arbitrary multiplicative constant (Kono, 1976) that, for future reference, is here called $C(t)$. This constant can be estimated by means of Fig. 4 of Gregori et al. (2025m) and the related arguments.

However, concerning the old epochs, as far as the ss radius is concerned either of the Nevanlinna's or of each one of the two Lowes' lines in the *LN* (Lowes-Nevanlinna's) plot (see, e.g., Gregori et al., 2025k), their respective radius[2] is known apart an unknown and arbitrary addition of a constant on the ordinate scale. On the other hand, the asymptotic radius depends only on the tilt Q of every line. That is, this asymptotic radius can be significantly computed also for every very old *SHE* models, even upon taking into account the aforementioned indeterminacy.

This asymptotic lower boundary – for the radius determined by this geomagnetic constraint, of either one of these three ss - is representative of a physical lower limit for the actual seismically determined radii of the *ICB*, *CMB*, and *ALB*, respectively. It is thus found that there is an underestimation roughly at most less than the order of $\sim 5\,\%$.

Hence, it is possible to compute the variation *vs.* time of these asymptotic radii, or - based on the previous assumption - of the actual physical radii of the *ICB, CMB,* and *ALB*.

The radius of the *ICB* can be estimated by means of the terms of the *SHE* with degree $n = 1, 2$. This is likely to be indicative of the radius of the *magpol IC*.

The radius of the *CMB* can be estimated by means of *SHE* terms with $n = 3, \ldots, 14$, and the radius of the *ALB* by means of *SHE* terms with $n > 14$.

The ancient *SHE* models were computed with series truncation at a very low n. Paradoxically therefore the radius of the *ICB* is always available - and certainly more reliable - even for the oldest epochs, as the terms with $n = 1, 2$ certainly predominate over all others, and can be determined with a comparably much smaller error bar.

Fig. 3 shows the result[3] for the radius $R^{(0)}(t)$ of the *ICB*. The minimum occurred in 1790±1 AD. A jerk occurred at that time (Barraclough and Malin, 1999). According to the analysis carried out in the present study, it appears to be the unique jerk involving the *IC* and it began in 1790 AD. The famous *French Revolution* conventionally began in 1789 AD. Hence, this can be briefly called the "*French Revolution jerk*".

This appears to be the unique observed jerk originated at the *ICB*, while the *CMB* is the likely source of all others jerks. Therefore, the "*French Revolution jerk*" deserves a specific investigation and discussion (not here given).

Fig. 3 shows also an empirical fit of $R^{(0)}(t)$ by means of a polynomial of varying order p, having a squared correlation coefficient ρ^2 that increases with p. At last, it has been arbitrarily chosen $p = 5$. The interpolating polynomial is

$$R^{(0)}(t) = \sum_{h=0}^{5} a_h\, t^h \qquad (t \text{ in years AD})$$

$$a_0 = 1069681.41962 \qquad a_1 = -2868.03242 \qquad a_2 = 3.08519$$

$$a_3 = -1.65810 \cdot 10^{-3} \qquad a_4 = 4.435990 \cdot 10^{-7}$$

$$a_5 = -4.70583 \cdot 10^{-11} \tag{1}$$

and the minimum of $R^{(0)}(t)$ is

$$R^{(0)}(1790) = 724.4203\ km \tag{2}$$

The lowest plot in Fig. 3 shows $[dR^{(0)}/dt]$ *vs.* t, evaluated by means of this polynomial.

According to the aforementioned argument, the *OC* appears to have experienced a warming until 1790 AD. Subsequently it started to cool. Hence, the *IC* progressively expanded. Since at present the Earth seems to experience the "*Iceland heartbeat*" and since at present the release of endogenous heat ought to be close to the maximum of the *heartbeat* - it appears likely to conclude that the maximum temperature inside very deep Earth occurred in ~1790 AD.

This is, indeed, supported by a physical argument. The argument is as follows.

On the basis of present physical understanding, it is impossible to give a full explanation of the energy balance of the interaction between a $\boldsymbol{j}$-loop and a *magpol* object, such as the *IC*. There should be need to appeal to some as yet not fully understood items of fundamental nuclear physics dealing with the physical implications of a nuclear moment. Fig. 3 means therefore that the maximum energy storage of the Earth battery occurred in 1790-1791 AD, when a geomagnetic jerk occurred.

[2] Note that, since the computation of the radius relies only on an energy balance argument, the estimate of this radius is independent of whether one considers the true *magpol IC* or some equivalent shell of $\boldsymbol{j}$-currents. See additional details in the following.

[3] The very first plot of Fig. 3 was derived in cooperation with Fabrizio T. Gizzi, while several subsequent analyses here reported in the following were carried out in cooperation with Gao Xiao-Qing (see, e.g., Gregori et al., 2025k).

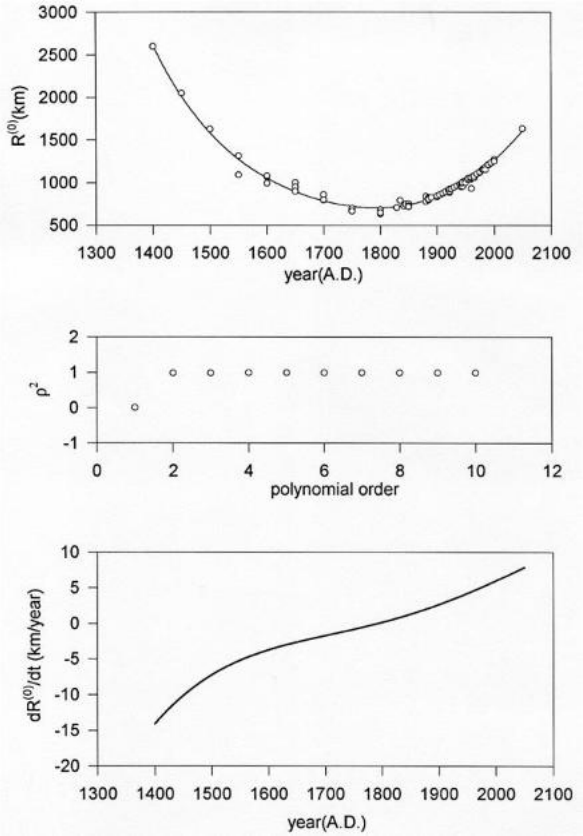

Fig. 3. *(a)* Time variation of $R^{(0)}$, and its interpolation by means of a 5th order polynomial. All *SHE*s are used. This is the apparent time variation during the last ~ 6 $centuries$ of the geomagnetically determined values (see text) of the radius of the *ICB* (in reality it is a lower bound limit for its physical value, implying a likely underestimate by, say, at most $\sim 5\%$. *(b)* Squared correlation coefficient ρ^2 of the fit of the observed points plotted in figure *(a)* in terms of a polynomial of a given order *vs.* order. *(c)* Plot of $[dR^{(0)}/dt]$ *vs.* year derived from the interpolating 5th order polynomial plotted in figure *(a)*. This plot was formerly obtained in cooperation with Fabrizio T. Gizzi (after Gregori, 1997). With kind permission of the late Wilfried Schrˆder.

In addition, however, one must consider the solar modulation on the effectiveness of the *TD*-dynamo.

The late Dong Choi (private communication, 2013)[4] claimed that "*it is now clear that we are heading for a major solar low cycle similar to the Dalton Minimum which is from 1793 to 1830*."

In the final analysis, the concern is therefore about whether some e.m. field of very-long period in the solar wind actually preceded the observed Dalton Minimum. In this case, the solar modulation ought to be responsible for a substantial reduction of the efficiency of the *TD*-dynamo, thus producing a reversal of the energy balance in the Earth's battery.

On the other hand, as mentioned above, the alternative possibility is that this reversal of the energy balance of the Earth's battery was originated by the opening to the "channels" through which the endogenous energy could be released through sea-urchin spikes etc. In the ultimate analysis, both effects can contribute to the same result.

Therefore, at present it appears difficult, if possible at all, to discriminate between these two possibilities. The problem is not of a mere academic concern. Indeed, the long-range trend of climate is strongly controlled by these phenomena. In either case, whether wrong or correct, this seems to be the unique presently available physical interpretation of the objective observational evidence of Fig. 3.

In any case, this figure can be conceived to be just as a simple or unusual way to represent the well-known geomagnetic *SV* (secular variation), which is classical observational evidence first discovered by Edmond Halley in 1701-1702 and that is still essentially unexplained.

Alternative and/or competing proposals are warmly welcome for the interpretation of Fig. 3. However, as far as no alternative explanation is eventually proposed, Fig. 3 can be considered as an observational "proof" of the credibility of the hypothesis of an *IC* in a *magpol* state.

In summary, it is reasonable to infer that, since 1790 AD the storage of endogenous energy ought to be decreasing. On the other hand, according to the evidence inferred from the Hawai'i hotspot (according to the derivation of the *electrocardiogram*), a time delay of the order of $\sim 50{,}000 - 100{,}000\ years$ could be observed before the occurrence of an effect at the Earth's surface.

When considering the case history of the *CMB*, compared to the *ICB,* the analogous data-handling concerning the time variation of the radius of the *CMB* suffers - as expected - by some substantially much larger error bars, and the plot appears much scattered. The reason is related to the comparatively worse determination of the terms with $n = 3, \ldots, 14$ of the *SHE* geomagnetic potential, compared to the terms with $n = 1, 2$. Fig. 4 shows several computed points, while some others are not shown, as they fall outside the range of the plot and are physically definitely untenable.

In addition, a smooth dotted line is shown, being somewhat arbitrarily interpolated over the points that appear likely to be physically more reliable. In fact, it is ultimately impossible to estimate any kind of formal error bars for every point. Every given *SHE* model of the geomagnetic potential suffers from two sources of error.

One primary concern is about the observational database - number of geomagnetic stations, their precision, more or less uneven spatial distribution, integration with ship-borne and/or air-borne measurement, and/or with satellite data.

In addition, an even more relevant source of error is the mathematical handling procedure, which experienced a large evolution altogether with the available computer facilities. It is essentially impossible to evaluate any error bar, as the detailed information needed, particularly on the numerical procedures, is insufficiently known.[5]

[4] We kindly acknowledge him for this important comment.

[5] The reliability of every model can be inferred upon comparing the regularity of the trend of the *SV* of several quantities derived from geomagnetic models of consecutive epochs. In particular, the *SHE* model computed for 1922 AD resulted very anomalous and unreliable.

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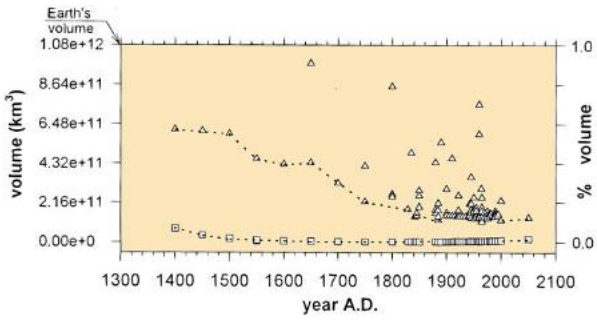

Fig. 4. Apparent time variation during the last $\sim 6\,centuries$ of the geomagnetically determined values (see text) of the radius of the *CMB* (in reality it is a lower bound limit for its physical value, implying a likely underestimate by, say, $\sim 5\%$. The plot is restricted by limiting its total extension - on the ordinate axis - inside some physically acceptable boundaries (i.e. the radius must be positive and not larger than the Earth radius). Every point is denoted by a small triangle, while the ordinate axis is expressed as the volumes of a sphere having the radius of the *CMB*. For comparison purposes, the same data of Fig. 3 are here plotted (denoted by squares) with this new ordinate axis. Some relevant errors of the *SHE* produces a large scatter - as expected only in the *CMB* datum. The points that - on a physical ground – appear more credible are connected by a dotted line. At present, the lower bound of the volume of the Earth's core is $\sim 10-15\%$ of the total volume of the Earth, while in 1400 AD it appears to have been as large as almost $\sim 60\%$. The trend to decrease of the volume of the liquid phase inside the Earth is basically monotone, except during some periods in which it remains almost constant on a "plateau", corresponding to epochs of comparatively higher solar activity. See text. These results were formerly obtained in cooperation with Fabrizio T. Gizzi. Figure after Gregori (1997). With kind permission of the late Wilfried Schrˆder.

Upon a closer inspection it is found that the "plateaus", i.e. the periods of time during which this dotted line appears almost horizontal, coincide with periods of comparatively more intense solar activity (Fig. 5). This fact envisages that, owing to more intense, induced currents in the mantle, the *TD*-geodynamo appears to be more effectively recharging during times of comparatively higher solar activity.

The Stuiver et al. tree rings ^{14}C curve is correlated with the variation vs. time of the energy supply to Etna and Vesuvius (Fig. 6) – which is independently shown to correlate with the time variation of all other volcanoes of the world (Gregori et al., 1994).

For the sake of completeness, it should be recalled that the possibility of a solar influence at the Earth's core had been envisaged by Ribin (1985), relying on an analysis of the $20\,year$ and $70\,year$ period variations of the geomagnetic field. His evidence, however, is biased by the great difficulty to assess and isolate these specific periodical components of $\boldsymbol{B}$. Nevertheless, even by facing the challenge of this relevant difficulty, he concluded that "*the hypothesis is advanced*" of an "*influence of the Sun on the liquid core of the Earth*".

A more detailed analysis on the time changes of the structure of the Earth's interior is discussed in Gregori et al. (2025k, 2025l,, 2025m,, 2025n,, 2025o).

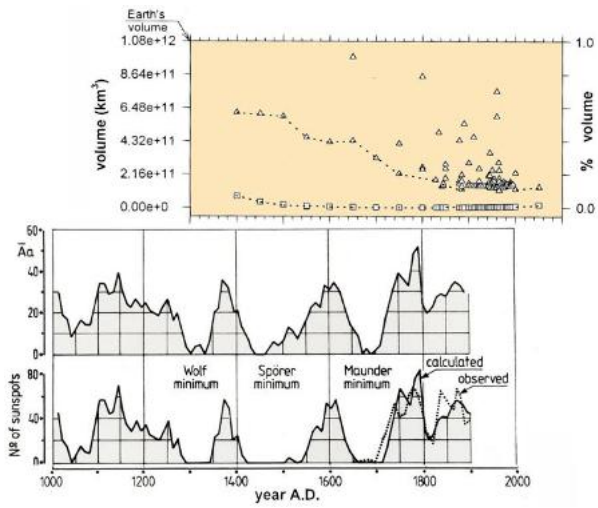

Fig. 5. Fig. 4 is re-plotted by combining it with another figure in order to show the solar control on the radius of the *CMB*. The explanation of the lower figure is as follows. The top and bottom diagrams were derived by Minze Stuiver et al. (Stuiver and Quay, 1980; Stuiver and Becker, 1986); Stuiver and Braziunas, 1988, 1989), upon considering that a comparatively higher solar activity implies a lower cosmic ray flux impinging on the Earth (Forbush decrease), hence a smaller ^{14}C production rate. The two needed regression lines for ^{14}C content - vs., respectively, either sunspots or indices of geomagnetic activity - were calibrated by means of the available historical observations. Then, the ^{14}C content within tree rings (of a given age) was used for inferring either the solar or the magnetic activity during previous epochs. The dotted line shows, for comparison purposes, the curve derived from direct sunspot observation. Figure after Gregori (1992) and Gregori (1997, 2002). With kind permission of the late Wilfried Schrˆder. These results were formerly obtained in cooperation with Fabrizio T. Gizzi. Unpublished figure.

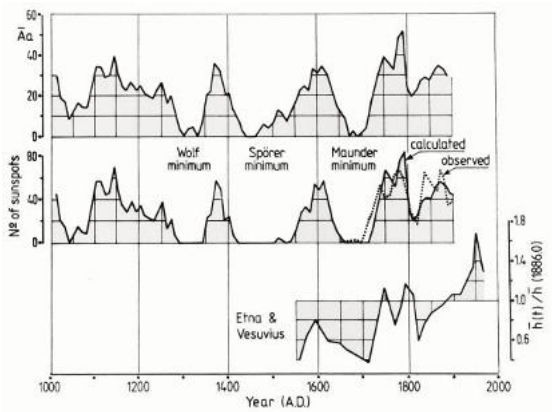

Fig. 6. The 1st and 2nd diagrams (top to bottom) are explained in the captions of Fig. 5. The 3rd plot shows the time variation of the primary energy supply to Etna and Vesuvius in terms of a "*calorimetric criterion*". Namely, assume that volcanoes behave much like a pressure cooker, displaying cyclic features, and that the duration of every cycle is inversely proportional to the average primary energy supply during every given cycle. Such a time variation of the primary supply to volcanoes seems to be synchronous for all historical volcanoes from all over the globe. Figure after Gregori et al. (1992) and Gregori (1997, 2002). With kind permission of the late Wilfried Schrñder.

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The *superrotation* of the *IC* computed by a beat effect of the geomagnetic *SV*

Gregori et al. (2025y) extensively discuss this item is in, and we report the abstract of that paper. We just emphasize the *objective significance* of this result, as it relies only on a simple mathematical analysis of observations, i.e. of the *SV*, with no additional working assumption. Every other investigation, on the shape and dynamics of the *IC* relative to Earth's surface, must take into account this inference that is derived from a simple formal "beat analysis".

"*The standard way to compute the geomagnetic* SV *is by using maps of yearly means, i.e., by averaging over* $365\ days$, *and over* $366\ days$ *during leap years. The generally reported value is a* WD ($Westward\ Drift$) *by* $\sim 0.2°\ year^{-1}$. *On the other hand, the observed* WD *can be a beat between the* $1\ year$ *period of the orbital motion of the Earth, arbitrarily introduced by choosing either* 365 *or* $366\ days$, *and the actual rotation of the* IC *with respect to Earth's surface. Hence, the amount of the observed* WD *must vary, if the average is taken of magnetic records over some period* $[365.25 - \Delta t]$ *vs.* Δt. *This is the basic rationale of the present analysis.*

The INTERMAGNET *database is used, available in 1999-2001 referred to complete records for* 73 *observatories. A stroboscopic effect is found that envisages an* IC *that spins faster than Earth's surface, with an apparent period of* $\sim 369.75 \pm 0.5$ *rotations (number of rotations during one solar year of* $365.25\ days$*). Hence, the* IC *seems to spin faster than Earth's surface by* $\sim 370/365.25 \cong 1.01$, *or by* $\sim 1\%$. *Therefore, if this is correct, a reasonable final indicative value is, say,* $\sim 370 \pm 0.3$ *rotations in* $1\ year$, *equivalent to a period (for one rotation) of* $\sim 0.9872 \pm 0.0008\ days \cong 23.69 \pm 0.02\ hours \cong 85,291 \pm 71\ sec$. *The reported observed* WD *of* $\sim 0.2°\ year^{-1}$ *ought to be a beat due to the arbitrary reference to annual mean values over* $\sim 365.25\ days$, *while in reality the* IC *experiences a* WD *of* $\sim [4.5 \pm 0.5] \times 360°/365.25\ year^{-1} \cong [4°.4 \pm 0.5]\ year^{-1}$.

This paradoxical evidence provided by the stroboscopic effect is $\sim 22\ times$ *larger than the expected* $\sim 0.2°\ year^{-1}$ *(or, more exactly,* $\sim 0.24°\ year^{-1}$ *concerning the specific data set used in the present computation). This has an unexpected physical implication. Upon a closer inspection on the data set used in this analysis, by means of a better algorithm than a simple visual inspection on geomagnetic maps, it is found a* WD *of* $0.287°\ year^{-1}$, *which is in fact close to the approximate* $\sim 0.24°\ year^{-1}$. *Hence, the discrepancy looks quite reasonable.*

A concern deals rather with the need to give a physical interpretation of the dramatically larger, and precise, estimate of $\sim [4.4° \pm 0.5°]\ year^{-1}$. *A possible reasonable explanation is related to the geodetic figure of the* IC. *That is, the* IC *is likely to have spatially repeated bumps in longitude, in such a way that its real* WD *is* $0.287°\ year^{-1}$, *while, by searching the stroboscopic effect, its speed is* $\sim 4.4°/0.2° = 22\ times$ *larger, due to some approximately regular "hills" and "valleys" on the* IC *surface. These items are extensively discussed, including future research perspectives".*

The claimed *superrotation* of the *IC* – Conflicting evidence

The time variation of the radius of the *ICB* was measured - in recent times - also by seismic methods, as shown by Figs 7 and 8, and the results confirm the same inference as per Fig. 3.

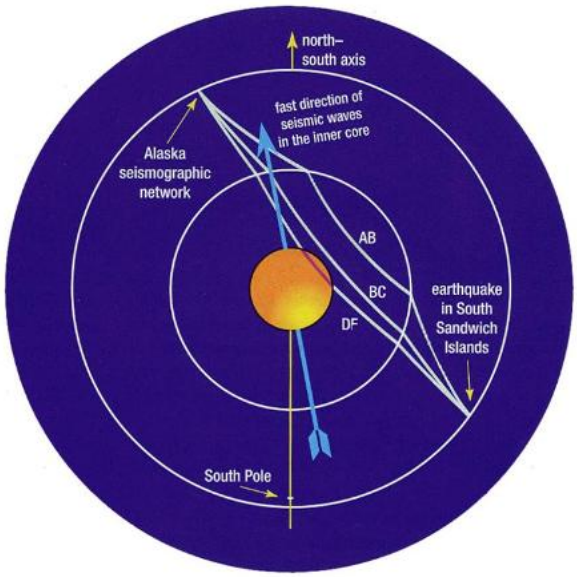

Fig. 7. "*The plane shown here contains three ray paths by which seismic waves, traveling through the core, propagate from a source region in the South Sandwich Islands to an observing region in Alaska. Two of these rays, labeled BC and AB, pass through the fluid core. DF, with part of its path colored violet, passes also through the solid core. The blue arrow, out of the plane of the rays, gives the fast direction of anisotropy. In general, the plane of the rays contains neither the fast axis nor the north-south axis. If the* IC *rotates eastward about the north-south axis, carrying the fast axis along with it, the angle the fast axis makes with the (violet-colored) ray path in the* IC *will be reduced, reducing the travel time along the DF ray path. This travel time becomes stationary when fast axis and ray are in the same plane. An alternative explanation of travel-time change is that the* IC *is inhomogeneous and material of different seismic velocity moves into the (violet-colored) path. Both mechanisms, anisotropy and inhomogeneity, can be present*." Figure and captions after Richards (2000). With kind permission of *Astronomy & Geophysics.*

These Figs 7 and 8 were, however, interpreted in the literature as evidence for a so-called "*superrotation*" of the *IC*. That is - as emphasized in the Introduction - at present it is generally and almost unanimously assumed that the Earth is a ball cooling in space like a Buffon's cannon ball. Hence, an *a priori* assumption - on no basis other than the aforementioned Buffon's model – is that the internal structure of the Earth, hence to *ICB*, cannot change so rapidly.

Therefore, they appeal to some speculated spherical anisotropy of the *IC*, whereby its radius, when it is

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determined at different times - but always by an identical track of some seismic waves (seismologists call ”seismic ray” every track) - eventually changes in time depending on a differential ”*superrotation*” of the “solid” *IC* with respect to Earth’s surface.

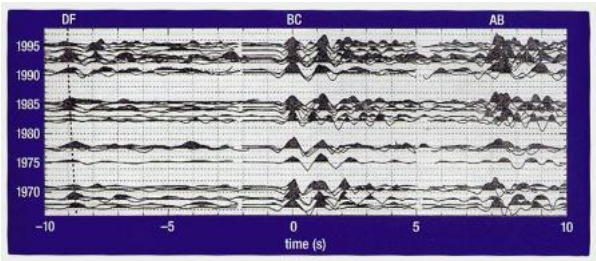

Fig. 8. ”*Seismograms recorded at station* COL *in Alaska, for South Sandwich Island earthquake over* $28\ years$. *These signals are aligned on the time of the BC arrival, and a slight time shift is applied to the first* $7\ sec$ *of records including the DF arrival, in order to correct the relative position of BC and DF to that expected at a common source-station distance of* $151°$. *(The time shift to a standard distance is necessary because these earthquakes actually occurred at slightly different locations.) The time difference between DF and BC arrivals is seen to increase over these decades by about* $0.3\ sec$. *(Courtesy by X. Song).*” This evidence was later disputed, although it should be re-interpreted according to the rationale of the present study. Figure and captions after Richards (2000). With kind permission of *Astronomy & Geophysics*.

However, systematic research was attempted by using all available tracks of seismic waves suited to probe the *IC* radius - rather than only a few specific case histories. It was thus found that this *superrotation* surprisingly was not confirmed. In contrast, the result (Dormy et al., 2000) was very controversial inside the error bars, sometimes even envisaging an opposite *superrotation* (if any).

Some debate raised. For instance, Souriau et al. (2003, 2003a) claim that ”*recent results seem to favor rotation rates below* $0.2°\ year^{-1}$.” Finally, Creager (2013) proposed ”*decadal variations in* IC *rotation rate*.” On the other hand, if this is correct, to our knowledge it appears difficult to envisage any reasonable physical explanation for such an effect.

Richards (2000, with additions in 2007) reviews and comments on this whole item. We mention only a few statements from his extensive discussion, and the interested reader ought to refer to his original paper.

The original estimate was given by Song and Richards (1996) envisaged a *superrotation* of a few $0.1°\ \mathrm{year}^{-1}$. Song and Helmberger (1998) and Vidale and Earle (2000) envisaged significant inhomogeneity in the *IC*, which could support the propagation of S waves as observed at the Earth’s surface.

Before making any additional discussion, Richards (2000) warns that ”*it must first be recognized as imposing a potentially unacceptable framework in which the* IC *is thought of as rotating essentially as a rigid body, when instead a low-viscosity* IC *will deform as well as undergoing rotation on average.”* On the other hand, we wonder how a ”solid” *IC* can be a ”*low viscosity*” object.

Su et al. (1996) used an anisotropic model and analyzed several thousands of reported absolute arrival times. He concluded with a rotation rate about three times faster than that of Song and Richards (1996). Richards (2000) comments that the use of a very large database implies large error bars, due to source location and origin time, so that their estimate of the rotation rate has large uncertainties. Dziewoński [6] and Su (1998) later concluded that their analysis “*implies a zero, or non-detectable, rotation rate.”*

Subsequent studies stressed the inadequacy of modeling *IC* seismic velocities by cylindrically-symmetric anisotropy. An early study by Tanaka and Hamaguchi (1997) envisages that there is great variability of travel times for paths approximately north-south through the *IC*.

Various studies (e.g. Durek and Romanowicz, 1999) agreed on the *IC* anisotropy. Creager (1999), using more than *2000* relative travel-time measurements concluded that the “IC *is strongly anisotropic (* $2-4\%$ *on average) throughout most of the western hemisphere from near the surface to its center and into the lowermost several hundred kilometers of the eastern hemisphere. In contrast, the outer half of the eastern hemisphere from 40° E to 160° E ... exhibits very weak anisotropy ... The symmetry direction is the fast direction and lies on or near the spin axis ... The* IC *appears to be organized in a very simple way with* $60-90\%$ *of its volume containing well-aligned crystals ...* ”

Then, Richards (2000) summarizes the subsequent debate between several authors, and comments as follows.

Creager (1997) avoided the assumption of homogeneous anisotropy and was the first to seek an explanation in terms of lateral heterogeneity in the *IC*, confirming the temporal changes reported by Song and Richards (1996), and giving an interpretation in terms of an Easterly rotation of an *IC*. Creager, using independent data, estimated a rotation rate of $\sim 0.2-0.3°\ \mathrm{year}^{-1}$.

Sharrock and Woodhouse (1998) used data for a 20 year period and *“concluded there is some indication of* IC *rotation but that the preferred direction is retrograde (i.e. to the west). However, they showed that the* 90% *confidence interval for the estimated rotation rate included prograde (eastward) values up to* $\sim 1°\ year^{-1}$*.”*

Laske and Masters (1999) presented a 20 year analysis and determined a relative rotation of the lateral heterogeneities in the *IC* for years from 1998 to 1977. Dahlen (1999) summarized their approach, confidently ruling out a differential rotation as high as $1°\ year^{-1}$, being, however, “*marginally consistent*” with the $0.2°-0.3°\ \mathrm{year}^{-1}$ eastward rate found by (Creager 1997).

Richards (2000) mentions a few additional studies. Ovtchinnikov et al. (1998) found an opposite behavior, although the result can be explained and reconciled with previous evidence by means of a few assumptions on the figure of the *IC* (see details in Richards, 2000).

[6] Adam Marian Dziewoński (1936-2016), Polish-American geophysicist.

Song and Li (2000) reported an increase of ~ 0.6 sec over a 37 year period. Song (2000) extended the original 28 year period of time to a 45 year period and found a similar trend over decades of data. He also combined these data over *100* stations of the *Alaska Seismographic Network* during the 1990s. "*Remarkably, ... he found evidence of* IC *rotation just from data in the 1990s*." Song (2000) concluded that the rotation rate must be in the range $0.3° - 1.1° \text{ year}^{-1}$ faster than the mantle.

John Vidale and his colleagues used short-period seismic waves, called "*coda*", back-scattered from the *IC*. Vidale and Earle (2000) document 200 sec of seismic waves scattered from the *IC* following the expected arrival time of the reflection (called *PKiKP*) from the *ICB*. They used *12* earthquakes and *4* underground nuclear explosions, using the *Large Aperture Seismographic Array* (*LASA*), operated in the 1960s and 1970s in Montana, USA. The result indicates a few% stiffness variations in the *IC* with a scale length of ~ 3 km.

Vidale et al. (1999) compared the *LASA* data for *PKiKP coda* of two nuclear explosions in Novaya Zemlya, made in 1971 and 1974 at almost the same location. They found that during 3 $years$ the western hemisphere of the *IC* seems to have moved toward *LASA*, and the eastern hemisphere has moved away. This is consistent with an Easterly *IC* rotation of about $0.15° \text{ year}^{-1}$.

Richards (2000) concludes therefore that "*the original claim of evidence for* IC *rotation was predicated upon a homogeneous cylindrically-symmetric model of* IC *anisotropy with fast axis tipped over from north-south ... Because of the complicated effects of* IC *lateral velocity gradients, upon travel times as the* IC *rotates, it might seem that several years of work will be needed to elucidate* IC *inhomogeneities in order to interpret travel time changes in terms of more precise rotation rates. The picture is also complicated by allowing for the possibility of low viscosity and hence deformation that is not well-summarized by rigid body rotation of the* IC. *... The* IC *is far less accessible to us than the surface of any planet in the Solar System. ...*"

Richards (2000), in his 2007 addition, mentions two new papers, Li and Richards (2003) and Zhang et al. (2005), where the evidence of *superrotation* is confirmed by means of earthquake waveform doublets. Li and Richards (2003) concluded that the "*estimated rotation rate ranges from* $0.4 - 1° \, year^{-1}$ *eastward*." Zhang et al. (2005c) analyzed "18 *high-quality waveform doublets with time separations of up to* 35 $years$" and concluded that the *"Earth's* IC *is rotating faster than the mantle and crust at* $\sim 0.3° - 0.5° \, year^{-1}$." Both these studies refer to earthquakes with epicenters in the same region, detected in the same area.

This whole discussion shows that different authors started from the *a priori* assumption of the existence of a *superrotation* and searched for confirmation of this hypothesis. Others tried to rebut the hypothesis. As far as the possible aforementioned speculated viscous structure is concerned of the *IC*, note that a *magpol IC* has no viscous structure at all. Nobody, however, seemingly thought about the possibility that the size of the *IC* could rapidly change *vs.* time – even by assuming that the Earth is like the Buffon's cooling cannon ball. It should never be claimed that any paradigm must be rebutted in favor of any other paradigm. One must emphasize, rather, that, as far as possible, every conscience-driven scientist should get rid of "every" possible paradigm.

A few subsequent investigations confirmed the aforementioned inferences. For instance, Wen (2006) investigated the compressional waves of two earthquakes occurred in South Sandwich, respectively on December 1st, 1993 (event "*93*") and September 6th, 2003 (event "*03*"), recorded at three seismic stations in Russia and Kyrgyzstan. The signal arrived at least $\sim 39 - 70 \, msec$ earlier in the 2003 event than in the 1993 event. They carefully considered two possible interpretations and concluded the *ICB* radius increased by $\sim 0.98 - 1.75$ km locally beneath middle Africa. Wen (2006) comments that an explanation for a change of the *ICB* can be either *(i)* by a differential motion of the *IC* and by assuming that *ICB* irregularities occur, fixed at the *IC*, or *(ii)* by a rapid growth of the *IC*.

That is, the observed increase rate is the order of $\sim 0.1 - 0.2 \, km \, year^{-1}$, while in Fig. 3 the present rate of increase is of the order of $\sim 0.5 \, km \, year^{-1}$. Consider, however, the intrinsic uncertainties deriving either from observational errors or from numerical-handling errors. In addition, the estimate of Fig. 3 is a planetary average, and it refers to a lower boundary for the radius of the *ICB*, while the Wen (2006) measurement is localized, and it is a seismically determined radius (i.e. it is not an asymptotic boundary). In any case, the agreement is certainly satisfactory.

However, if the effect is a differential rotation, some hypothesis must explain why this effect is localized only underneath Africa. In addition, Wen (*ibid.*) stresses that, according to the *superrotation* hypothesis, one must assume that no change occurred of the shape of the *IC*. The alternative explanation implies.

In an intriguing comment, Wen (2006) stresses that the *ICB* is controlled by the temperature - and by the *OC* composition that - he specifies - is composed of iron and its companion light elements (Fearn et al. 1981). "*Something unknown*" should be responsible for the localized growth. Otherwise, one should assume *"a regional perturbation of temperature and/or composition near the* ICB*"*. Wen (2006) suggests two possible mechanisms: "*a heterogeneous heat-flow flux at the bottom of the* OC" (Sumita and Olson, 2002) or a "*small-scale compositional convection in the top of the* IC" (Worster, 1992). In either case, Wen (2006) emphasizes the irregular geographically not-uniform topography of the *ICB*, and the related growth of the *IC*, with consequent energy implications. The conclusion by Wen (*ibid.*) is a concern about the difficulty of the conventional models, which appeal to core convection, to the Elsasser-Bullard dynamo, etc. in justifying this seemingly localized phenomenon.

In contrast, the sea-urchin spike mechanism requires some observed effect that should can be highly localized. Maybe, it is not a matter of chance that this specific region of Africa is the same that is concerned with Zaïre and/or with the Afar triangle and with the general East-Africa rift system, i.e. with regions that - according to several evidence that for brevity purpose cannot be here reviewed - ought to

be the site of an ongoing penetration of some large bunch of sea-urchin spikes.

In a figure not here shown, but shown by Wen (2006), the slight increase ought to be pointed out that is observed also in the middle of the Indian Ocean and of the Atlantic Ocean. That is, the pattern resembles some kind of mega-plumes transporting heat from the *ICB* through the *OC*.

A conspicuous amount of literature appeared dealing with this often controversial inference (e.g. Souriau, 1998, 1998a; Richards and Song, 1998) about an *IC superrotation*.[7] For instance, (with no presumption for completeness) mere observational investigations are Song and Richards (1996), Souriau (1998, 1998a), Xu and Song (2003) ... Some modeling was also attempted (e.g. Aurnou et al., 1996; Dumberry and Bloxham, 2002, 2004; Dumberry, 2007; ...), including some papers directly referring to the standard Elsasser-Bullard dynamo (they are not here mentioned because this "standard" dynamo is here rejected as nonphysical).

Isse and Nakanishi (2002) investigated the possibility of differential rotation with reference to the regional structure of the *IC* beneath Australia. They found no significant evidence of differential rotation, even though they do not *"rule out a small rate of* $\sim 0.2° \; year^{-1}$ *or less*".

M%inen and Deuss (2011) carried out a global analysis spanning $25 \; years$ and concluded that their "*results suggest that structure in either the* IC *or the* OC *is varying with time, over relatively short timescales and in ways that cannot be explained by, and do not support, a differentially rotating* IC."

A more detailed observational analysis was carried out by Su et al. (1996) who investigated the apparent tilt variations of the *superrotation* axis of the *IC*. They show a figure (not here shown) of their results including the apparent large effects associated to a geomagnetic jerk. This is, however, a different way to represent the geomagnetic *SV*, and also its anomaly on the occasion of a jerk, while its eventual interpretation ought to be considered with suitable care, in terms of a displacement of the spin axis of the *IC*.

These seismological investigations, carried out by several authors - who seemingly were not aware of the *TD*-dynamo and of the consequent time variation of the *IC* which is envisaged by Fig. 3 and which is derived from geomagnetic records alone - definitely favor the time variation of the *IC* radius, rather than its speculated "*superrotation*".

Several investigations are reported in the literature[8] dealing with the anisotropy of the *IC* - or more generally of some other deep Earth's features - which are supposed to be time-constant structures, and to change however *vs.* latitude and longitude, rather than eventually *vs*. time.

Ishii and Dziewoński (2002) even report having evidenced "*an innermost* IC*, with a radius of* $\sim 300 \; km$*, that exhibits a distinct transverse isotropy relative to the bulk* IC*. Specifically, within the innermost* IC*, the slowest direction of wave propagation is* $\sim 45°$ *from the east-west direction. In contrast, the direction of the slowest wave propagation in the overlying* IC *is east-west ...* "

For instance, Yu et al. (2005) find - and confirm similar previous evidence for - a "*distinct 'east-west' hemispheric pattern*" where the "*eastern*" hemisphere is between 40°E-180°E, and the "*western*" hemisphere between 100°W-40°E. They conclude that "*different velocity gradients at the bottom of the* OC *indicate that there may exist a compositional difference and/or a large-scale temperature difference there, and that* IC *formation processes may be different between the two hemispheres. Different* IC *formation processes may produce different geometric inclusions of melt in the top of the* IC*, and thus may provide an explanation to the hemispheric variation of seismic velocity and attenuation in the top of the* IC*. The seismic data also suggest that the variation of seismic velocity in the tangential cylinder of the outer core, if it exists, is* $< 0.1\%$ *...* "

Note, however, that several investigations rely on the *a priori* assumption of a time-invariant shape of the *IC*. In contrast, if the *IC* changes size and geometry during some reasonably short time span, the time of every determination is important. In fact, estimates referring to different regions, but referring to different times, could be the result of a temporal change of the *IC*, rather than of a deviation from spherical symmetry.

Alboussière et al. (2010) proposed an interpretation: "*in addition to its global North-South anisotropy ... , there are two other enigmatic seismological observations related to the Earth's* IC*: asymmetry between its eastern and western hemispheres ... and the presence of a layer of reduced seismic velocity at the base of the* OC *... This* $250 \; km$*-thick layer has been interpreted as a stably stratified region of reduced composition in light elements ... we show that this layer can be generated by simultaneous crystallization and melting at the surface of the* IC." However, they appeal to mantle convection etc.

A more recent investigation was made by Wang et al. (2015b), who rely on a systematic analysis of the earthquake *coda*, maybe better known as "*earthquake duration magnitude*", according to a former proposal by Bisztricsany (1958). This is the interval of the seismic wave measured on the time axis starting with the first seismic wave onset until the amplitude of the wave-train diminishes to at least *10%* of its maximum recorded value. In general, larger earthquakes display longer seismograms. The analysis by Wang et al. (2015b) is strictly seismological. According to the interpretation proposed in the present study their findings are to be commented (we refer to the abstract of Wang et al., 2015b).

[7] Also anisotropy in the "*liquid*" (?) *OC* was investigated. For instance, Souriau et al. (2003, 2003a) concluded that "*the data do not reveal heterogeneity or anisotropy inside the tangent cylinder, nor the presence of anomalous polar caps.*"

[8] Just a few papers are Tanaka and Hamaguchi (1997); Creager (1999); Garcìa and Souriau (2000); Niu and Wen (2001); Ishii et al. (2002a); Ishii and Dziewoński (2003); Romanowicz et al. (2003); Rost and Garnero (2004); Poupinet and Kennett (2004); Carlson (2005); Garcìa et al. (2006); Wang et al. (2006); Yu and Wen (2006, 2006a); Cormier (2007); Niu and Chen (2008); Deuss et al. (2010); …

"*The Earth's solid* IC *exhibits strong anisotropy ... , with wave velocity dependent on the direction of propagation due to the preferential alignment of iron crystals ...* [The *IC* is not "solid", and one must refer to no iron crystals, rather one must consider the *magpol* pattern.]

Variations in the anisotropic structure, laterally and with depth ... , provide markers for measuring IC *rotation ... and offer clues into the formation and dynamics of the* IC ... [This is a mention to the aforementioned *superrotation* concepts.]

Previous anisotropy models of the IC *have assumed a cylindrical anisotropy in which the symmetry axis is parallel to the Earth's spin axis. An inner part of the* IC *with a distinct form of anisotropy has been suggested ... , but there is considerable uncertainty regarding its existence and characteristics ...* [This is part of the speculation that has been envisaged in an attempt to solve the several aforementioned conflicting evidences.]

Here we analyze the autocorrelation of earthquake coda *measured by global broadband seismic arrays between 1992 and 2012, and find that the differential travel times of two types of core-penetrating waves vary at low latitudes by up to* $10\ sec$. *Our findings are consistent with seismic anisotropy in the innermost inner core (*IIC*) that has a fast axis near the equatorial plane through Central America and Southeast Asia, in contrast to the North-South alignment of anisotropy in the outer inner core* OIC. *The different orientations and forms of anisotropy may represent a shift in the evolution of the* IC."

They synthesize their results in two figures (not here shown) that they comment as follows.

"*...We observed clear* IC *arrivals ... in the stacked* empirical Green's functions *(*EGF*s) at* 57 *...For an earthquake source,* [a first] *phase (a compressional wave traversing the* IC*) ... is reflected at the Earth's surface and continues as another ... phase to arrive at a receiving station....* [A] *phase traverses the top of the* IC *and has additional underside reflections at the* ICB. *In this study, the source and the receiver are at exactly the same location; that is, they have zero offset between them or the corresponding ... phases are at exactly* $180°$ *between the source (or the receiver) and its antipode, and thus the ray paths of* [either one] *phase at a station and its antipode are exactly the same.*

As a result of the weak reflection at the ICB, the [first] *phase (not to mention the* [second] *phase) is generally not observable from earthquakes unless at near-antipodal distances with the focusing effect ...* "

For additional details, the interested reader must refer to the original paper. In any case, these papers show that some relevant anisotropy characterizes the deep Earth's interior.

In general, as we already stressed, these authors use some large number of earthquakes, which are recorded over large distances. However, they have no concern about the different occurrence-time of every event (i.e. they assume a steady state of the Earth during the time lag spanned by all available seismic observations).

This dichotomy - i.e. either time or space variation of a given parameter - recalls the same concern about the records performed by a space probe, whereby a measured data series can either refer

(i) to a datum uniform and constant in space, which changes *vs.* time, or alternatively

(ii) to a time-constant datum, which changes *vs.* site.

This dilemma can be solved only by launching two or more identical probes (sometimes called mother-daughter, or twin probes, or cluster of probes, etc.), moving along approximately identical orbits with a "slight" time delay, in order to be able to compare the same measurements carried out at different times and inside some "limited", and approximately the same, regions of space.

However, this is not possible for the study of deep Earth - explored by means of occasional earthquakes - where it is rather tacitly assumed that changes *vs.* time occur only on time scales much longer compared to the time span of all used earthquakes. Some cognitive hazard, however, is always implied by averaging over several occurrences, much like an average animal between a spider and an insect ought to have seven legs, but it does not exist in nature.

Concerning the deep Earth's structure, some intriguing results are reported even from the time-constant viewpoint. The Africa area is specifically addressed by Yu and Wen (2007), and by Wang et al. (2008) who state: "*the presence of the low velocity zone with large velocity reductions beneath southern Africa suggests existence of a low-density anomaly beneath the lithospheric* LID*, which may provide an explanation to the observed localized uplift in the* 'African Superswell'.*"* This is, indeed, the bunch of sea-urchin spikes identified with the East African rift, and with the Zaïre negative gravity anomaly (see Fig. 9).

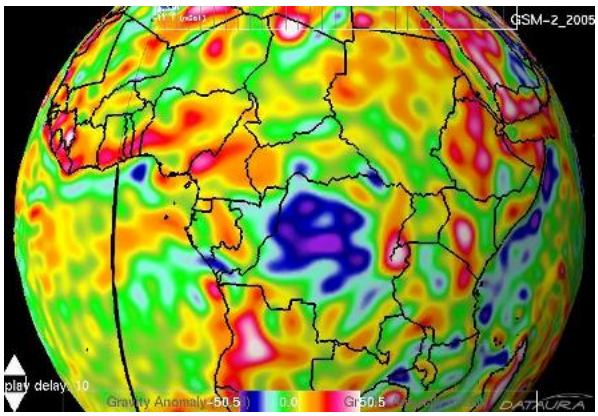

Fig. 9. Detail dealing with Zaïre .of a planetary figure that shows the "*Magnetic Anomaly Map of the World with Mercator and polar stereographic projections. The anomaly field is shown at an altitude of* $5\ km$ *above the WGS84 ellipsoid. ... the entire data set is displayed using the natural color scale (red = high, blue = low) with a shaded relief effect using artificial illumination. ... The original map is at a scale of* $1:50\ million$." Figure and captions after Purucker (2007). This figure is also reported by Thébault et al. (2010), who call it "*World Digital Magnetic Anomaly Map*" (*WDMAM*) and quote Khorhonen et al. (2007). *AGU* copyright free policy.

He et al. (2006a) investigated the anomalous structure of the Pacific Ocean region, compared to an isotropic Earth. They comment: "*such a strong negative shear-velocity*

gradient can be explained by partial melting of a compositional anomaly produced early in the Earth history located within a bottom thermal boundary layer. Our travel time data also exhibit small-scale variations inside the anomaly, indicating existence of internal small-scale seismic heterogeneities inside the 'Pacific anomaly*'*." That is, a much hotter mantle occurs underneath the entire Pacific Ocean area, consistently with the "quatrefoil" pattern of "*Tuzo*" and "*Jason*" patterns proposed by Burke (2011).

From this same viewpoint, He et al. (2006a) specify that the case history of the Pacific Ocean is "... *similar to those of a very-low velocity province beneath the South Atlantic Ocean and the Indian Ocean*". That is, these are also areas of superswells.

Summarizing, the mere seismic evidence concerned with the deep Earth's interior, even including geochemical speculations, appears to be a particularly difficult topic, and the details that can be inferred are therefore scanty and often uncertain. The problem is here reconsidered in the next section, where it is shown how the geometrical figure of the *IC* can be mapped, and how it can change during the years.

Earthquakes and perturbations of pole motion and *l.o.d.*

The figure of the IC

We can infer the figure of the *IC* by means of a combination of observations dealing with geomagnetism, gravity, and changes in the astronomical motion of the Earth. Four kinds of evidence are available.

(i) A first evidence derives from the quantitative information provided by the (presently well-known although completely non-understood) observed correlation between some large earthquakes and pole motion, *l.o.d.* (length of the day) variations, and changes in the Chandler wobble.[9] The available literature is almost endless, and it spans over one century. The most recent violent earthquakes are more significant, due to the improved capability to detect some lesser details of the astronomical motion of the Earth. We extensively discuss below this whole topic, although only as far as the items are concerned that are relevant for the present study. No exhaustive review can be here given.

(ii) A second evidence deals with the correlation between the geomagnetic and gravitational potentials. The concern is mostly about a conceptual approach to the interpretation of some apparent correlation of available observations. The few related papers on this item, we are aware of, are here discussed in some detail.

(iii) - A third evidence can be derived from the (longitudinal) westward drift (*WD*) of the geomagnetic secular variation (*SV*). This is discussed below, and in Gregori et al. (2025q).

(iv) - The fourth kind of evidence is still unexploited. It deals with the latitudinal drift of the geomagnetic *SV*, and its correlation with pole motion and/or eventual *l.o.d.* variation. This is discussed below.

Large earthquakes and their effects on the astronomical motion of the Earth.

A well-known although completely unexplained effect - which has often been observed and reported - is the influence on the astronomical motion of the Earth caused by the occurrence of some strong earthquake. This is manifested e.g. as a stepwise discontinuity in pole motion, or in the Chandler wobble.

"*Changes in the moment of inertia of solid Earth associated with very large earthquakes have also been invoked in attempts to explain the Chandler wobble (for references see e.g. Munk and MacDonald, 1960; Lambeck, 1980; and Barnes et al., 1983)*" (Hide,[10] 1985).

The difficulty, which is encountered by every attempt to give an interpretation of this phenomenon, deals with the obvious need for a change the moment of inertia of the Earth, much like it occurs for a ballerina - or ice skater - who moves her arms and changes her spinning speed. It appears, however, awkward - if meaningful at all - to envisage a suitable mass displacement inside the Earth capable of justifying any significant change of its moment of inertia. Therefore, the problem is generally reported as being unsolvable

In addition, following the great earthquakes and tsunami that followed some recent events [Sumatra-Andaman 2004, Maule or Biobio (Chile) 2010, and Sendai (Japan) March 2011], it is likely that a rejuvenation will occur of these studies, also considering the improved monitoring capability.

For instance, Chao and Gross (2005) studied the case history of the Sumatra-Andaman earthquake (26 December 2004), and specify that "*following Chao and Gross (1987; see also Chao and Gross, 2000), we have been routinely calculating earthquakes' coseismic effects in changing the Earth's rotation (in both* l.o.d. *and polar motion) as well as the low-degree gravitational field ... The results are reported and updated on the Web site of the* Special Bureau for Mantle of the International Earth Rotation and Reference Systems Service's (IERS) Global Geophysical

[9] The Chandler wobble is a change of the Earth's spin axis, superposed over other tiny and well assessed periodical variations. This phenomenon was discovered in 1891 by the American astronomer Seth Carlo Chandler (1846-1913). For a historical account see e.g. Carter and Carter (2003). Its order of magnitude, reckoned at Earth's surface, is $\sim 9\,m$ and its period $433\,days$. However, it displays some mysterious discontinuous trends, everyone observed like an abrupt cusp. No interpretation seems available, unlike a few other classical and more regular cyclic features of the astronomical motion of the Earth that are successfully explained by astronomers. We give some details *passim* whenever suited.

[10] Raymond Hide (1929-2016), eminent British physicist, and very nice person, Professor of physics at the *University of Oxford* and, since 2000, senior research investigator at *Imperial College*, London.

Fluids Center (IERS/GGFC Special Bureau for Mantle, 2007). *Currently included are* 21,600 *major earthquakes worldwide with magnitude* > 5 *since 1977.*

Their cumulative, coseismic geodynamic effects show intriguing long-term trends for geophysicists to ponder. For instance, the earthquakes collectively have an extremely strong tendency to make the whole Earth rounder and more compact in all directions, shortening l.o.d. *They have also been nudging the mean North Pole position toward the direction of* $\sim 140° E$. *However, they did these so very slightly that the resultant signals have so far eluded detection, even with today's space geodetic technique capabilities. Worse still, these signals were buried in other signals that are orders of magnitude larger resulting from various other geophysical and climatic causes occurring all the time.*

This was the case at least up until recently. Previously, however, there had been two gigantic earthquakes in the 1960s that had also been geophysically modeled, namely, the 1960 Chilean event and the 1964 Alaskan event ... For example, the Chilean earthquake should have shifted the North Pole toward $\sim 115° E$ *by ~23 mas,*[11] *corresponding to* $\sim 70\ cm$, *compared with today's sub-cm measurement precision. The corresponding change in* l.o.d., *on the other hand, was only* $-8\ \mu sec$, *a few times below today's detection level. The Alaskan earthquake should have changed the Earth's oblateness*[12] *J2 by* $+5.3 \times 10^{-11}$, *which would take the postglacial rebound* $2\ years$ *to 'iron out', compared with today's detectability level of* $\sim 10^{-11}$ *by the satellite-laser ranging (*SLR*) technique.*"

Concerning the Sumatra-Andaman earthquake, "*estimating the seismic moment at* $39.5 \times 10^{231}\ N\ m$, *this earthquake is the fourth largest in the century-long modern record, about half the size of the Alaskan event.*

Our calculation results in the following for the coseismic changes: (1) l.o.d. *decreased by* $2.68\ \mu sec$ ... (2) *Mean North Pole was shifted by* $\sim 2.5\ cm$ *in the direction of* $\sim 145° E$ *.The latter is remarkably continuing the aforementioned coseismic cumulative trend.* (3) *Earth's oblateness J2 decreased by* 0.90×10^{-11}, *continuing the trend in making the Earth less oblate.* (4) *Earth's pear-shapedness J3 decreased by* 0.19×10^{-11}. *Note that this earthquake being near the equator maximizes its effects on J2 and J4 (antinode at equator) and minimizes its effects on J3 and polar motion (node at equator), although these effects are really integrations over the entire body of the Earth.*

To put these quantities in a human perspective, the great Three Gorges reservoir of China, when filled, will impound $40\ km^3$ *of water. This net mass redistribution on Earth will lengthen* l.o.d. *by only* 0.06 μsec, *increase J2 by only* 0.03×10^{-11}, *and shift the pole position by as much as* $0.64\ mas$, *or* $\sim 2\ cm$. *Incidentally, the physical reason why the pole is in general relatively easy to shift is that its excitation needs only to overcome the Earth's oblateness in the form of* C-A *(*C *and* A *being the axial and equatorial moments of inertia, respectively), which is about* $1/300$ *of* C *itself which is to be overcome in exciting* l.o.d. *changes.*

... the Sumatra earthquake has caused a l.o.d. *change too small to detect, an oblateness change barely detectable, and a pole shift large enough to be possibly identified in the observation series ...*

Finally, we should stress that the above only refers to the coseismic effects, independent of any anelastic preseismic or postseismic movements or aseismic deformations, which normally augment the coseismic effects with an amount that varies from case to case."

On February 27, 2010, a strong earthquake hit the Chilean coast, magnitude 8.8. Phillips (2010) reported some information, relying on an interview to Richard Gross, who is one of the most authoritative specialists. The earthquake seemingly moved the Earth's figure axis by $\sim 8\ cm$. However, "*on its own, the figure axis moves* $\sim 10\ cm\ year^{-1}$ *as a result of 'Ice Age rebound'*." That is, the Chilean earthquake caused in a matter of minutes what normally occurs during a whole year.

Phillips (2010d) show Figs 10 and 11. When more accurate measurements will be carried out, the result ought to appear like a "spike" on these plots. Fig. 12 shows another plot similar to Fig. 11.

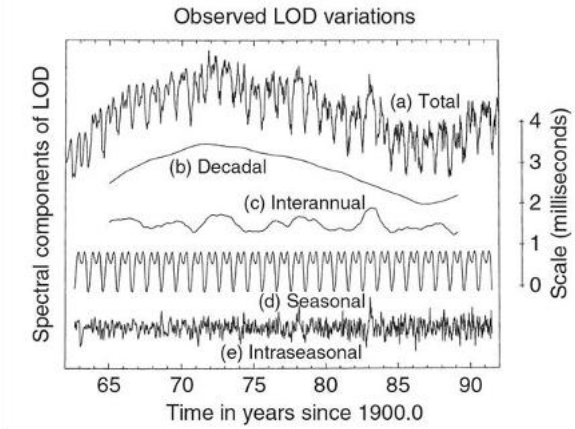

Fig. 10. "*Observed changes in Earth's* l.o.d. *caused by tides, winds, ocean currents and other factors. From Gross (2007).*" Figure and captions after Phillips (2010d).

Phillips (2010d) comments that "*recent news reports have focused on Earth's* l.o.d., *noting that the Chilean earthquake might have shortened days by as much as* $1.26\ \mu sec$ *out of* $24\ hours$. *That's true. But it's also negligible compared to the normal effect of wind and tides, which can lengthen or shorten days a thousand times more than earthquakes can. The real news, as Gross sees it, is the possible shift in Earth's figure axis ...*

No one has ever measured a shift in Earth's axis due to an earthquake before. Back in 2004, Gross looked for a shift from the magnitude 9.1 *earthquake in Sumatra, but failed*

[11] The *mas unit* is a *milli-astronomical second*, i.e. $1\ mas = 1/3{,}600{,}000\ deg$.

[12] The formal definition and treatment cannot be here given of the tensor that describes the moment of inertia of the Earth. Refer e.g. to Munk and MacDonald (1960). A concise treatment of a few items related to the anomalies of the astronomical motion of the Earth is given below.

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to find a signal. The Sumatra quake was less effective in altering Earth's figure axis because of its location near the equator and the orientation of the underlying fault. The Chilean quake, albeit weaker, may have produced a bigger shift.

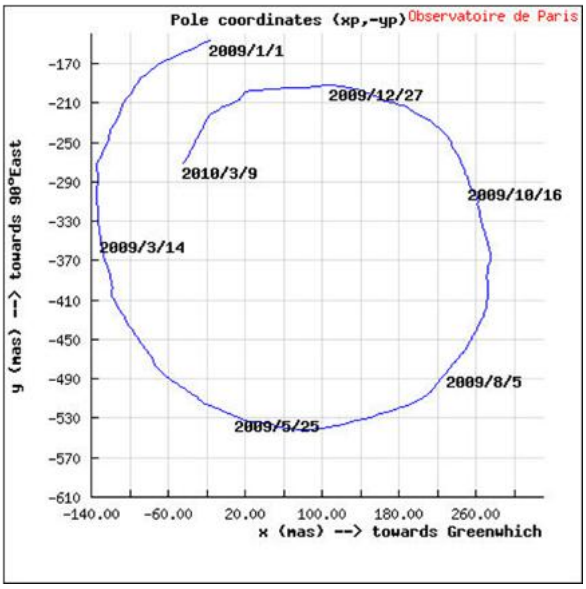

Fig. 11. "*The normal wobble of Earth's axis since Jan 2009 as reported by the* International Earth Rotation Service. *The grid is scaled in* mas *(milliarcseconds);* $1\ mas = 1/3{,}600{,}000\ deg$*).*" Figure and captions after Phillips (2010d). *NASA* copyright free policy.

The stage is set for discovery. 'Computing power is at an all-time high. Our models of tides, winds and ocean currents have never been better. And the orientation of the Chilean fault favors a stronger signal'."

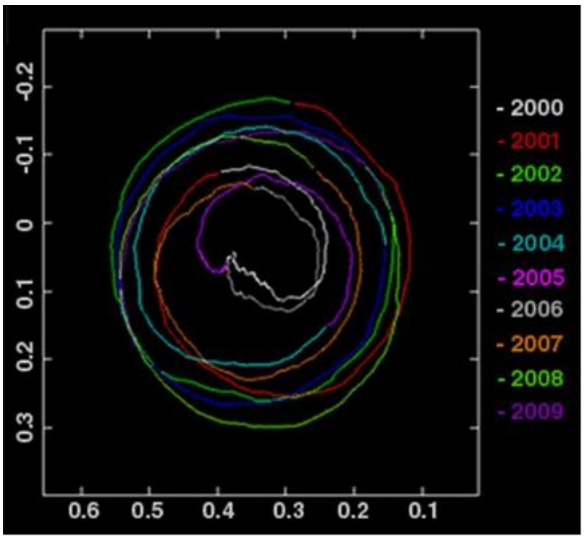

Fig. 12. "*The spiral lines on this graph track wobbling in Earth's axis of rotation from 2000 to 2009. This wobbling is called polar motion, because it temporarily changes the location of the rotational North and South Poles. (Courtesy* USNO*).*" Units are $arcseconds$. Figure and captions after Beitler (2010). *NASA* copyright free policy.

IERS/GGFC Special Bureau for Mantle (2007) is an authoritative synthesis of the state-of-the-art - including a historical account - concerning the available observational evidence, mainly focused on coseismic effects. A few highlights and quotations are here reported from that authoritative source.

The largest ever recorded earthquake (1960, Chile) caused a decrease of the *l.o.d.* by 8 μsec and a kink in the polar path of 23 $nsec$, and the second largest one (1964, Alaska) caused an increase of *J2* by 5.3×10^{-11}, which is "*still an order of magnitude smaller than the observed short-term fluctuations mostly due to atmospheric mass transport*".

Milne (1907) made the first proposal, when the Chandler wobble had been discovered, and Cecchini (1928) found during the years 1900-1908 a correlation between the large polar motion and seismicity. Subsequent investigations confirmed his finding, until the important and classical monograph by Munk and MacDonald (1960) who showed that even large earthquakes cannot be responsible for these effects. After the 1964 Alaskan earthquake, "*based on a strainmeter record in Hawai'i, Press (1965) announced that a static displacement was recorded at teleseismic distances several thousand kilometers from the epicenter.*" This rejuvenated the investigations, but the quality of polar motion data was insufficient for this analysis. In the later half of the 1980s, the improved observational techniques - and the availability of the *Harvard centroid moment tensor* (*CMT*) catalog of all major earthquakes - triggered substantial improvements.

The findings are described as follows in *IERS/GGFC Special Bureau for Mantle* (2007). "*Chao and Gross (1987) ... computed the seismic excitation of polar motion for all events listed in the* CMT *catalog, but using the normal-mode summation scheme of Gilbert (1970).*" They used the *21,600* major events listed in the *Harvard CMT* catalog (magnitude > 5 since 1977). "*Their method has since remained a most efficient way of computing the seismic excitation of not only polar motion, but also of other important geodynamic parameters such as gravitational field changes. Furthermore, Chao and Gross (1995) and Chao et al. (1995) extended the formulation to compute earthquake-induced changes in rotational energy and gravitational energy, respectively. These papers and later Chao et al. (1996a, 1996b) have updated, and in fact strengthened, the results of Chao and Gross (1987) who found many earthquake-induced phenomena having intriguing geodynamical implications ... .*"

Their findings are synthesized in five figures (not here shown) that show the cumulative effect between 1977 and 2005, respectively, of polar motion excitation (two components X, Y), *l.o.d.*, gravitational zonal " J " coefficients, moment of inertia, and difference of two equatorial principal moments of inertia. We note that the aforementioned "*extremely strong tendency to make the whole Earth rounder and more compact in all directions*", which is emphasized by Chao and Gross (2005), is in close

agreement with the rationale, by which the Pekeris force[13] was a possible concurrent driver for lithospheric sliding on the slopes of superswells (according to *WMT,.*" warm mud tectonics"). We refer to the northward migration of Alaska, to the southward migration of Antarctica, and (maybe) refer to the splitting of North and South America, leaving in between the gap of the Gulf of Mexico. The Gulf of Mexico, however, was probably originated mainly by the clockwise rotation of South America (see Gregori and Leybourne, 2021).

All events, which occurred after the Alaska earthquake, were much weaker ($< 1/20^{th}$ the energy of the Alaska event). Altogether, their effects were two orders of magnitude smaller than natural fluctuations, hence they were undiscernible compared to background.

"*The collective effects of all earthquakes with magnitude* > 5 *in the last two decades have an extremely strong statistical tendency with time. The parameters that show the strongest non-randomness are the dynamic oblateness* $J2$*, the total moment of inertia (the trace of the inertia tensor), the* l.o.d.*, the sum of the two equatorial principal moments of inertia, and the difference* J_{22} *between the two equatorial principal moments of inertia. Their time series all exhibit a strong decrease with time, indicating the tendency of earthquakes to make the Earth rounder and more compact. No such tendency is evident for higher harmonics of the gravitational field changes caused by earthquakes (e.g.* $J3$*,* $J4$*,* $J5$*).*"

"*A similar strong tendency is seen in the polar motion excitation: earthquakes cumulatively are trying to 'nudge' the Earth rotation pole towards* $\sim 140° E$ *, roughly opposite to that of the observed polar drift. However, the speed of this earthquake- induced polar drift in the last two decades is two orders of magnitude smaller than that observed.*" [This discrepancy suggests that the present understanding is insufficient to explain phenomena. Therefore, there is need for some substantial new physical driver that, in fact, could be identified, perhaps, with the "*sail*" effect envisaged here below.]

In addition, it is recalled that, in contrast with coseismic effects, also "*the inelastic pre- or post-seismic movements that are often associated with large earthquakes on timescales of months to years have been studied based on rheological modeling (e.g., Dragoni et al., 1983; Sabadini et al., 1984; Soldati and Spada, 1999). These effects typically augment the coseismic ones by a factor depending on the source mechanism and mantle rheology*."

In recent years, following the great improvement achieved by *GRACE* monitoring of the gravity field, the time variation of the Earth's oblateness can be measured, modeled, interpreted, etc. Phenomena appear very intriguing. They open an unprecedented "window" on deep Earth. Their interpretation is likely to involve substantial achievements in our understanding of deep processes. Several different concurrent causes drive these anomalies. The focus of the present study is restricted to e.m. phenomena. Hence, according to the rationale that is here considered, two kinds of effects ought to be envisaged.

The first effect speculates about an e.m. action that originates a time-varying external moment applied to the Earth's body. On the one hand, this modifies the astronomical motion of the Earth, and, on the other, it originates some relevant crustal stress, which accidentally can trigger an earthquake in some seismic area.

This interpretation is confirmed by the analysis by Barsukov (1991), who correlated with earthquakes either the sudden storm commencements (*ssc*) or the geomagnetic storms, finding that an earthquake paradoxically triggers a geomagnetic storm. In fact, the one must consider that a solar event triggers an *ssc*, and - through Foucault's induced stray currents $\boldsymbol{j}$ into the crust - it causes also an extra crustal stress that eventually triggers an earthquake. The *ssc*, however, precedes the occurrence of a geomagnetic storm, according to the intrinsic temporal evolution of the solar wind/magnetosphere interaction, etc. Hence, it appears that an earthquake triggers a geomagnetic storm, as they both have the same trigger, i.e. a solar event and the *ssc*.

Concerning the second mechanism that is here envisaged - and that can be briefly called "*sail*" effect - a few details can be introduced as follows. Consider first the case history of a strong earthquake that causes a great tsunami, such as e.g. the tragic event of December 26th 2004. The occurrence of a tsunami is not only concerned with the intensity of the earthquake, but rather with the mechanical motion that is produced inside the ocean or sea. If the earthquake is only a simple horizontal slip of a fault with unimportant vertical percussion on the water body, no significant tsunami is triggered.

The tsunami wave started from the ocean close to Sumatra and it propagated through the Indian Ocean until reaching the African coast. Later, a significant wave crossed through the Southern Atlantic Ocean, and it struck the Argentinean coast.

This wave caused a "*sail*" effect against Africa - and partly also against South America. The intensity of such a "*sail*" effect depends on the energy of the original input, which caused a tsunami-wave of a given amplitude. Even independent of the local causalities and/or damages, the space integral along the Africa coast of the "*sail*" effect is always very strong - as it equals the primary energy input, apart the energy dispersion originated by different causes during tsunami propagation. The entire final energy will be more or less distributed over some time interval depending on the geometry - relative to the impinging tsunami wave - of the continent coast.

[13] The figure of the Earth is excessively flattened, and - if the Earth is a fluid - a poleward "*Pekeris force*"(see to Jeffreys, 1976, or, for thermal contraction, Bott, 1971; Collette ,1974); and Turcotte, 1974), …) ought to be observed with maximum at $\pm 45°$ latitude. This large poleward force ought to be observed in some way. In fact, some morphological features - such as the formation of the Aleutian and of the Kuril Islands, or as a contributing driver, perhaps, the Alpine-Himalayan belt folding, or the opening of the Gulf of Mexico, or the steady poleward pattern found by Steinberger and Torsvik (2008) in their model computation - might be (maybe) intuitively well explained by this mechanism.

The total angular momentum of the system is unchanged. Continents and ocean water - owing to the action-reaction principle - experience an opposite "*sail*" effect: it is like the recoil that you experience when you shoot a gun.

However, the measurement of Earth's spin rate are carried out at Earth's surface. Hence, one must observe an effect on the astronomical motion of the Earth.

This interpretation can be tested and confirmed by monitoring the crustal stress propagation. This will be possible when a planetary network of *AE* (acoustic emission) stations will be available (see Gregori et al., 2026a and references therein). This crustal stress can also eventually trigger some local earthquakes somewhere on the globe etc. In principle, the timing - and the raising and decay time, including their respective time lags - can be recognized, which are associated with the tsunami wave propagation and strike against the coasts of a given continent, etc.

Larmat et al. (2006) gave intriguing related evidence. They applied a time-reversal (*TR*) algorithm, similar to what was previously successfully applied for acoustic waves in many fields like medical imaging, underwater acoustics and non-destructive testing. Larmat et al. (2010) give a more extensive discussion of the method. Some complications are found when the focal volume of the earthquake cannot be likened to a point-like source. They discuss this complication - and as far as possible they get rid of it - but this is not pertinent for the concern of the present discussion.

Larmat et al. (2006) used the *PREM* (preliminary reference Earth model) (Dziewoński and Anderson, 1981) and claim - "*is a very good approximation of the real Earth and accurate enough to provide a good agreement between observed and synthetic seismograms at very long periods*." They applied it to the great Sumatra-Andaman earthquake. See also McCloskey et al. (2005). It is worthwhile to report here their results in some detail.

"*On Decemberc 26, 2004 the subduction zone starts to rupture in the Northern part of Sumatra up to the Andaman Islands,* $\sim 1200\ km$ *away. A special issue of* Science *(Lay et al., 2005; Ammon et al., 2005; Park et al., 2005, 2005a) was devoted to the first results obtained from the investigation of seismic and other geophysical data. This event lasted* $\sim 6-7\ min$ *and it is the largest earthquake to have occurred since the Chile earthquake in 1960 and the Alaska earthquake in 1964 and since the advent of the* Broadband Digital Seismology Network *(Romanowicz and Giardini, 2001)."*

They used the records from *165* stations with good quality of their vertical records. They computed a *TR* $8000\ sec$ long time-window. "*The origin of the earthquake corresponds to* $t_0 = 1000\ sec$*, i.e., to a reversed time* Tr *of* $7000\ sec$ *. Fig. 13 shows three snapshots of the* TR *wavefield at different times* $Tr = 6000\ sec$*,* $7000\ sec$ *and* $7500\ sec$*. The maximum focusing is observed at the time* Tr=7000-50 sec *(*$\pm 20\ sec$*) and at the right spatial location: at latitude* $3°\ N$ *and longitude* $95°\ E$ *(*$\pm 200\ km$*) ...* " A slightly different - and maybe more expressive - Fig. 14 is borrowed after Larmat et al. (2010).

Since the earthquake lasted $\sim 400\ sec$, this was the time required by the $\sim 1{,}500\ km$ fault to break, consistently with the "*domino effect*" propagation of a microcrack at a typical speed of $10\ cm\ sec^{-1}$ (see Gregori, 2013a). Hence, Fig. 14 refers to a time instant during which the fault rupture was still in progress.

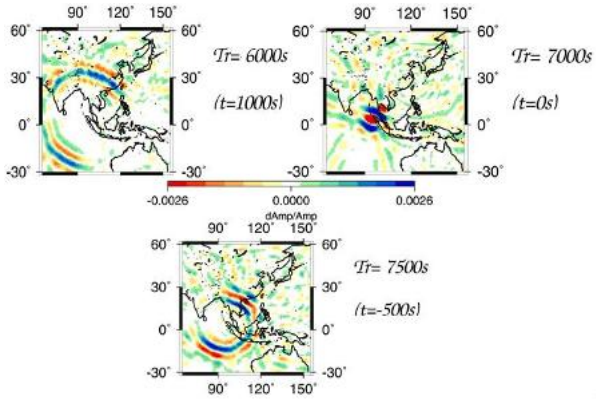

Fig. 13. "*Vertical component of the time-reversed field at different times for the giant Sumatra-Andaman event.* t *is the absolute real time;* Tr *is the reversed time and* $Tr = 7000\ sec$ *corresponds to source initial time (* $t = 0\ s$ *).*" Figure and captions after Larmat et al. (2006).

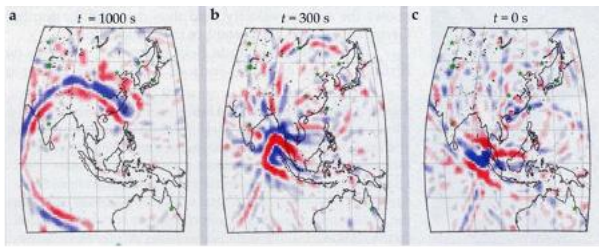

Fig. 14. "*The great Sumatra earthquake of 2004. The quake, lasting* $\sim 400\ sec$*, resulted from a* $1200\ km$ *long rupture between tectonic plates. Seismic records from* 165 *stations worldwide were time-reversed and rebroadcast into a model Earth. The three maps, each extending from Siberia to Australia, show the propagation of the vertical displacement field thus deduced in reverse time order, labeled by time* t *since the quake's onset. Blue and red indicate, respectively, upward and downward displacements. The contracting time-reversed wave field begins collapsing onto the extended fault at about* $400\ sec$*".* Adapted after Larmat et al. (2006) and captions after Larmat et al. (2010). *AGU* copyright free policy.

Note the difference of phenomena depending on the medium where the "*domino effect*" propagation occurs.

If the crack propagates through the serpentosphere, the phenomenon is monitored by *AE* records (see Gregori et al., 2026a and references therein). The evidence is thus found of a "*crustal storm*" (Gregori, 2013). This is not a seismic precursor. Rather, this envisages that the system is experiencing some perturbation crossing through its region according to some planetary scale propagation of crustal stress through the serpentosphere (see Gregori and Hovland, 2025).

In contrast, if the crack propagates inside the crust and along a fault, the *AE* records are interpreted according to the rationale that is called "*crustal substorm*". This phenomenon is the signature of an important yield by an

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active fault. Therefore, unlike a "*crustal storm*", a "*crustal substorm*" is a disquieting precursor of a seismic shock, although its intensity is related to the size of the fault, hence to the elastic energy that it could store inside the fault during its previous history.

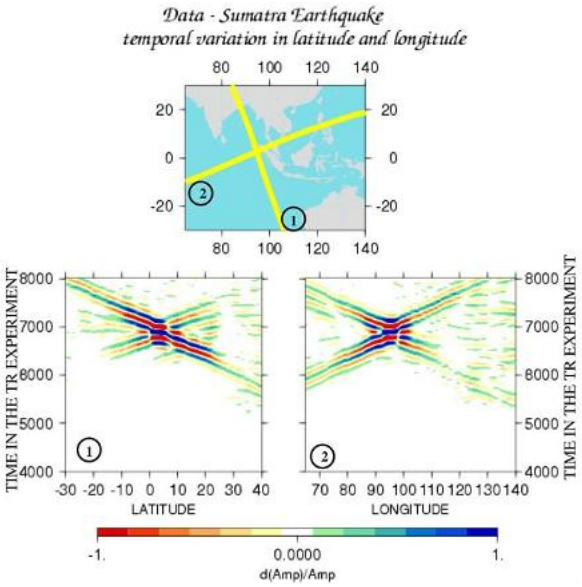

Fig. 15. "*Application of time reversal method to data of Sumatra-Andaman earthquake (*$3.09°\ N,\ 94.26°\ E$*). The time* $7000\ sec$ *corresponds to the origin time. The 2 cross-sections along the yellow lines are displayed: on the left, a near latitudinal cross-section (~ along the fault plane) showing a strong asymmetry, on the right an orthogonal cross-section.*" Figure and captions after Larmat et al. (2006). *AGU* copyright free policy.

In both cases the same "*domino effect*" rationale, although the consequences can be dramatically different. The large vertical motion generated by the earthquake along the $\sim 1{,}500\ km$ fault is impressive and shown in Fig. 14c. It was essential for the generation of the tsunami wave. Other earthquakes, with comparable magnitude, but with no comparable vertical motion, certainly generated comparable crustal stress propagation, although they caused no relevant tsunami.

The "leopard skin" pattern, which sometimes appears on either one of these figures, might be associated (maybe) with the algorithm used for this very complicated and lengthy computation - but the computational details given in the published papers do not mention this item.

In addition, a curious circular pattern in the upper part Fig. 14 seems to have its center roughly at the mid of the eastern coast of China. However, in contrast with the circular pattern of Fig. 14a where blue and red circles are fully developed and alternate each other, the aforementioned circular pattern in Fig. 14b shows a dashed sequence in blue/red color, being suggestive of a mathematical, rather than of a physical, effect.

A similar, although less clear, secondary circular feature is shown, perhaps, in Fig. 14c with center located roughly in the Philippines.

Either one of these circular features is suggestive of a secondary thump that hit some area, eventually causing no earthquake, triggering however a wavy propagation reminding about the oscillation of the membrane of a drum hit by a stick. This reminds us of the fact that an earthquake is an occasional event that, however, occurs only in some extreme condition. It is an irreversible phenomenon, although, in contrast, the crust can eventually suffer by some mechanical and reversible vibration that implies no irreversible rupture.

Larmat et al. (2006) refined their analysis as follows. "*Two cross-sections of the displacement* $u(\theta, \phi, Tr)$ *(where* θ *is the latitude,* ϕ*, the longitude) are extracted for two lines, parallel (basically latitudinal cross-section) and orthogonal to the plate boundary (longitudinal cross-section). They are shown in Fig. 15 for reversed times from* $4000\ sec$ *to* $8000\ sec$*. On both cross-sections, we see that when focusing occurs, seismic waves map the fault plane with a different sign in amplitude on either side of the fault. The focusing for the longitudinal cross-sections is more symmetrical before and after the focusing, whereas a very pronounced asymmetry in amplitude can be seen on the latitudinal cross-section as soon as* $Tr = 6000\ sec$ *(*$t = t_0 + 1000\ sec$*), suggesting a very strong directivity effect. It is not an artifact due to the uneven station distribution ... Data inversion for a pre-shock on November 2, 2002 does not show this asymmetry ... .* [They computed this event, which has a source that can be more correctly likened to a point-like origin.] *We have to bear in mind that the first observed point of refocusing in the* TR *experiment corresponds to the last part of the actual rupture and that, when waves start diverging, this point can be associated with the initial rupture point. Thus we observe on both cross-sections that the rupture starts approximately at* $3°\ N,\ 98°\ E$*. The final latitude is difficult to determine due to the strong directivity of the source but seems to be located between* $10°\ N$ *and* $20°\ N$*."*

As far as the present paper is concerned, we must add a few comments. The event lasted $\sim 400\ sec$. See Figs 15b and c, which refer to the time duration of the earthquake. The crustal stress propagated almost radially, crossing Himalaya and reaching China by $\sim 1000\ sec$, at a distance from Sumatra along the Earth's surface of $\sim 3{,}800\ km$. This means that the effect propagated at a speed of $\sim 3800/1000 = 3.8\ km\ sec^{-1}$. Hence, the effect reached the central Mediterranean area, which is at $\sim 9{,}600\ km$ from Sumatra, with a delay of $\sim 42\ min$ after the earthquake.

Hence, two effects are to be reasonably expected, and sometimes should be observed.

- An array of *AE* recorders will certainly detect the crustal stress crossing through its respective monitored area, allowing for a detailed mapping of local crystal anisotropies.
- A "*sail*" effect could perhaps result to be eventually applied to comparatively larger solid crustal masses, such as the Himalaya chain compared to flat land, etc. In principle, its integrated effect might contribute (perhaps) to affect the Earth's spin rate and pole motion. In any case, a local monitoring ought to be carried out of the anomalies either of crustal stress, and/or also of the astronomical motion of every single site, which is feasible (at least in principle) by means either of the Sagnac effect

(Gregori et al., 2025w; Gregori and Gregori, 2025), or of the Josephson effect.[14]

Therefore, it appears reasonable that a "*sail*" effect ought to be likely to occur everywhere inside the Earth's body, from the crust down to the *IC*. Thus, every kind of anisotropy - including the *IC* deviation from spherical symmetry – plays a crucial role in causing an effect on the observed anomalies of the astronomical motion of Earth.

This astronomical effect should therefore be eventually observed following every intense earthquake that originates no tsunami, when no "*sail*" effect is expected by ocean water striking against continental coasts.

Indeed, these strong earthquakes cause a "*sail*" effect against a non-spherical *magpol IC*. The effect will therefore depend on the relative location of the epicenter with respect to the exotic figure of the *IC*. Fig. 16 is a cartoon that shows just two possibilities.

Consider, however, that the figure of the *IC* is unknown, and that the epicenter can be located at any site in the crust, while Fig. 16 shows for simplicity - qualitatively and out-of-scale - only case histories of epicenters located at the equator.

Therefore, suppose to express the figure of the *IC* by a *SHE* similarly to what is conventionally made by geodesists for representing the geoid. Consider the list of all case histories triggered by strong earthquakes. For every case history compute the "*sail*" effect to be expected to occur on the given *IC* figure described by the pre-chosen *SHE* with unknown coefficients. Identify this computed "*sail*" effect with the actual observed effect on the astronomical Earth's motion. By a least square fit, by means of a suitable number of different earthquakes, compute the values of the coefficients of the *SHE*, and in this way determine the actual figure of the *IC*.

Note that, by applying this method to several strong earthquakes, it is possible to compute the figure of the *IC*, its changes *vs.* time, and even its dynamics.

In terms of a qualitative description, one can expect either that the *IC* is reasonably stable, i.e. its motion occurs e.g. on time scale of the geomagnetic *SV*. However, in principle we must consider the possibility that it is found to move freely, maybe even very fast, almost with no friction inside the *OC*. Every situation is possible, as the computation can give every kind of evidence.

The drawback is that a mathematical procedure of this kind always gives a solution. Therefore, one wonders whether this inference can be *ad hoc*. However, maybe, it is possible to check how the result fits with other independent observational evidence.

In fact, suppose that the *IC* has an orientation that is reasonably stable *vs.* time. The bumps of the *IC* ought to be associated with regions of comparatively lower temperature inside the *OC*. Hence, these regions ought to be associated in some way with the thermal propagation through the *OC*. This thermal structure of the *OC* ought therefore to be correlated with the superswell distribution, with the quatrefoil pattern, etc. In contrast, if the *IC* moves "*very fast*", no simple correlation can be envisaged between *IC* and surface phenomena.

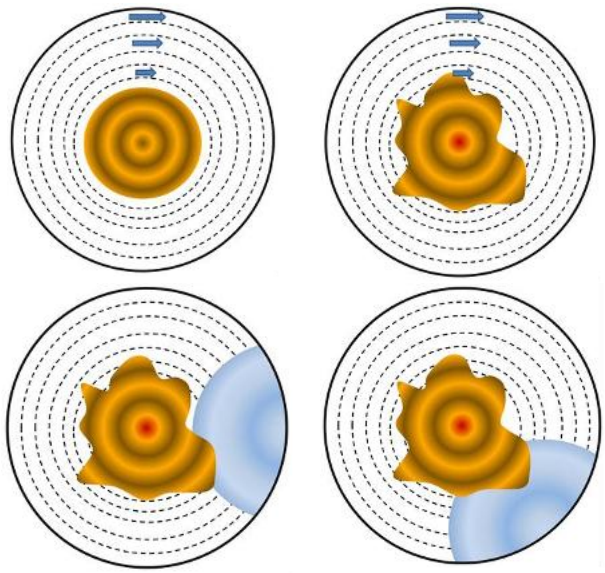

Fig. 16. Out-of-scale cartoon showing the Earth observed from the North Pole, and two case histories of a hypothetical earthquake with epicenter located somewhere in the equatorial belt. However, the concept is general, and it applies to every general case history. The seismic wave propagates through the Earth's body, and through the "*metallic*" fluid *OC*, until it reaches the hard *magpol IC*. While striking it, this phenomenon originates an anomalous "*sail*" effect, and a recoil that propagates until Earth's surface. The astronomical motion of the Earth is monitored by observatories located at Earth's surface. Hence, a strong earthquake - through the "*sail*" effect by the seismic wave that hits the *IC* - originates a change in the astronomical motion of the Earth. *(a)* No "*sail*" effect occurs on a perfectly spherical *IC*, unlike for a non-spherical *IC* [*(b)*], and the "*sail*" effect depends on the location of the epicenter [*(c)* and *(d)*]. After Gregori and Leybourne (2026i).

In any case, in the final analysis, a whole deep Earth's model is thus implemented. Nobody will ever afford and drill a hole into the *IC*. We can only rely on indirect evidence and on reasonable inferences. This entire scenario - when it will be eventually exploited - offers a reasonable warranty of being realistic.

We point out that such a "*sail*" effect is a pressure on the *IC* originated either *(i)* by ocean waters - such as in the 2004 great tsunami when colliding against Africa - or *(ii)* by the fluid *OC*. In either case the same physical process is involved, by which a change - with respect to their respective "normal" circulation - of the total angular momentum either of the atmosphere, or of ocean waters, or

[14] This effect was first predicted in 1962 by the Nobel Prize Laureate Brian David Josephson (1940-). Some information can be found in Packard (2006), or also in "*NASA/Jet Propulsion Laboratory (2001, Jun 8). High-Tech Helium Tricks May Benefit Earth and Space. ScienceDaily. Retrieved Jan 26*" and in "*How fast does the world turn? Quantum gyro may tell, NASA/JPL News Release, Posted: Jul 6, 2001*". In principle, some lesser events, simultaneously recorded in different areas, are expected to be eventually different, being thus corrected with specific occurrences of crustal stress propagation. This technique is also applied to test some subtle relativistic effects.

of the fluid/"*metallic*" *OC* originates a corresponding variation of the spin rate of the Earth. This is just a requirement for total angular momentum conservation.

In any case, compared to the present generally agreed and naïve idea of a "*solid*" *IC* - which is assumed almost spherical, basically because the information of seismic rays can hardly provide evidence about its deviations with respect to spherical symmetry - all this appears to be a substantial achievement.

Geomagnetism and gravity

Additional intriguing presently unexplained physical evidence can be derived from the gravity field, according to evidence reported since the 1970s, which.

Hide and Malin (1970, 1971) and Hide (1970) studied the correlation of the observed non-dipolar part of the geomagnetic field with the gravity field. They investigated the *SHE*s of these two fields and searched for a relative longitudinal shift that optimizes their apparent correlation. The correlation analysis of two fields expressed by their respective *SHE* requires a careful discussion of mathematical methodology, which cannot be here reviewed.

They considered either one *SHE* up to $n^* = 4$ (i.e., up to $n = 4$ and $m = 0, 1, \ldots 4$). They called $\hat{k}$ and $\hat{\phi}$ the values - of the correlation coefficient and of the associated longitude shift, respectively - corresponding to maximum apparent correlation. They commented: "*attention is confined to displacements in longitude alone, a procedure which avoids the complications of transforming* SH *series from one polar axis to another, but a physically reasonable one because motions are probably mainly zonal* ... " They used a large set of models both for V (for the geomagnetic potential) and for V_G (for the gravity potential), and their maximum correlation $\hat{k}$ was attained for epoch 1965.

Fig. 17 shows the result, including the 95% confidence limits. Hide and Malin (1970) carried out the computation upon considering the correlation either at the Earth's surface, or on the *CMB* - by extrapolating their analysis by means of the analytical downward continuation of their respective *SHE*s. They carried out some attempts to improve the analysis of this correlation.

It is worthwhile reporting about some specific attempts aimed to improve the analysis of this correlation. Let us quote the summary given by Gregori (2002). "*The classical* t*-Student significance test, where the number of d.o.f.s (degrees of freedom) is fixed by the choice* $n^* = 4$*, seems to support a significant correlation. They further improved the test for significance by a different method, upon considering the leading role in the computation played by the largest* SHE *coefficients, i.e. by* $(m, n) = (1,3)$ *and* $(1,4)$*, and concluded that the significance level is* $\sim 3.4\%$ *and that when removing such leading terms it worsens to* $\sim 8.3\%$ *(they also mention that an additional improved test carried out by F. J. Lowes and R. M. Hill gave a significance between* $\sim 4. - 5.4\%$*). They investigated the dependence of* $\hat{k}$ *on* n^* *and found, for* $n^* = 2$ *to* $n^* = 8$*, at* $r = a$ *a decrease from* $\hat{k} = 1$ *to* $= 0.78$*, and at* $r = r_{CMB}$ *from* $\hat{k} = 1$ *to* $= 0.24$ *(*$\hat{\phi}$ *results to be more robust, and it ranges, respectively, between* $\sim 158° - 162°$ *and* $\sim 156° - 174°$*). They claimed that this indicates that the higher n terms of* V_G *ought to be apparently originated in the upper part of the mantle (though, maybe, this could more simply be a consequences of errors). In any case, they claimed that*' for reasons that are not very clear (having regard for the arguments that prompted the investigation) the correlation is not quite so high at the *CMB.'* ... "

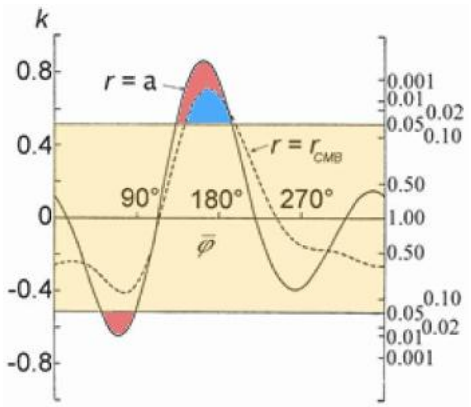

Fig. 17. Correlation coefficient k (call $\hat{k}$ its relative maximum) as a function of the eastward displacement $\hat{\phi}$ of the geomagnetic potential V relative to the gravity potential V_G, evaluated either at the Earth's surface ($r = a$) or at $r = r_{CMB}$. Along the vertical axis on the right, the t-Student significance limits are indicated, and two horizontal lines denote the 5% conventional threshold, thus envisaging a credible result, better evident at $r = a$. The maximum occurs at $\sim 160°$ with $\sim 83.81\,\%$, and $\sim 166°$ with $\sim 64.27\,\%$, respectively. Redrawn for Gregori (2002) after Hide and Malin (1970).

Concerning the geomagnetic potential V, we know from the *Lowes-Nevanlinna*'s (LN's) *plot* (see Gregori, 2002; Gregori et al., 2026a) that the terms with $n = 1,2$ refer to the *magpol IC* dipole contribution, the terms with $n = 3, 14$ refer to the *CMB* $\boldsymbol{j}$-currents, and the terms with $n = 15, \ldots$ refer to crustal magnetization.

No equivalent information is available concerning the gravity potential V_G, Hence, the better correlation at Earth's surface compared to *CMB* can be indicative of the fact that the mass distribution inside the mantle is correlated with the geomagnetic field - or equivalently, according to the rationale here envisaged, the geomagnetic field (by its sea-urchins) controls the mass distribution through the mantle.

Another possible explanation, however, is that the (unknown) errors are large, which are implied by this downward analytical continuation of either one of the two fields. In any case, the aforementioned comment by Hide and Malin (1970) refers to the fact that they searched for evidence to be attributed to the standard *MHD* dynamo within the *OC*. Hence, they expected a better correlation on the *CMB* compared to Earth's surface. Also, this fact - i.e. this (expected) agreement with the *TD* dynamo, and the (unexpected) disagreement with the standard *MHD* dynamo - is an indirect support in favor of the *TD* geodynamo, compared to the standard *MHD* Larmor-Elsasser-Bullard dynamo (Gregori and Leybourne, 2025aa).

In addition, Hide and Malin (1970) evaluated the time variation of the relative longitudinal shift - eastward of the geomagnetic relative to the gravimetric field - that optimizes their apparent correlation (they show a figure, noit here shown, also reported by Gregori, 2002, and by Jacobs, 1975, 1987b). They interpolated the straight line

$$\hat{\phi} = (126.2 \pm 0.2)° + (0.273 \pm 0.005)[t \pm 10 - 1835]° \quad (3)$$

where the standard errors are indicated, and t is expressed in $years\ AD$. This line gives a vanishing $\hat{\phi}$ for epoch ~1373 AD.[15]

Since they found an *ED* (Eastward Drift) of geomagnetic relative to gravity field, they observed a *WD* of the gravity relative to the geomagnetic field, which is representative of the location of the non-spherical *IC*. This implies that the gravity anomalies are caused by heterogeneities located in the *malicrust.* This also confirms that the correlation investigated at Earth's surface is much better than at the *CMB*'s.

Hide and Malin (1971a) improved the computation by allowing for a relative displacement also in terms of latitude between V and V_G. They found almost the same result, with a minor displacement of the pole by $\sim 5° - 6°$ (this inclination drifts *vs.* t), whereby the correlation increased to $\sim 0.84 - 0.85$. In addition, a high degree of negative correlation was found when applying a relative displacement of $\sim 69°$. This feature, however, does not seem to share the drift *vs.* t displayed by the maximum. They do not carry out a formal test of statistical significance, although the addition of new *d.o.f.*s (for defining the displacement of the pole) can only improve the previous significance level.

These results appear therefore to support the existence of the topographic features at the *CMB* that were tentatively speculated by several authors.[16] In principle, however, a linear correlation analysis is, sometimes, misleading when applied to intrinsically nonlinear processes. Moreover, the evidence is in any case indirect, and Hide (1970) clearly and honestly emphasizes that "*it is, of course, possible that the correlation ... can be explained without invoking bumps on the core-mantle interface*", and he adds a discussion of possible different similar interpretations. For instance, he points out that convection patterns (in the mantle), or temperature gradients with consequent implications on mass density $\check{\rho}$ and on σ, could give alternative explanations, also for the unexplained comparatively lesser correlation for $r = r_{CMB}$.

Also remind about the evidence of a possible time variation of the *IC* radius mentioned above.

This intriguing and clever analysis by Hide and Malin (1970) - which since 1970 appeared unexplained to its discoverers and ultimately to every author - appears to be a present flash-instant condition within the planetary and long-range temporal average of the relative displacement of different layers inside deep Earth.

This result was the object of some debate, and we attempt to report here by some relevant items.

A previous discussion on the role of the topography of the *CMB* or *ICB* etc. is reviewed by Gregori (2002, p. 209-210). The previous literature is important for the present discussion, for comparison purposes with the model that is here proposed. The short review by Gregori (2002) is therefore here entirely reported.

"*Different mechanisms for justifying the* IC*/mantle coupling have been proposed by an extensive literature. The papers are first here considered that specifically refer only to what occurs close to the* CMB *(other papers that use different assumptions are discussed below). A few different kinds of prime mechanisms were considered, and everyone can be expected to contribute by a different amount:*

- *viscous (however, the* OC *is generally believed to be almost inviscid; hence, such mechanism is often neglected or sometimes not mentioned at all),*
- *topographic (depending on the presence of hills and valleys on the* CMB*),*
- *compositional (following chemical differentiation, with consequent generation of heterogeneities of the mass density $\check{\rho}$, and/or of buoyancy forces, with associated angular momentum transfer and Coriolis' forces, etc.; an additional effect can be concerned with spatial gradients either of composition or of the thermal field, with consequent implications on $\check{\rho}$, on σ, etc.),*
- *gravitational (resulting from $\check{\rho}$ inhomogeneities of any origin, either fossil, or deriving from chemical differentiation, etc.), or*
- *electromagnetic (but, in such a case, one must assume that the magnetic energy density is comparable with, or larger than, the kinetic energy density, which is an assumption in apparent contradiction with the previous hypotheses ultimately being the key point of Biermann's argument, which was originally applied to sunspot cooling, and which leads to a full blocking within the Earth's interior that should thus result to be even much more rigid than the hardest conceivable rock).*

Even the eventual magnetostatic and/or electrostatic coupling has been formally investigated by Hide (1998), though its application could be suited only for some planet other than the Earth (e.g. to Mercury).

All such ideas permeate the entire literature by various extents. Topography deals with deviations from spherical symmetry (or, according to Hide, it deals with the phrenology) either of the CMB*, or of the* ICB*. The* CMB

[15] They interpret this by arguing that the drifting part of the *SV* was originated by an interaction that started up *5* or *6 centuries* ago. They note that between 1110-1400 AD (see their papers for references), the *WD* was much slower than at present, and possibly even eastward. In any case, the very old geomagnetic measurements are affected by large errors and uncertainties. In addition, they do not consider the areas of *ED* of the geomagnetic secular variation, according to the analysis carried out by Janackova and Urban interpreted by Gregori (1993). The locus of zero drift (no *WD*, no *ED*) coincides with the *MOR* network. See below. This evidence contributed to generate the *TD*-dynamo concept and Gregori (2002).

[16] Refer to Gregori (2002) for details and references.

concern was discussed by Hide (1969), which is often quoted and can be considered a classical paper that triggered an extensive discussion that is still on. Hide and Horai (1968) inferred the guessed topography of the CMB *by assuming that the geoid deviations from the ellipsoid are caused by difference of the mass density* $\check{\rho}$ *between core and mantle. They considered only terms of the* SHE *of the gravity field with* $n \leq n^{\circ}$. *They found maximum amplitudes of the height excursions of* $\sim 8.7\ km$ *for* $n^{\circ} = 4$, *of* $\sim 30.9\ km$ *for* $n^{\circ} = 6$, *and of* $\sim 132\ km$ *for* $n^{\circ} = 8$. *In any case, the height of such hills can ultimately be only speculated, the concern being about envisaging a sufficient height for justifying some conspicuous coupling in terms of anyone of the aforementioned speculated mechanisms. For instance, Voorhies*[17] *(1984) reports that the topographic relief at the* CMB *is* ≤10 km *(Bufe and Carder, 1972), and probably only* $a\ few\ km$ *(Jordan and Anderson, 1974), though it is generally reported that deviations from spherical symmetry of the order of magnitude of say* $\sim 0.1 - 1.\ km$ *ought to be sufficient for justifying some relevant effect.*[18]"

It appears difficult to envisage whether the previous estimates about the topography of the *ICB* are more or less in agreement with the figure of the *ICB* evaluated according to the procedure here envisaged.

More recent additional investigations related to this item are as follows.

Krasnoshchekov et al. (2005) investigated the spatial gradient of R_{ICB} *vs.* latitude and longitude, as it can be inferred from seismic evidence. They give evidence for a "mosaic" pattern that denotes that the *ICB* is not a mere spherical surface. However, at least at present - and to our knowledge and as far as the present study is concerned - these investigations appear to contribute no new hunch.

For instance, a systematic investigation was carried out by Khan (1971a), referring to the gravity field, to the geomagnetic field and to its *SV*, even upon distinguishing between its drifting and non-drifting part, and comparing the inferred evidence with the observed sea-level change - which resulted biased by excessively large errors for inferring any significant evidence. In general, sea-level series are affected by several drivers. Hence, they are likely to be poorly representative of any one given single effect considered alone. No clear result was attained, and - according to our feeling – maybe this fact resulted also from the fact that the rationale of convection within the mantle, or of some exotic topographic bumps on the *CMB* or of other speculated mass density heterogeneities, etc., rely on some relevant speculation.

In contrast, compared to the aforementioned inference by sea-level change, an observationally more accurate investigation was carried out (Wagner, 1973) by comparing the long-range trend of the orbits of *8* approximately stationary satellites monitored during 6 $years$. The results, however, showed no drift relative to Earth's surface of the gravity field. The measured upper limit for this drift was $< 0.05°\ year^{-1}$.

No additional details are here reported - and no subsequent discussion. These findings were objected e.g. by Khan (1971), Lowes (1971), reply by Hide and Malin (1971), Lambeck (1980a), as reported e.g. also by Jacobs (1975, 1987b) and Merrill et al. (1996), based either on statistical procedures, or on the interpretation of this correlation that seems to exist.

In fact, this apparent correlation could derive from temperature inhomogeneities within the mantle, rather than from the topography of the *CMB*. Conversely, according to the interpretation here proposed, the bumps either on the *ICB* or on the *CMB* are closely associated with the thermal structure inside the *OC*.

Robinson (1974) applied a model of mantle convection and showed that in this way he could justify a displacement of the *CMB* by $\sim 1.5\ km$, which is the correct order of magnitude needed by Hide and Malin in order to justify their topographic coupling.

Baranova et al. (1973) extended backward the same Hide and Malin's analysis until AD 1600 by means of the model by Ben'kova et al. (1972). They found a correlation, although more complicated than during the $\sim 1\ century$ time interval used by Hide and Malin. The *WD* is distinct in the non-dipole $\boldsymbol{B}$ and is practically absent in the quadrupole $\boldsymbol{B}$. A discussion is given by Malin and Hide (1982), by which they show that their inferred evidence cannot be the result of a coincidence.

We add some comments according to the general rationale of the present study.

A crucial concern deals with the precision of the observational database. The error-bars are poorly known of the *SHE*s either of V or of V_G. According to our background in geophysics, we are better aware of the reliability of V models, while a geodesist is certainly better acquainted with the precision of V_G models. Nobody can tell whether the quality is comparable with each other - or not- of the two observational inputs in the aforementioned correlation computation, i.e. of V and of V_G.

Another concern deals with the restriction to consideration of the "non-dipole part" of V.

In fact, suppose that the correlation analysis is carried out by considering the terms of V with $n = 1, 2$. If one assumes that the gravity field experiences no relevant longitudinal drift (reckoned with respect to the standard geographical reference frame at Earth's surface), it is

[17] Coerte V. Voorhies (†2021), American geophysicist.

[18] A discussion of the topographic (and other) coupling item is given e.g. by Hide (1970, 1986, 1988, 1988b, 1989, 1990), Aldridge (1990), Dehant and Wahr (1990), Hinderer and Legros (1990), Jault and Le Mouël (1991), Braginsky (1999), Sarson and Jones (1999), etc. Some debates were sometimes reported. For instance, Hide (1998a) rejected the inference by Kuang and Bloxham (1997b) who had claimed that the axial component of the torque deriving from the topographic coupling cannot be non-zero (to the first order of bumpiness), and that therefore every non-null value only derived from observational errors. Hide (1998a) rather emphasized that such axial component of the torque can vanish *'only in very special (and geophysically unlikely) circumstances'*. In addition, he stressed the crucial importance also of the topography of the *ICB*.

concluded that the well-known *WD* ought to be detected of V relative to the geographical reference frame. That is, this would be just a different way to give a graphical representation of the well-known *WD* of the geomagnetic *SV*.

Every different result ought to be interpreted as an indirect, though clear, evidence of a drift - of either direction - of V_G with respect to the geographical reference frame.

Instead, Hide and Malin (1970) considered the "*non-dipole part*" of V. That is, they excluded only the $n = 1$ terms and considered the $n = 2, 3, 4$ terms. The $n = 2$ part ought to imply a *WD*. In contrast, they found an *ED*. Is this significant inside the (unknown) error-bars? Conversely, consider Gregori et al. (2025q) that clearly show that the *WD* involves strictly only the $n = 1, 2$ terms.

The concern about the error-bars either of V or of V_G can be related to the aforementioned analysis by Marino (2004) about a stroboscopic effect. The original idea was to search for evidence of a very fast rotating *IC* inside an almost inviscid *OC*. The result was negative. In contrast, by his computation Marino (2004) found that his result can be explained only by admitting that the *ICB* has a surface topography that, in terms of longitudinal variation, is characterized by a *SHE* term with order $m = 22$.

This remarkable result - which was derived by means of a heavy computation - shows the heuristic capability of the search for stroboscopic effects associated to the variation of the adopted time-lag over which a mean is computed.

Therefore, a similar analysis ought to be carried out also on the gravity field, i.e. dealing with V_G. However, we are aware of no investigation of this kind.

In any case, as a reasonable working hypothesis, suppose that inside either the shallow or the deep Earth's interior two kinds of physical sources can be envisaged: one source is the mean origin of a given geomagnetic signal (for instance, the V terms associated with some pre-chosen degree n), and another source is equivalently responsible for the mean origin of some terms of V_G.

Note that these two sources can be physically different. In fact, the gravity field can be associated, e.g., with some density anomalies inside some shallow layers, compared to the geomagnetic sources that could be associated to some electric current deeper inside the Earth. *A priori* every hypothesis can be envisaged.

Suppose that these two distinct sources spin with an angular speed, respectively, ω and ω_G, relative to the frame of reference which is identified with the geographical distribution of continents at the Earth's surface. Note that, in general, ω and ω_G can be either different or equal each other.

In any case, the observed longitudinal drift - which would result from an analysis of the kind carried out by Hide and Malin (1970) - can be interpreted just like a beat. Its frequency depends on three physical parameters, i.e. on ω, on ω_G, and on the time-lag that we choose in order to compute the means either during one year, or during some different time-lag.

Therefore, in principle, we can expect to find every kind of result, or of its opposite. Indeed, a large number of *d.o.f.*s enter into play, which are unknown, and every result can thus be found.

Summarizing, a much more astute analysis has to be carried out - both on the geomagnetic and/or on the gravity data and on the computation of their respective *SHE*s - before being capable of achieving a physically significant interpretation of every correlation between geomagnetism and gravity.

Therefore, according to the general rationale of the present study, no final interpretation can be proposed of this study by Hide and Malin (1970) and of the subsequent astute discussion.

This discussion is here mentioned to remind you about the large number of controversial viewpoints that - in the final analysis - rely on some conscious or subconscious preliminary choice: everybody seems to recall and emphasize only the arguments that support his paradigms, etc. No general agreement seems to have ever been attained, and every *a priori* speculated model seems to survive. Other viewpoints - more or less closely related to the speculated *MHD* dynamo - are briefly reviewed and discussed by Gregori (2002), including the speculation about the so-called *D"* layer, etc. However, they are of no direct concern for the present study.

Therefore, all these debated items further support the "simple" and "beautiful" interpretation that is here proposed.

In any case, the same analysis should be carried out by referring to impulsive phenomena, i.e. to the effects of the kind expected to be associated with the Foucault $\boldsymbol{j}$ - and, for such a purpose, the transoceanic communication cables are a relevant source of observational information (Lanzerotti and Gregori, 1986).

For the sake of completeness, the *WD*s are also to be recalled, whereby Eurasia appears to drift westward at a speed $\geq 3 \times 10^{-6}$ degress year^{-1}, while according to the Hillier (2006) argument the *WD* of the Pacific Ocean lithosphere seems to be by $\sim 10^{-6}\ degrees\ year^{-1}$. On the other hand, this depends on the choice of the reference frame. We cannot enter here in these details

*The geomagnetic evidence alone - The westward drift (*WD*) of the geomagnetic secular variation (*SV*).*

Let me recall a few historical items[19] dealing with the *SV*. In 1692 Sir Edmond Halley discovered the *WD*. Subsequent investigations showed that the average *WD* is by $\sim 0.20\ year^{-1}$, although - at some stations - it can be smaller or even eastward. Later, Parkinson[20] (1983, p. 101) authoritatively stated that "*there is no theoretical reason why there should be a westward drift rather than an eastward drift.*" The difficulty can be highlighted e.g. in the cartoon of Fig. 18.

[19] The present section derives from a cooperation with Alberto Incoronato.

[20] Prof. Wilfred Dudley Parkinson (1919-2001), prominent Australian geophysicist.

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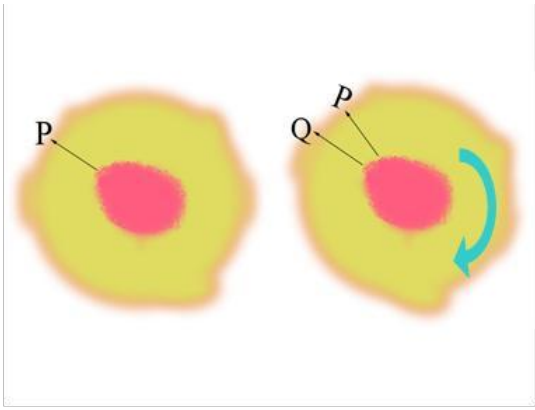

Fig. 18. [*left*] Cartoon showing an equatorial cross-section of the Earth, observed from the celestial North Pole, where a hypothetical *IC* with just one bump can move inside the fluid *OC*. At a given instant of time this bump is supposed to be located underneath a point P at Earth's surface. [*right*] – The same, after considering that the tidal pull displaces clockwise the *malicrust* relative to the *IC*. Hence, the bump of the *IC* results underneath a point Q located at Earth's surface. An observer located at Earth's surface will claim that the *SV* displays a longitudinal drift, although it is an *ED* rather than a *WD*, which is the actually observed case. Hence, this argument is paradoxical and certainly it cannot apply to the real Earth. Unpublished figure.

In 1989, Janackova et al. (1989), Janackova and Urban (1990), and Urban and Janackova (1990) gave the - unexplained although very clear - evidence that the geometrical locus of the sites where the drift of the *SV* is neither *WD* nor *ED* coincides with the planetary network of the *MOR*s. Shortly afterwards, Gregori (1993) gave the unique presently available explanation, upon considering that the *j* - that flow underneath the *MOR*s, and are responsible for the generation of the geomagnetic field - seemingly rise and flow up to some shallow depth. Therefore, an eventual drift of the deep ***j*** cannot be monitored on top of a *MOR*, due to the much closer distance of the ***j*** from the recording magnetometer. This rationale - integrated into a wider perspective, including several other unexplained observations - led to the implementation of the theory of the *TD*-geodynamo (Gregori, 2002; Gregori and Leybourne, 2021; etc.).

Two different (fully original) explanations are going to be here proposed for the *WD* of the *SV*. The key physical concern can be illustrated as follows (see Fig. 19).

Consider an Earth's model characterized by an approximately spherical symmetry. The tidal driver - either solid Earth's tide or loading tide - is active on the outermost layers. Let the Earth be ideally rigid like a perfect solid body. In this case, a braking torque is exerted on the whole Earth's body, thus implying a uniform reduction of the angular speed of the spin of every spherical shell inside the Earth (as it is shown in Fig. 19).

If the Earth is not a perfect solid, and it is rather "plastic" or "viscoelastic", every comparatively outer layer will experience a larger tidal braking compared to its respective inner layers. This is a strict and unavoidable logical requirement of the tidal pull.

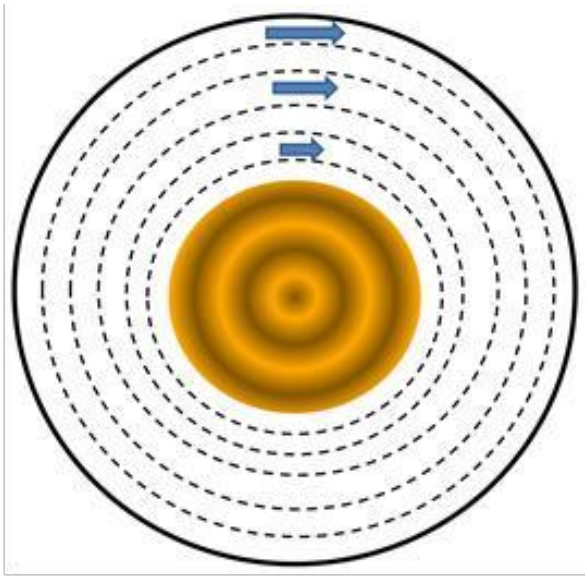

Fig. 19. Out-of-scale cartoon showing a hypothetical perfectly spherical Earth's model, observed from the North Pole, with a supposedly spherical *IC*. The Earth is subject to a tidal torque, either by the Earth tide, or by the loading tide. If the Earth is a perfect rigid object, the reduction of the spin rate is the same for every concentric spherical layer of the Earth. If the Earth is viscoelastic, the outer layers experience a more pronounced spin rate reduction compared to their respective inner layers. Unpublished figure.

Hence, owing to the argument of Fig. 18, one should observe an *ED* and never a *WD* of the *SV*. Every suggested explanation for the *WD* must therefore justify such a reversal of the primary direction of the expected drift. The first concern is not about the intensity of phenomena, but rather just about a first idea. After having defined a model, a quantitative analysis will state whether it is quantitatively more or less likely.

The first proposed explanation appeals to merely e.m. effects, which in the final analysis are reckoned to the e.m. induction law. Hence, this is denoted as the "*e.m. explanation*". As a first guess, upon a quantitative subsequent estimate, its actual occurrence may appear problematic, even though, after a more careful and rigorous analysis, it will be shown that it plays a measurable and crucial role in the entire phenomenon, revealing an unexpected heuristic information.

The second proposed explanation is rather of mechanical character, hence intuitively more easily understandable. Owing to the reason clarified below, it is here simply denoted as the "*sail*" effect explanation.

In any case, the combined analysis with the aforementioned approach allows checking the correctness of this inference.

I - *E.m. explanation* - The rationale is according to the *TD*-geodynamo. A key point for the item here of concern deals with the classical long-lasting debate about the Cowling theorem, when it is generalized to a more general and rigorous form (Gregori et al., 2026d), by which a *TD*-dynamo can be effective only in a body with no perfect cylindrical symmetry. However, every real natural system never has a strictly perfect cylindrical symmetry. Hence, no

concern applies. Different causes can determine the violation of an ideal cylindrical symmetry (e.g. Todoeschuck et al., 1981; Stevenson, 1982, 1982a).

As far as the present discussion is concerned, the important point is that the *TD*-geodynamo results from a westward pull of some outer portions of the Earth's body, relative to some inner part. The energy supply is either the loading tide or the Foucault $\boldsymbol{j}$ (to be separately discussed).

Refer to the principle of magnetic energy variation (Gregori et al., 2025e), and in particular to the relation

$$\delta W = \delta U_j = -\,\delta U_{s1} = -\,\delta U_{s2} \qquad (4)$$

which holds in the case that no Joule dispersion occurs in either one loop. However, it is shown that even the role of Joule dispersion can be included, implying some formal although unessential complication. Hence, with no loss of generality, in the following the effect of Joule heat can be neglected.

Therefore, consider a geocentric reference frame that does not corotate with the Earth. Apply the argument associated with two ideal loops (Gregori et al., 2025e). As an average representation, refer to the charged matter, which is basically composed only of electrons that move inside the Earth and are responsible for the *TD*-geodynamo. Liken this charged matter to some inner loop, which is supposed to be approximately circular. Owing to the externally applied westward pull (either tidal or by stray currents), the rotational kinetic energy of the outer loop - i.e. of *malicrust* – is reduced. In fact, this is the observed well-known increase of the *l.o.d*.

The system was formerly in a state of equilibrium, which - owing to Hamilton's variational principle (Gregori et al., 2025e) - implies the maximum possible U_j. The westward pull implies a $\delta U_j < 0$, or a $\delta W < 0$, and - owing to (4) - it is $\delta U_{s1} = \delta U_{s2} > 0$. That is, the applied energy variation that affects the kinetic energy is transferred into a decrease of U_j and into identical increases of U_{s1} and U_{s2}. The system must therefore attempt to increase anew U_j towards its relative maximum, which is the necessary condition for stable equilibrium. Hence, the inner part of the Earth must move westward. Therefore, the *SV* must display a *WD*.

The reader should now refer to the entire detailed discussion given in Gregori et al., (2025e). The basic rationale is exactly the same as the two-loop system, where the loop L_2 was supposed to have been rotated counterclockwise relative to L_1, which is equivalent to a clockwise rotation of L_1 relative to L_2 (which is the case of the tidal action referred to a celestial reference frame). Intuitively, the kinetic energy supplied to the $\boldsymbol{j}$-loops is irrelevant in terms of increased $\boldsymbol{j}$ intensity. But it cannot be neglected in order to avoid a paradox in the energy balance. When this effect is integrated over the whole Earth's body, it must give a total energy input δW that, owing to (4) can be rigorously identified with U_j , or with the measurable $-\delta U_{s1} = -\delta U_{s2}$.

As mentioned above, the *IC* field is to be associated with the terms - of the *SHE* of the geomagnetic potential V– of degree n=1, 2. Hence, upon identifying the *IC* source with L_2, U_{s2} can be formally computed by means of the *SHE* of V at every given epoch. Hence, also δU_{s2} can be evaluated.

Let us stress that the argument relies on the fact that the Maxwell laws must be applied to material objects, such as the electrons, while, the simple consideration of Maxwell laws in vacuum leads to "*virtual*" quantities and, unavoidably, to paradoxes when the energy balance is computed (see, e.g., Gregori et al., 2025w, or Gregori and Gregori, 2025).

The inward propagation of the tidal drive from the outer layers of the Earth easily occurs through the *OC*, unlike when it strikes against the "*hard*" *magpol IC*. It is therefore reasonable to expect, depending on the geometry of the *IC*, that a real "*sail*" effect occurs. That is, relative to *malicrust* and *OC* - hence relative to an observer at Earth's surface - the *IC* will be pushed westward.

This proof is straightforward, "simple", "beautiful", and its key is the generalized Cowling theorem (Gregori et al., 2026d). It applies in general to several different case histories. As far as the present application is concerned, in the final analysis the paradoxical expectation of an *ED* rather than the observed *WD* is overcome by appealing to the Faraday induction law.

II - The explanation by the "*sail*" effect - The rationale of Fig. 19 ought to be reconsidered in terms of Fig. 20, which is the same, apart the fact that the *IC* is no more spherical. Rather, it is a "*hard*" (not "*solid*") *magpol* object, which has a substantially different behavior compared to the "*metallic*" or "*fluid*" *OC* (see above).

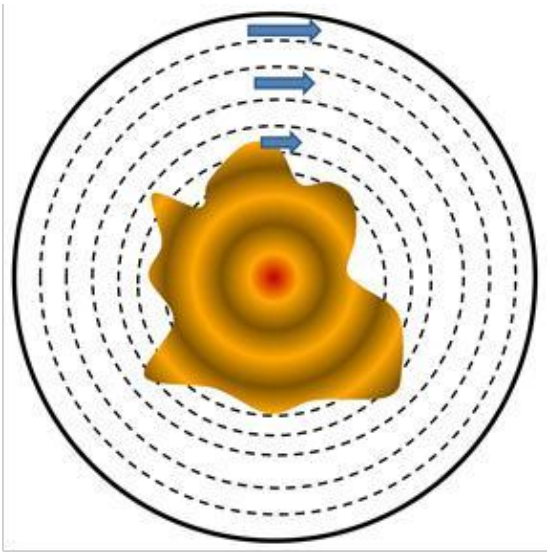

Fig. 20. Out-of-scale cartoon showing a hypothetical perfectly spherical Earth's model, observed from the North Pole, with a non-spherical *magpol IC*. The Earth is subjected to a tidal torque, either by the Earth tide, or by the loading tide. Compared to Fig. 19, consider the role of the substantial difference of the "*metallic*" *OC* compared to the *magpol IC*. The flow of the *OC* exerts pressure on the IC, much like wind against a sail. That is, a "*sail*" effect occurs, which makes the *IC* to drift westward. The amount of the effect depends very much on the deviation of the *IC* compared to perfect symmetry. See text. Unpublished figure.

That is, the *WD* - instead of an ED - of the *SV* results from a "*sail*" effect caused by a "*hard*" *magpol IC*, which has a figure that deviates by some substantial amount with respect to spherical symmetry. That is, this is just a matter of "phrenology" of the *IC*, according to the Raymond Hide's lexicon.

This interpretation - which relies on a mechanical interaction that can be briefly called "*sail*" or "*IC recoil*" effect - appears undoubtedly reasonable, much more than the aforementioned merely e.m. process that relies on the principle of magnetic energy variation.

On the other hand, this "*sail*" effect interpretation relies on a speculated *ad hoc* assumption of a substantial deviation of the *IC* from spherical symmetry.

This was found by applying the stroboscopic argument (see above), even though, in principle, a much more detailed investigation can be carried out.

There is need for additional observational confirmation, but this appears to be possible also by means of a different and important inference.

Latitudinal drift of the geomagnetic SV*, and its correlation with pole motion and/or* l.o.d. *variation.*

This still unexploited observational inference ought to rely on the evidence provided by the maps of the atlas Gregori et al. (2025q), and on the correlation of the latitudinal drift of the *SV* with anomalies in the astronomical motion of the Earth. The target is to check the correct change of the moment of inertia of the Earth, when the *magpol IC* experiences a latitudinal rotation.

The correlation between geomagnetism and l.o.d.

A similar inference concerning the figure of the *IC* derives from the correlation between the *SV* and the variations of the *l.o.d.,* in terms of a straightforward argument, where the seemingly Foucault stray currents $\boldsymbol{j}$ are the primary driver, but according to the literature this correlation is unexplained.

This kind of analysis is similar either when - as mentioned above - the focus is on the latitudinal drift of the *SV*, or - as in the present analysis – the focus is more generally on the entire *SV*, which is dominated by the longitudinal dependence. However, compared to the analogous latitudinal effect, the longitudinal effect is stronger, hence a conspicuous literature exists on it. Let us recall some historical items.

The seemingly first-reported evidence was given by Stoyko[21] (1951) and by Vestine[22] (1953). Subsequently, during over half a century, several re-discoveries and confirmations were given by later authors - but, to our understanding, no reasonable explanation was ever proposed. Gregori (2002) reviewed and extensively discussed this issue but gave no physical explanation. The interested reader ought to refer to Gregori (2002). We reproduce here only Tables 1 and 2 that synthesize the result. For explanation of every entry refer to Gregori (2002, p. 209-244).

Table 1. Correlation trends according to the "*e.m. explanation*" of different parameters related to *l.o.d.* or to geomagnetic *SV*

item code	description	trend	
P1	*l.o.d.*	+	-
P2	$\delta\omega$ at Earth's surface	-	+
P3	δW (variation of kinetic energy)	-	+
P4	δU_{s1} and δU_{s2} (variations of magnetic self-energies)	+	-
P5	$\delta\lvert\boldsymbol{B}\rvert$	-	-
P6	$\delta\{g_n^m\ ;\ h_n^m\}$ (variations of Gauss' "elements")	+	.
P7	$\delta[WD]$	+	-
P8	$\delta\ year\ duration$	-	+
P9	[the sign depends on case history		
P10	$\delta[WD]$ rotation of the eccentric dipole	+	-
P11	$\delta\omega$ of the outer 200 km layer of the *OC*	-	+
P12	motion of the eccentric dipole	-	+
P13	solar cycle duration	+	-
P14	seismicity	-	+

Table 2. "*E.m. explanation*" of observed correlation between *l.o.d.* and geomagnetic *SV* (item code in Table 1)

explained by	Reference
P1-P5	Stoyko (1951)
P6-P8-P10	Yukutake (1973)
P6-P8	Yukutake (1973)
P1-P7	Le Mouël et al. (1981)
P1-P7	Courtillot and Le Mouël (1984)
P1-P2-P9	Le Mouël and Courtillot (1981)
P1-P10-P12	Vestine (1953)
P1-P2-P12	Ball et al. (1968) and Kahle et al. (1969)
P1-P2-P12	Runcorn (1975)
P11-P12	Vestine and Kahle (1968)
P2-P13-P14	Feng Song and Tang Maocang (Fig. 21)

The conclusion is that an increase of the *l.o.d.* - or a decrease of the kinetic energy $\delta W < 0$ - triggers an identical increase, as per (4), of the self-energies δU_{s1} and δU_{s2} of the $\boldsymbol{j}$-loops inside the geodynamo of the Earth, i.e. an increase of the geomagnetic field, altogether with an increase of the leading terms of the *SHE* of its geomagnetic potential V. In addition, the more intense is the decrease $\delta W < 0$, the larger is the resulting *WD*.

Moreover, consider that an increase of the *l.o.d.* implies a decrease of the apparent duration of the year. In fact - if one neglects the effects of the Foucault $\boldsymbol{j}$ on the speed of the Earth, measured along its orbit around the Sun[23] - the total duration of the year is invariant when it is observed, e.g., from the sidereal reference frame. Therefore, if the *l.o.d.* is increased, the number of days included within the time lag of one year - measured by the return time of the same

[21] Nicolas Stoyko has been *Director* of the *Bureau International de l'Heure*, in Paris. His biography is given by Lévy (2007).

[22] Ernest Harry Vestine (1906-1968), American geophysicist.

[23] In principle, this effect ought to exist, although - to our knowledge - it was never extensively and specifically investigated, being (maybe correctly) considered a lesser effect. As far as the present section is concerned - this problem can be neglected with no loss of generality.

heliocentric longitude of the Earth along the ecliptic reckoned in the sidereal reference frame - must correspondingly decrease. That is, an increase of the *l.o.d.* corresponds to an apparent decrease in the duration of the year (and vice versa).

In addition, whenever, owing to some reason, some abrupt change occurs of the spin rate of the Earth - that is significantly more intense than the aforementioned case histories - a comparatively rapid change ought to occur to the geomagnetic field. These events are generally called "*jerks*". They are a well-known observational fact. On the other hand, some confusion is likely to exist concerning their definition, as every occurrence of this kind is conventional and simply likened to just one and the same phenomenon. This item ought to request some more specific and detailed discussion that, however, is outside the scope of the present study although it is often discussed *passim* whenever needed. In fact, every different case history requires its specific discussion, and no general "thumb rule" can be given.

Refer to Table 2. Several plots, which are not here reported (see Gregori (2002, p. 209-244) show specific trends. One figure by Stoyko (1951) shows that the increase of the *l.o.d.* is correlated with the intensity of the geomagnetic field. A figure by Yukutake (1973) shows that a decrease of the duration of the year is correlated with a *SV* decrease of $g_1^0 0$ and of the *WD* rate of the g_2^2 term. Another figure by Yukutake (1973) shows the same, showinging also Moon's longitude, consistently with the hypothesis of a *TD*-geodynamo, which is energetically controlled by the tide. A figure by Le Mouël et al. (1981) shows the correlation between the variation of the *l.o.d.* and the *SV* of the component D of the geomagnetic field $\boldsymbol{B}$ at one given station (Chambon-la-Forèt). A figure by Courtillot and Le Mouël (1984) shows the same with some additional details and with an expanded historical time interval - envisaging some relevant role of the error-bars in past geomagnetic records. A figure by Le Mouël and Courtillot (1981b) shows a clear correlation between some jerks and some minima of the *l.o.d*. As a conclusion, the simple rationale of (4) leads to the correct explanation of the observed correlation between *l.o.d*. - or duration of the year - and the *SV*.

All these plots can be even more easily explained by means of the "*sail*" effect. In fact, if owing to any reason - i.e. Foucault currents $\boldsymbol{j}$ or other - an impulsive torque causes an abrupt variation of the spin rate of *malicrust*, this impulse propagates inward until causing through recoil a "*sail*" effect on the non-spherical "*hard*" *magpol IC*.

Note, however, that, owing to the crucial role played by the geometry and orientation of the bumps at the *ICB*, the trends in Table 1 might be different.

Let us recall about an additional intriguing correlation shown in Fig. 21, borrowed after a preliminary short note,[24] which is addressed to investigate the relation between sunspot cycle length (*SCL*), Earth's angular speed (or *l.o.d.*), and seismicity. It is found that the shorter the solar cycle is, the faster the spin rate of the Earth or the shorter is the *l.o.d*.

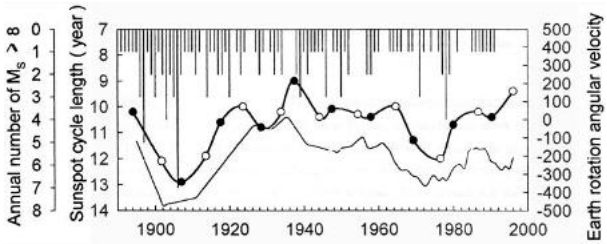

Fig. 21. Sunspot cycle length (*SCL*, curves with black or white mini circles), Earth's spin angular speed, and large earthquakes ($M_s \geq 8$) (planetary datum) during the last ~ 100 $years$. After a short preliminary note by Feng Song and Tang Maocang. Private communication. Unpublished figure.

As far as seismicity is concerned, the correlation is less clear, although years with a larger number of earthquakes tend to occur with longer solar cycle duration and with longer *l.o.d.* This can be interpreted by supposing that a longer solar cycle ought to imply a greater efficiency of the *TD*-dynamo (see Gregori et al., 2026c), stronger dynamics in the crust, causing a slowing down of the spin rate of the Earth, and originating a comparatively higher crustal stress and seismicity. All this evidences appear in close agreement with the *TD*-geodynamo, resulting into an important new entry in the list of several observations that fit with the *TD*-dynamo and cannot be explained by previous models. All these effects, however, must require consideration of a time resolution that - unlike what is usually made - has to be much more detailed than a simple yearly (or diurnal) average.

Some relevant updating - including a systematic extensive approach in terms of a search for bivariate correlation analysis between long series of various geophysical parameters, including *l.o.d.* and pole position and motion - is reported in a book by the late John M. Quinn (2010), thus confirming in greater detail all aforementioned evidence.

This completes the physical interpretation of the available observations dealing with the correlation between *l.o.d.* variations and *SV*. We guess, however, that some additional comments deserve better physical understanding.

As mentioned above, this "simple" and "beautiful" explanation was missed by Gregori (2002), who rather speculated about a possible stroboscopic effect. In fact, the *SV* is investigated by plotting *vs.* time the yearly averages of the magnetic elements - eventually after rejecting magnetically perturbed periods etc. Suppose as a working hypothesis, that the *IC* spins faster than the *malicrust.* Therefore, suppose - for a moment and consistently with what is presently generally reported in the literature - that the *OC* is a fluid, and - in addition - that it is almost inviscid. It should be recalled that its viscosity has been measured by the decay of the oscillations of the "*solid*" *IC* inside the fluid *OC*, according to the observational evidence provided by the anomalies of both *l.o.d*. and pole motion.[25]

[24] By Feng Song and Tang Maocang, circulated approximately in 1997; private communication by Gao Xiaoqing.

[25] See Gregori (2002, its Appendix A). Note that in principle the same analysis can be applied also to the case of a "*hard*"

If all this is correct, the observed *WD* ought to result from an aliasing effect associated with the fact that only yearly averages are considered. If this concern is real, the *SV* ought to be investigated by seeking a beat effect (Gregori et al., 2025y; see above).

Gregori (2002) even made an order of magnitude estimate of the total energy balance. Consistently with a speculation by planetologists - and according to a simple backward extrapolation of the present slowing trend of the spin rate of the Earth - a tentative assumption is that at present the *IC* is still moving as fast as the Earth did at the early times of the formation of the Solar System. The Earth is generally reported having, at that time, supposedly to spin with a period of $\sim 5-7\,hours$. If the *IC* eventually maintained such a fast-spinning rate, the available kinetic energy for the *TD*-dynamo can be evaluated. It is thus shown to result in a power of $\sim 4-5\times 10^{12}\,W$, which should be compared with the total present endogenous energy release, according to the estimate of Table 1 of Gregori and Leybourne (2021), also in Gregori (2002), i.e. $\sim 7.54\times 10^{13}\,W$.

Consider that this estimate - of the present endogenous energy release – corresponds to a comparatively anomalous period, characterized by a pronounced relative maximum while the Earth is displaying a heartbeat. Upon considering the conspicuous uncertainties and approximations within this rough computation, Gregori (2002) felt satisfied. Therefore, consider the beat analysis mentioned above and based on the *Thesis* by Marino (2004).

Really, Gregori (2002) missed first of all the crucial point that the state of the *OC* is not fluid, and that, rather, it is in a "*metallic*" state (see above).

Consider the, classical, and skillful, analysis reported in the literature of the variations of the *l.o.d.* and of pole motion (see references in the Appendix A of Gregori, 2002): it is the basis for an estimate of the viscosity of the *OC*. Its rationale, however, applies a model that must be accordingly changed, upon considering the "*metallic*" state of the *OC* and the " *hard*" *magpol* state of the *IC*. In addition, the interaction is in terms of *MHD*, not of fluid dynamics alone.

According to the different rationale, which is here considered, one has unavoidably to refer to the e.m. induced currents that operate on the sea-urchin structure through the mantle. In addition, some implications ought to be eventually considered about the mega-spikes pattern of the *ICB* (see Fig. 22), which are likely to exist, according to several geophysical evidences. In any case, however, this is an oversimplifying picture, as the boundary between *magpol* region and "*metallic*" state region is not very sharp, and this is the mechanism by which the Earth's battery stores and releases energy (see the detailed aforementioned discussion). Differently stated, the physics is not a simple matter of e.m. induction. Rather, it involves the e.m. interaction of nuclear magnetic moments with their environment.

Fig. 22. Out-of-scale cartoon showing the two mega-spikes, or mega-plumes, represented like upward bumps of the contour surfaces of equal σ (i.e. not of the rheological properties), which can be pictorially associated with the upwelling plumes of the conventional "*fluid*" model, while, in reality, the *OC* is in a "*metallic*" state. Differently stated, as already mentioned, that a much hotter mantle occurs underneath the entire Pacific Ocean area, consistently with the "quatrefoil" pattern of "*Tuzo*" and "*Jason*" patterns proposed by Burke (2011). See text. Figure after Gregori and Leybourne (2021). With kind permission of *American Journal of Engineering and Applied Science*.

Therefore, the temporal evolution - of the variations of the *l.o.d.* and of pole motion - ought to reflect the evolution of the e.m. induction by the solar wind. However, at present, it appears hard to envisage a practical way suited to carry out a computation of this kind, due to the difficulty to compute e.m induction onside a non-spherical Earth, with an unknown internal geometry, and with an unknown space and time distribution of its internal electrical conductivity σ. Some harder thinking is needed before attaining an achievement in this direction.

In other words, from the viewpoint of the "*e.m. explanation*", the joint magnetic energy U_j between two bodies, i.e. *malicrust* and *IC* - through the complicated e.m. interaction within the highly conducting "*metallic*" *OC* - involves a mutual inductance coefficient L, which is essentially totally unknown.[26] If L is low, the stroboscopic effect must exist. If L is large - as it occurs due to the role of some very strong Biermann's blocking - no stroboscopic effect can exist. Therefore, we can basically arbitrarily manage the unknown L - and by this we can fit any need for the final energy balance.

Differently stated, according to the rationale of the *e.m. explanation*, the tidal slowing down of *malicrust* "pulls" -

magpol IC. The concern is rather about the Biermann's blocking. The use of superconducting gravimeters (*SG*) records for this kind of application is discussed e.g. by Rosat et al., (2009a). The role of *SG* records, and of the presently growing international network of *SG* observatories, are briefly mentioned below.

[26] In reality, one should consider the e.m. coupling between concentric layers of progressively decreasing radius, as mentioned above, etc., by applying the identical rationale that, for simplicity and with no loss of generality, is here referred to the simple case history of two interacting objects.

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and it slows down - the *IC* that, however, responds only with some delay. And, in fact, the final effect is the resulting explanation of the *WD* as outlined here above.

Much simpler is the explanation by means of the "*sail*" effect, where however the rationale is not in terms of e.m. coupling, rather it is in terms of a mechanical action, just like wind on the sail of a boat. The "*sail*" effect appears intuitively more appealing, while the "*e.m. explanation*" maintains its conceptual clear value.

In either case, compared to what was formerly envisaged, everything appears therefore much "simpler" and more "beautiful", and better and logically self-consistent. Three additional, relevant, observational facts appear to support the mechanism of the *TD*-geodynamo:

(i) - the (previously unexplained) *WD* of the *SV* - including its spatial irregularities, which are clearly indicative of the sea-urchin structure;
(ii) - the (previously unexplained) correlation between the *SV* and the anomalies of the *l.o.d.* and of the length of the year;
(iii) - the result of the search for the stroboscopic effect that - owing to a rethinking of its trigger - had a relevant final input for understanding the physical implication.

Some additional information cannot be here reported. Several previously unexplained items appear therefore now well understandable. Hence, the frontier of research moves forward, and the focus can thus shift on a few new main new targets.

*Earth's rotation anomalies and the "*French Revolution*" jerk.*

One unique present striking feature is the great "stove" located approximately close to the Hawai'i hotspot: call it *tout court* the Hawai'i anomaly (*HWA*). Let us investigate how this feature fits in the analysis of the previous sections of the correlation between *SV* and anomalies of the astronomical motion of the Earth. It clearly displays a regular *WD*, as it is discussed in the present section. A more detailed analysis relies on the aforementioned Marino (2004) analysis.

The trend of the *HWA* is shown in Figs 23 through 26, resulting in an apparent *WD* of $\sim 00.2 - 0.03\ year^{-1}$. Figs 24 and 25 show an analytical interpolation *vs.* t, respectively, of the latitude $\lambda_{HWA}(t)$ and of the longitude $\varphi_{HWA}(t)$, in terms of polynomials that were conventionally chosen of order *5*. Fig. 26 shows the velocity and acceleration of either $\lambda_{HWA}(t)$ or $\varphi_{HWA}(t)$, both ones derived by means of the aforementioned polynomial fit of order *5*.

These plots show that a substantial change of trend occurred for the latitude, not for the longitude, of *HWA*, which steadily varied according to a much regular *WD* (Figs 24 and 25).

Fig. 26 shows that, during the "*French Revolution*" jerk, a maximum acceleration occurred in the time variation of the *HWA* latitude, while the acceleration of its longitude started an abrupt increase.

In the final analysis, this is only a different way to represent the geomagnetic *SV*.

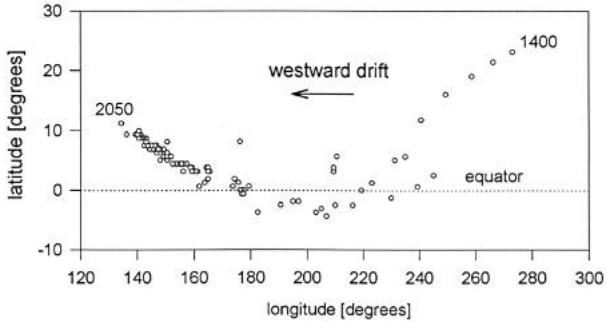

Fig. 23. Hawai'i anomaly - Latitude $\lambda_{HWA}(t)$ *vs.* longitude $\varphi_{HWA}(t)$ for the entire data set. Unpublished figure.

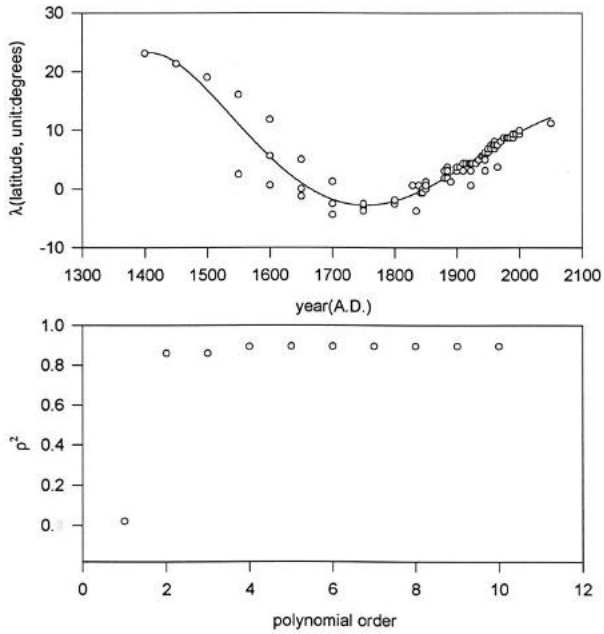

Fig. 24. [*upper plot*] - $\lambda_{HWA}(t)$ *vs.* t interpolated by a *5th* order polynomial; [*lower plot*] - squared correlation coefficient ρ^2 *vs.* the order of the interpolating polynomial chosen for the upper plot. Unpublished figure.

However, only a few of the not-shown figures span a time range which includes also the "*French Revolution*" jerk. However, only one figure (after Rikitake, 1973) displays a clear change. A maximum occurs of g_1^0 as expected, as a geomagnetic element with $n = 1$ ought to change, although less clear is the variation displayed by the *WD* rate of the term with $n = m = 2$. More intriguingly appears the maximum of the Moon's longitude. In addition, the length of the year is reported to be steadily decreasing, but it displays an acceleration that, when the "*French Revolution*" jerk, abruptly increased from negative to become positive (and the trend is also more scattered).

According to the aforementioned battery argument, the "*French Revolution*" jerk can be interpreted as the time of maximum storage of thermal energy inside the Earth's battery, and of minimum radius of the *IC*. The correlation with a maximum of g_1^0 means that the dipole field is larger, which is generated by the *TD*-dynamo, compared to the dipole field of the *magpol IC*. The change of trend of the length of the year means that a change occurred in the mass

distribution inside the Earth, thus implying a change of its moment of inertia, and of the *l.o.d.*

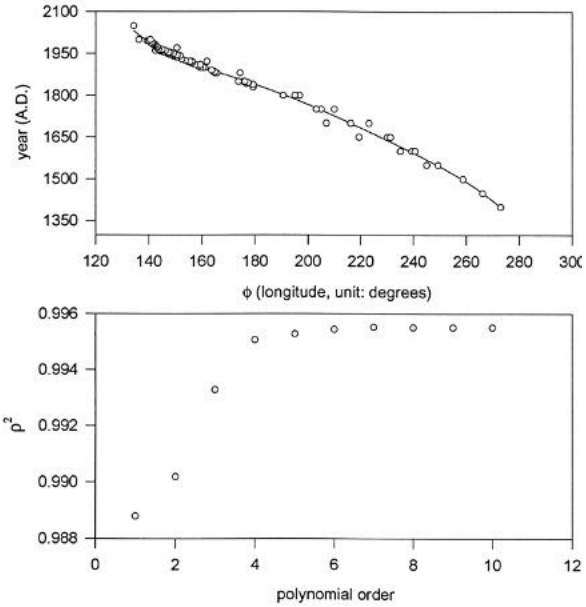

Fig. 25. The same as for Fig. 24 but referring to φ_HWA (t) (instead of $\lambda_{HWA}(t)$ *vs.* t. Unpublished figure.

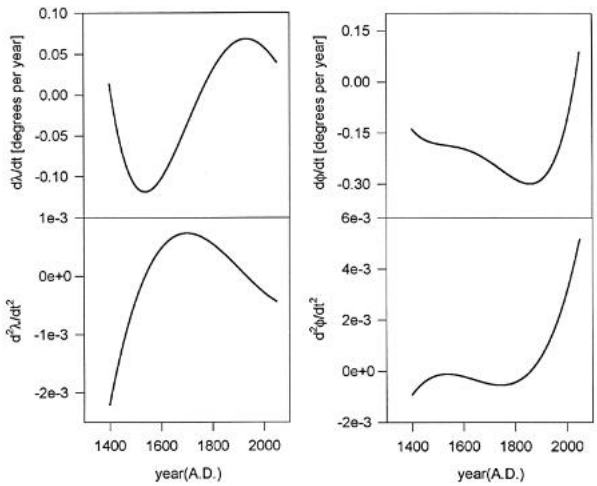

Fig. 26. *(a), (b), (c), (d),* (respectively) $[d\lambda(t)/dt]$, $[d\varphi(t)/dt]$, $[d^2\lambda(t)/dt^2]$, and $[d^2\varphi(t)/dt^2]$ *vs.* t computed by means of the *5th* order polynomial interpolation shown in Figs 24 and 25. Unpublished figure.

This ought to be also the explanation of the changes in the orbit of the Moon, as the Earth/Moon system is controlled by the moment of inertia of the Earth. In this respect, the scatter of the length of the year, which was observed in more recent times, appears to be correlated with the lesser oscillations displayed by the plot of the Moon's longitude.

In any case, to our knowledge, the presently available observational information appears insufficient to infer any better assessment.

Measuring and monitoring the IC - *The dualism e.m. induction* vs. *P-wave pressure*

Owing to the previous discussion, no dualism exists in natural reality concerning the kind of actions that affect the *IC*, i.e. either a mere e.m. induction or a pressure by P-waves acting on the non-spherical *IC*.

This entire scenario can rather be summarized and reconsidered in the framework of comparative evidence provided by four different observational hunches:

(a) - effects on the astronomical motion of the Earth triggered by large earthquakes,
(b) - correlations between the geomagnetic *SV* and the temporal variations of the planetary gravity field,
(c) - analysis of long time series of high precision gravimetry records, and
(d) - *WD* of the geomagnetic *SV*.

The rationale for data analysis relies on four key items.

(i) - Both effects (e.m. induction and P-wave pressure) are active on the *IC*, just for a matter of energy conservation.
(ii) - The aforementioned hunches (a), (b) and (c) can be explained only by means of the P-wave pressure effect. By them, it is possible both to evaluate the instant geometrical figure and orientation of the *IC*, and to monitor its time change.
(iii) - Both e.m. induction and P-wave pressure effects contribute to originating the *WD* of the *SV*. By this, it is possible to evaluate the kinetic energy of the *IC*, and to monitor its time variation.
(iv) - Since the instant geometrical figure and spatial orientation is known of the *IC*, and since we know its kinetic energy, it is possible to evaluate its average density, and to check the expected constancy in time of its average density, even in the case of a substantial time variation of the *IC* volume.

As a final by-product it is thus possible to monitor - in addition to the instant geometrical figure and orientation of the *IC* - also the transformations that occur across the *ICB* and are associated with the battery effect and with the transformation of matter between the *magpol* state of the *IC* and the "*metallic*" state of the *OC*, and viceversa. In addition, the motion of the *IC* can be monitored, in terms either of rotation or of oscillation relative to *OC* and mantle.

The operative approach for data handling is as follows.

Express the geometrical figure of the *IC* by means of a *SHE* analogous to the algorithm applied, as a standard, by geodesists for the description of the geoid.

Then consider every strong earthquake that determined a variation of the astronomical motion of the Earth. Since the epicenter is known, according to the rationale of Fig. 16 it is possible to infer the total force and torque applied by the P-wave on the *IC* described by the aforementioned *SHE*.

Carry out this computation over the entire observational set dealing with all available strong earthquakes of this kind.

Then, apply a least square fit and compute the coefficients of the *SHE*.

In addition, the correlation between the geomagnetic *SV* and the planetary pattern of the gravity field must fit into this computation.

This computation can be substantially refined in great detail by means of the long-lasting high-precision local record series of gravimetric measurements collected at a few fixed locations at the Earth's surface.

In this way, the geometrical figure and orientation of the *IC* can be effectively monitored, including its time variation.

Consider the tidal drive, originated by the loading tide on *malicrust*. Since the figure of the *IC* is known, it is possible to compute the resultant force and torque, which is exerted on the bumps of the *IC* by the concentric layers of the "*metallic*" *OC*. By this, we know the torque and forces that act on the *IC*, we know its motion and rotation, and we know its geometrical figure. Hence, we can compute its moment of inertia, apart from an unknown multiplicative factor, i.e. its average density.

However, as mentioned above, it is possible to estimate also the average density of the *IC* upon combining all this information. In addition, according to the rationale of the definition of *magpol* state, this density ought to be strictly constant, while the size of the *IC* can change - in principle - through the transformation associated with battery effect, etc.

In summary, the overall understanding is likely to have a substantial achievement in the study of deep Earth, according to a specific strategy, which we try to summarize in the next session. A list of the literature is important for future reference, although it cannot be here entirely discussed in detail.[27]

A strategy to investigate the deep structure of the Earth[28]

The general frame

A general strategy for the investigation of the deep Earth's interior is briefly outlined, including both present available observations and future possible - or maybe even likely - new facilities. Refer to the tentative list in Table 3, and we add a few comments to a few entries.

One must distinguish causes and effects.

The steady increase of the *l.o.d.* is an assessed consequence of the loading tide that *per se* involves a comparatively shallow Earth's layer. Hence, it does not seem to be suited for the investigation of the deep Earth's structure. However, the causes of the seemingly erratic variations of the *l.o.d.* and of pole motion must be associated with several drivers that sometimes involve deep Earth's processes, as outlined in the cartoon of Fig. 27.

Table 3. A strategy to investigate the deep Earth's structure

observations	*potential maximum time resolution*	*potential maximum spatial resolution*	*signal-to-noise ratio*
Causes			
atmospheric circulation	daily	planetary (or regional)	good
marine circulation, El Niño	daily	planetary (or regional)	good
transoceanic communication cables and geomagnetic records	instant	planetary (or ocean aize)	good
seismic activity and/or tsunami	once in a while	occasional	?
great volcanic explosions (?)	once in a while	occasional	?
Effects			
star position, or *VLBI*, or *LLR*	several hours	continental	good
space geodesy	instant	local	good
Sagnac effect, or Josephson effect	instant	local	good
Doppler effect from interplanetary probe	instant	planetary	good
AE (crustal stress monitoring)	instant	local	good
soil exhalation and springs	days (?)	occasional	poor
geomagnetism *WD* of the *SV*	several hours	planetary	good
correlation with pole movement and *l.o.d.* variation	several hours		good
figure of the *IC*	yearly	planetary	good
gravity planetary models	months or days?	planetary	good
CGPS, SG, AG, InSAR record series	instant	local	good

As a first order approximation and according to a much simplifying rationale, two primary and steady - although time varying - classes of drivers, can be considered, plus two occasional and sporadic perturbations of very short duration. In addition, long-term *SV* could be originated by the planetary tidal control on the Sun, as suggested by Tattersall (2013a).

(i) Owing to conservation of total angular momentum of the Earth system, the variation of the angular momentum - either of atmospheric circulation and/or

[27] Some early references are Milne (1907), Lambert (1925), Cecchini (1928), Munk and Mac-Donald (1960), Press (1965), Mansinha and Smylie (1967), Smylie and Mansinha (1968), Ben-Menahem and Israel (1970), Gilbert (1970), Mansinha et al. (1970), Runcorn (1970), Dahlen (1971), Smylie and Mansinha (1971), Rice and Chinnery (1972), Dahlen (1973), Israel et al. (1973), Pines and Shaham (1973), Israel and Ben-Menahem (1975), Press and Briggs (1975), Kanamori (1976), O'Connell and Dziewoński (1976), Smith (1977), Mansinha et al. (1979), Dragoni et al. (1983), Dziewoński and Woodhouse (1983), Chao (1984), Sabadini et al. (1984), Souriau and Cazenave (1985), Gross (1986), Chao and Gross (1987), Chao (1994), Vaníček and Christou (1994), Chao and Gross (1995), Chao et al. (1995, 1996a, 1996b), Spada (1997), Soldati and Spada (1999), Chao and Gross (2000), Dick et al. (2000), Gross and Chao (2001), Sun and Okubo (2004), Chao and Gross (2005), IERS/GGFC Special Bureau for Mantle (2007) ... More recent papers are more easily available and - compared to the older literature - can rely on a greatly improved quality of the astronomical information.

[28] A substantial part of the present section derives from a discussion with – and contribution by - the late Prof. Iginio Marson (1951-2025).

of oceanic circulation - implies a corresponding and opposite variation of the angular momentum of solid Earth. These circulation patterns, of both fluid components of the Earth system, are controlled by all phenomena dealing with thermodynamics and fluid dynamics, eventually including also processes caused by e.m. induction (such as e.g. in ocean water). They include thermo-elastic, seasonal, and tidal effects, plus ice rebound implication, etc., and all seemingly more or less erratic variations that, either directly or indirectly, are associated to fluid motions through the whole Earth system. This is time-varying and steady driver.

(ii) The Foucault currents $\boldsymbol{j}$ generated by e.m. induction into the *malicrust* are responsible not only for the solar modulation of the *TD*-dynamo, but also for the generation of torques, similarly to what occurs in the e.m. brakes of a train. This is time-varying and steady driver.

(iii) Strong earthquakes, with or without relevant tsunami, can be correlated, or not, with variations *(a)* of the moment of inertia of the Earth, *(b)* of pole motion, *(c)* of *l.o.d.*, and *(d)* even with a shift of the spin axis of the Earth (i.e. shift of the point inside the Earth's body where the spin axis is applied). This is an occasional driver.

(iv) Maybe, even catastrophic volcanic explosions can sometime produce effects like a strong earthquake, although this kind of effects was only seldom considered and reported (see below for discussion on this point). This is, maybe, another occasional driver.

(v) In addition, the computation of the geometrical figure of the *IC* ought to be considered, as extensively discussed above. This is possibly related to the aforementioned strong earthquake related effect.

The atmospheric and oceanic circulation patterns involve a planetary-scale effect. The time resolution of these models can be, say, at most up to $\sim 1\,day$. The database relies on the entire set of observations available either by ground-based observatories, or by satellite remote sensing. The signal-to- noise ratio depends on the accuracy of the present model skill. In this same respect, consider several other effects that can be recognized by space geodesy methods mentioned below.

In principle, also a much better time resolution can be attained, but a substantial achievement is likely to require a much longer database than the presently available series.

The Foucault current effect can be measured by a combined information provided by standard geomagnetic observatories and by a planetary network of submarine communication cables (Lanzerotti and Gregori, 1986). The time resolution can be very high, as it is the same time resolution of data acquisition either of geomagnetic observatories or of the induced e.m. potential in transoceanic communication cables. The space resolution is determined by the spatial span of cables. Violent induction effects occur inside cables laid across some longitudinal sectors of the Earth, while, simultaneously, other cables can be even almost undisturbed.[29]

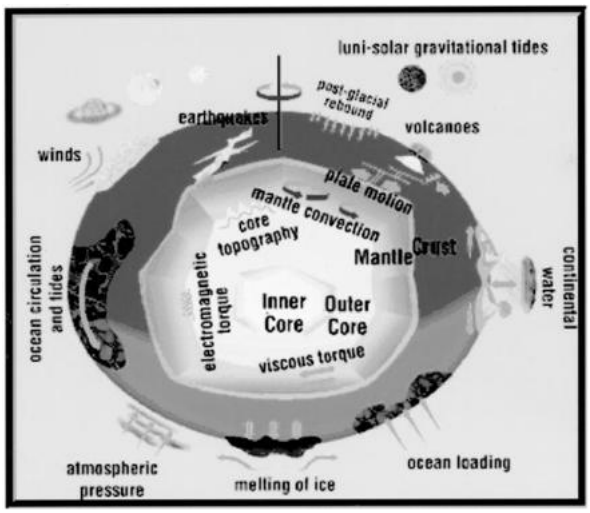

Fig. 27 - *"Geophysical fluid processes that involve large-scale mass transports and produce variations in Earth's rotation, gravity field, and geocenter*." Figure and captions after Chao et al. (2000). *AGU* copyright free policy.

As far as the effects are concerned that deal with the aforementioned perturbation on *l.o.d.* and pole motion, the primary observations directly deal with monitoring the astronomical motion of the Earth. This can be measured either by astrometric methods (star position observation), or by *VLBI* (very long baseline interferometry), or by *LLR* techniques, or more recently by gravity or by space geodesy techniques (*CGPS, SG, AG networks, InSAR,* etc.).

At present, space geodesy techniques are rapidly improving. In principle, it is possible to improve the former time resolution of $1\,day$ and to provide data with a much higher detail both in time and space.

In principle, mostly the Sagnac effect (Gregori et al. 2025w and Gregori and Gregori, 2025), and the Josephson effect can provide with an instrument that can measure locally - and on an instant basis – the time variation of the astronomical motion. These records can be very useful in order to infer the role of the torques applied to different parts of the Earth's crust, as a possible trigger for seismic activity, etc. The operative difficulty, however, is at present concerned with the practical feasibility of a suitable array, due to cost and operation of instruments.

All these kinds of information can also result very useful for correlation analysis with crustal stress monitored by *AE* techniques (see Gregori et al., 2026a and references therein).

A new possibility is represented by the *GPS* facility (Phillips, 2010). In fact, the phase and timing of the signals emitted by satellites posed on Earth's orbit provide with a monitoring, at high resolution, of the Earth's spin rate and pole motion. This monitoring tool is presently in operation.

[29] Refer e.g. to the famous communication blackout that occurred on February 11, 1958 during a violent solar storm. Communications across the Atlantic Ocean were impossible while the communication cable from California to Hawai'i was almost undisturbed.

Other possible changes of the astronomical motion of the Earth - which, however, seemingly were never measured - can be concerned either *(i)* with a shift of the Earth's axis (i.e. a displacement of the barycenter of the Earth), or *(ii)* with a variation of the orbital motion of the Earth around the Sun.

A shift of the Earth's spin axis can occur due a significant mass displacement inside the Earth's body, by which the location of the Earth's barycenter - e.g. with respect to an antenna located at Earth's surface that receives a signal from an interplanetary probe - results to be seemingly changed. This possibility is mentioned by Phillips (2010). He quotes Richard S. Gross (from *JPL*) who claims that in 2004 he looked for this effect related to the $M_w = 9.3$ Sumatra-Andaman December 26, 2004, earthquake, which caused the famous tsunami. However, he failed to detect any signal. Maybe, as he claims, the great $M \sim 8.8$ Maule earthquake (Chile), February 27, 2010, might have produced a bigger shift.[30]

No mass displacement inside the Earth's body can cause any time variation of the orbital motion of the Earth around the Sun, as the orbital motion of the Earth refers to its entire body as a whole, independent of the location of the Earth's barycenter.

In contrast, in principle, the electric currents induced by the interaction with the solar wind must originate, on the planet Earth, both *(i)* a total torque (thus affecting *l.o.d.* and pole motion) and *(ii)* a total force, which can change the orbital motion of the Earth. In principle, the total force can be measured - similarly to the total torque - by means of a planetary network of submarine communication cables, altogether with the records available from the planetary array of geomagnetic observatories (see Lanzerotti and Gregori, 1986 and some aforementioned mentions concerning the Foucault currents).

In any case, a great amount of investigation is still needed in order to improve our knowledge and monitoring of the different facets of the astronomical motion of the Earth. As already mentioned, arrays of *AE* stations can provide an instant measurement of the crustal stress on a local basis. This information can be very useful in order to infer, in real time, the stress propagation through the crust, and to investigate its correlation with the observed changes of the astronomical motion of the Earth - in addition to provide an essential and extremely valuable information on earthquake precursors and possible "prediction" (see Gregori et al., 2018).

A model of the gravity field, evaluated by space geodesy techniques, can require, perhaps, at least a few days of records, depending on the number of available satellites in Earth's orbit. Hence, the correlation with the geomagnetic *SV* can be carried out on the planetary scale, and with a time resolution of at most a few days.

Soil exhalation records, and the geochemistry of (either hot or cold) springs, are a significant recorder of the changes of underground fluid flow. These kinds of phenomena are well-known to be earthquake precursors. Their information, however, is occasional, as they depend on the location either of the spring or of the exhalation of endogenous fluids. In addition, the information is perturbed by unknown accidental perturbations. Hence, this information looks scattered with poor signal-to-noise ratio (refer to the case histories of Stromboli (Paparo et al., 2004, 2004a) or of Bagno di Romagna (Paparo et al., 2006). The response - to crustal stress variation - of fluid flow can be rapid, due to the large mobility of fluids underground, but it can be also delayed - maybe even by a matter of days – depending on some unpredictable behavior of underground structures.

Geomagnetic records are certainly valuable. However, according to the rationale, which is here outlined, specific reference is to be made to the geomagnetic *SV* and more specifically both to its *WD* and to its latitudinal drift. However, these features ought to be estimated - maybe - even a few times every day (in this respect see the aforementioned details about the beat effect of the *SV*). At present the time resolution is $1\,year$. Their spatial resolution depends on the density of simultaneously operated recording stations.

To our knowledge, the latitudinal drift of the *SV* was only very seldom investigated. However, the typical latitudinal rotation speed - which is implied by a geomagnetic excursion or by a *FR* (field reversal) - is of the order of $\sim 1/5$ of the typical longitudinal *WD*. As shown above, if it is possible to monitor this seemingly lesser effect, it can be important to infer the presumable behavior of the *magpol IC*, while it flips during a time lag of, say, $\sim 5{,}000\,years$ event (or $\sim 1{,}000 - 10{,}000\,years$) thus leading either to an excursion or to a *FR* (see above).

Unprecedented evidence deals with intense electric air-earth currents. The former original reasonable working hypothesis made by Gauss was the assumption of a negligible mean effect of air-earth currents, thus allowing for the classical separation of the geomagnetic potential of internal and of external origin. Two very recent facts, however, gave different evidence. A long series of papers was recently published on devoted issues of *NCGT*. The reader ought to refer to the different facets of this crucial phenomenon. A study in preparation deals with the role of air-earth currents in the variation of atmospheric density and composition of the palæo-atmosphere of the Earth.

In summary, several findings open an unprecedented scenario in the e.m. interaction between solar wind and Earth's interior, with consequent possible relevant effects on the astronomical motion of the Earth. Therefore, there is need to implement new monitoring and modeling techniques, relying on an unprecedented viewpoint. Some hard thinking is requested.

[30]This technique - i.e. relying on the anomaly of observed orbits compared to the *a priori* computed orbits - reminds about the well-known debated problem of the so-called *Pioneer* anomaly (see Gregori, 2010 and references therein), although these two case histories refer to different items and perspective.

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High-precision gravimetry and AE *arrays*

A special mention is deserved for a comparatively recent and important achievement,[31] i.e. *(i)* data series of high precision gravimetric records, monitored by networks either of superconducting gravimeters (*SG*), and/or of absolute gravity (*AG*) monitoring, combined with *GRACE* and/or *InSAR* measurements.

No review is here given of this important branch of investigation. Reference is made to the very authoritative account given by Van Camp et al. (2017, 2017a) who report about the $22\ year$ records at the Membach geophysical station in Belgium. A few excerpts are here reported.

"... a silver-colored sphere of Nb *metal [weight* $\sim 4\ g$*] floats in a vacuum that is only slightly warmer than the temperature in outer space, suspended by a magnetic field that exactly balances the force of Earth's gravity. Small fluctuations in the gravitational field pull and tug on the sphere, shifting its position ever so slightly, perturbing the magnetic field and sending electrical signals to nearby sensors ... This has been going on for the past* $22\ years$*... it's also the longest levitation of a superconducting mass. ...For more than 2 decades, the* SG *in Belgium has faithfully recorded mass shifts caused by groundwater movements, the weight of storm surge water on the surface, and other phenomena that affect the nearby gravitational field (Van Camp et al., 2017, 2017a)...*

... On average, one absolute gravity measurement is performed every month... Absolute gravity is measured by repeatedly dropping a test mass inside a vacuum chamber and tracking its free fall using a laser interferometer... These numerous absolute data points, combined with data from the SG*, enabled the study of the uncertainties associated with the setup of an absolute gravimeter (*AG*) (Van Camp et al., 2005)...*

Long-term fluctuations in gravity records remain poorly understood (Fig. 28) despite their importance for geodesists. Long-period gravity changes are most likely induced by climatic or hydrogeological variations. Membach was one of the first SG *sites where a comprehensive hydrogeological investigation could clearly show and quantify the influence of changes in groundwater within the unsaturated zone (Van Camp and Francis, 2006). The effect is about* $50\ nm1\ sec^{-2}$ *(*$5 \times 10^{-9}\ g$*) over the course of a year.*

... The Membach SG *is also able to measure the diurnal evapotranspiration from the deciduous forest above the station: Van Camp et al. (2016) identified average daily changes in gravity* $< 1\ nm1\ sec^{-2}$ *(*$10^{-10}\ g$*), equivalent to a depletion of* $1.7\ mm$ *of water per sunny summer day, which is at the limit of the resolution of terrestrial gravity measurements in the time domain.*

On the large end of the scale, after a large earthquake, seismic waves interfere and cause Earth to ring like a bell at frequencies between $0.3 - 20\ mHz$*. The spectra of Earth's bell-like normal vibrational modes provide valuable information on the structure of the planet ... . (Van Camp, 1999)...*

Storm surges in the North Sea also affect local gravity by loading Earth's crust, depressing it as much as a few centimeters along the coastlines. Instruments at the Membach station, $200\ km$ *away from the coast, successfully measured an increase in gravity of about* $20\ nm\ sec^{-2}$ *associated with one such storm (Fratepietro et al., 2006).... (see also Lecocq et al., 2017)."*

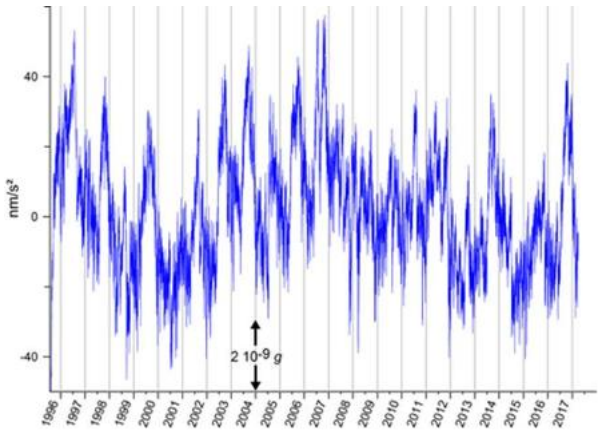

Fig. 28. "*This* $22\ year$ *time series shows gravity changes monitored by* SG C021*, after correcting for instrumental drift, tidal, polar, and atmospheric effects. What remains is essentially due to hydrogeological effects. For example, during the summer, gravity increases because there is less groundwater above the instrument. The long-term variations remain poorly understood*." Figure and captions after Van Camp et al. (2017, 2017a). *AGU* copyright free policy.

For clarity purposes, while dealing with these difficult investigations, the items here of concern can be better focused by referring to one specific case history borrowed after Zerbini et al. (2007). It refers to measurements carried out from the beginning of 1998 through the end of 2004, at Medicina, located east of Bologna (Italy). The result of their analysis can be commented as follows, by synthesizing the description given by the authors. [32]

They used continuous *SG* data. The instrumental linear drift was estimated by comparison with a series of *AG* observations carried out by different instruments (Niebauer et al., 1995). They assessed and selected the gravitational effects due to the Earth's and ocean's tides, from tidal periods up to the solar semiannual constituent (call it *SA*). "*The* $18.6\ year$ *tide, the effects introduced by polar motion, and the annual tide* SA *constituent have been scaled by* 1.16 *to take into account the elastic behavior of the Earth. All these tidal and long-term effects have been removed*."

[31] I am particularly grateful to the late Prof. Iginio Marson for calling my attention on these comparatively important recent developments.

[32] Owing to brevity purpose, no previous reference is here mentioned. The interested reader ought to refer to the references quoted in Zerbini et al. (2007). Susanna Zerbini (1948.) is an Italian geophysicist, geodesist, and geodynamicist, a pioneer in developing and applying satellite geodesy for research in geodynamics and Earth system sciences. GPG is indebted to her for several comments and discussions.

They removed local air-pressure variations ($-0.3\, mGal\, hPa^{-1}$) and the vertical air mass effect (Simon, 2003) that estimated by means of the $12\, hour$ radiosonde data regularly acquired close to Medicina. They detected the seasonal oscillations and, concerning the *GPS* analysis, they modeled the observed seasonal gravity oscillations. In the case of gravity, however, they had to consider a geometrical component (the height variations), the Newtonian attraction, and a change in gravitational potential

"*The gravity variations due to nontidal oceanic effects were estimated by convolving the* $12-hourly$ ECCO *ocean bottom pressure data with Farrell's (1972) Green's functions." ECCO* is the acronym for *Estimating the Circulation and Climate of the Ocean*. It was established in 1998 as part of the *World Ocean Circulation Experiment* (*WOCE*). The purpose was to combine a *general circulation model* (*GCM*) with other observations. It specifies *ocean bottom pressure* (*OBP*), as estimated by the *ECCO Project*. *OBP* is the sum of the mass of the atmosphere and ocean in a "cylinder" above seafloor. *WOCE* data show the state of the oceans during the 1990s, used as baseline for changes observed

We do not give details. The ocean is warming, and it has been estimated that it represents up 93% of the excess heat in the entire Earth system, even though this energy balance ought to be related to a more general perspective (Gregori and Leybourne, 2021; Gregori et al., 2026a). The 93% estimate is claimed to be composed for more than 30% by the abyssal ocean below $700\, m$ and for 16% in the ocean below $2000\, m$, and warming is claimed to beconcentrated in the Southern Ocean. Thse data are inconsisten with the increase of endogenous heat flow, which is mainly concentrated at the vertices of the tetrahedrom, and along the *MOR* network (Gregori and Leybourne, 2021).

GRACE measures gravity, and the *ECCO* model is conceived to keep an ocean of constant mass, which is inconsistent with the global water cycle, including serpentinization (Gregori and Hovland, 2025).

Zerbini et al. (2007) specify that this procedure accounts for the change in gravity due to surface displacement and Newtonian attraction. However, according to a previous investigation, their model resulted in underestimating observations by a factor two. Hence, Zerbini et al. (2007) empirically corrected their estimate by doubling their computed non-tidal effect.

Also soil consolidation effects were taken into account, and the thermal expansion of the geodetic monument and of the pillars of the *GPS* antenna that amounted to a $\sim 1\, mm$ seasonal variation (Romagnoli et al. 2003).

We point out that the result depends on a great skill in data handling, and on a clever subtraction of unwanted effects and perturbations. These corrections were often empirically determined in order to fit with other measurements.

As far as the present "strategy" is concerned, they found a linear trend of the background, although it is likely that its justification has to wait for a collection of a much longer database. Two possibilities are going to be here envisaged, either *(i)* a tectonic/geodynamic effect, or *(ii)* a dependence on the motion of the *IC*. Therefore, no criticism is made in the following discussion, rather the focus is on the possibility that, maybe, an eventual unwanted bias might affect the final plots. Zerbini et al. (2007) warn, however, about the limited number of measurements that are presently available. We also stress that every discrepancy can also derive, maybe, by one or a few additional effects associated to the explanation of the presently unexplained background trend.

In any case, we must emphasize the great skill, and multidisciplinary approach, of these lengthy and very accurate data handling and critical multi-technique analysis. In the final analysis, their present main concern is to afford to recognize and to subtract seasonal and tidal variations. This is very important for the assessment of error-bars in order to improve the quality of the evaluated long-range trend. This result ought then to be used to infer additional physical information about geodynamic or other deep Earth's effects, e.g. according to the strategy that is here tentatively outlined.

As long as no *SG* data series are available that span at least a few decades, it appears impossible to carry out any kind of more detailed and final analysis on their long-range trend and to assess a corresponding primary driver. At present, a strategy can be guessed, but precision requirements, and error-bars, are fundamental for the significance of every kind of future analysis.

The present network of *SG* stations is shown by Crossley and Hinderer (2008), although it is being rapidly updated. *AG* has a comparatively much denser network. Similarly to what happens with several other kinds of measurements, every continuous record (such as *SG*) has an instrumental drift that must be checked by absolute measurements in order to constrain error-bars.

As far as the long-range trend is concerned, the *AG* measurements are discontinuous in time, hence the temporal variations cannot be detected of comparatively high frequency. On the other hand, they are suited for long-range trend observations, and for getting a much denser spatial coverage of the array of measured sites.

Wilmes et al. (2009) show the present map of the *AGrav* station network, which is the international *AG* database implemented by *BGI* (*Bureau Gravimétrique International,* Toulouse) and *BKG* (*Bundesamt für Kartographie und Geodäsie*, Frankfurt a.M.) as a contribution to the *Global Geodynamics Project* (*GGP*), according to a former proposal by the *IGFS* (*International Gravity Field Service*) for the *GGOS* (*Global Geodetic Observing System*) initiative.

The methodological items are discussed by Crossley and Hinderer (2008, 2009) and by Wiese et al. (2009). The correction for hydrological effects is discussed by Longuevergne (2008). Rosat et al. (2009) show another case history, which refers to the Strasbourg *SG* station.

A Table, shown in a presentation by H. Virtanen, M. Bilker-Koivula, J. Màkinen, M. Nordman, and J. Virtanen, at the *DynaQlim/GGOS Workshop*, June 23-26, 2009, Espoo, Finland lists the different surface gravity effects. See also Virtanen (2006) and Virtanen et al. (2006).

Concerning the spatial variation of the observed effects when arrays of SG stations are considered, attempts are being made to interpolate over suitably corrected measurements. They envisage that large areas - of regional to almost continental size - eventually appear to move vertically up and down, almost like a membrane of a drum, held horizontally and stricken vertically.

Crossley et al. (2005) examine 4.5 $years$ (1997-2001) from *8 SG* stations and simulate the time variations that might be seen by a satellite. They correct the original signal by subtracting "*the solid Earth and ocean tides, a global atmospheric loading using a vertical perfect gas law ....*" They find a clear annual component "*that, if truly regional, should be easily detectable by a satellite such as* GRACE. *The signal is consistent with expected continental water storage*".

The regional - in any case sub-continental - scale of this (seemingly real) effect ought to be pointed out. On the one hand, the primary driver of every tidal effect is certainly associated with a much wider spatial scale. On the other hand, also smaller scale effects could be observed, which derive from indirect changes that are induced into the crust. These indirect effects ought therefore to result in tectonic features, crustal stress, geodynamic actions, etc.

Other effects of sub-continental scale could be associated with baric meteorological fields, etc., including, maybe, some indirectly related effects on ocean circulation, or on hydrology, on the time varying water table, etc. These effects, however, were already formally subtracted from some data series.

For instance, just as an example, Hickok (2018d) shows maps of California with a seasonal oscillation of $\pm 25\ mm$ amplitude and a steady linear subsidence of $100\ mm$ during 1995-2003. She refers to the study by Riel et al. (2018), who summarize their investigation.

Therefore, concerning the *SG* records, this very intriguing effect - "*if truly regional*" - envisages a concrete possibility of a relevant role played by regional tectonic effects. Crossley et al. (2005) emphasize that *GRACE* could monitor these effects.

We emphasize that also regional to continental *AE* arrays can provide a very important observational input dealing with crustal stress distribution and propagation. That is, an *AE* array that monitors this regional area can provide with a direct information to be correlated with the corrected *SG* data series.

Indeed, a similarity - with all these case histories of *SG* data series - seems to characterize the *HF AE* records. According to Poscolieri et al. (2006, 2006a) the guessed interpretation is by means of the rationale shown in the cartoon of Fig. 29, although they computed no related quantitative model.

If this phenomenon really derives from a westward propagation of crustal stress from the Eurasian eastern shelf to the Mediterranean area, a hypothetical *HF AE* station - located somewhere roughly at the middle of the Eurasian continent - ought to display a similar trend, although with a different phase. Note that the propagation speed of crustal stress can be measured by means of this additional *AE* station.

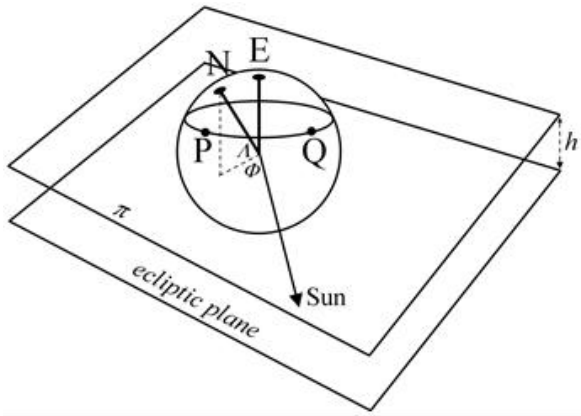

Fig. 29. Position and orientation of the Earth, and the mechanism of the loading tide. Consider two planes, i.e. the ecliptic plane, and the plane π parallel to it and located at a distance h. The sphere is the Earth's surface. The North Pole is denoted by N, and the perpendicular to the ecliptic plane crosses the Earth's surface at E. Two angles Λ and Φ denote the orientation of the Earth relative to the Sun and to the ecliptic plane. The point P is along the Eurasian coast, and the point Q is along the North American coast. It is supposed that the loading tide that pushes on the continental shelf at P is proportional to the linear extension of the arc PQ along the circle that is the intersection of with the Earth's surface. The total loading tide on Eurasia is an integral of this effect for every point along the Eurasian coast. The lunar effect is computed in a very similar way, where however the direction of the Sun must be substituted by the position of the Moon. The solar variation gives a seasonal oscillation; the lunar variation gives a $\sim 29\ days$ period oscillation. However, at some large distance along the Earth's surface, the shorter period oscillation is damped off due to the greater plastic behavior of the Earth's crust. In fact, the crust behaves like an elastic body in response to the seasonal variation. Hence, one should observe a seasonal variation of the stress propagating through the crust. After Poscolieri et al. (2006). *Natural Hazards and Earth System Sciences* is an "*Open Access*" journal. With kind *EGU* permission by CC BY 3.0 license.

For comparison purpose, consider that a seismic wave is a much more intense signal that propagates through the crust. A much weaker *AE* stress is a comparatively very different phenomenon. In fact, the *AE* signal, which is in the ultrasound band, cannot propagate through the crust.

Rather, it propagates through the serpentosphere, located just underneath the *ALB*, where a large fracturing occurs soaked with supercritical water (Gregori and Hovland, 2025). Then, the *AE* stress perturbation propagates locally from the serpentosphere through the overlying crust, and it affects the solid compact components of the crust. That is, these compact components are "*natural probes*".

In addition, the signal propagation through the serpentosphere is likely to be associated also with preferential "*wave-guides*" identified with the morphological features that, according to plate tectonics, are considered a part of plate boundaries (see Gregori and Leybourne, 2021).

In any case, the propagation through the serpentosphere, and the propagation through the solid components of the crust, relies on different physical processes. The stress propagation through the solid components of the crust ought to occur according to the "*domino effect*" at $\sim 10\ cm\ sec^{-1}$ (Gregori, 2013a). In contrast, the propagation through the serpentosphere occurs by a substantially different mechanism. Hence, in principle, also a substantially different speed can be observed.

On the other hand, the inference from *AE* records (Poscolieri et al., 2006, 2006a) is concerned with continental-size propagation. Hence, it seems that also the propagation speed through the serpentosphere ought to be comparable to the "*domino effect*" propagation speed through a solid structure. In fact, the "*domino effect*" is computed by means of long-distance propagation inside the serpentosphere. (Gregori, 2013a).

The seasonal *AE* trend is clearly shown in figure 30, which displays the cumulative *HF AE* records collected at the Raponi site[33] during 2002-2009. The maximum occurs approximately close to the middle of August.

That is, no simple agreement is found concerning the time of the year when a relative maximum is observed in the *SG* figures with figure 30. In general, it seems therefore that this disagreement between different case histories can be understood only by means of simultaneous operation of *AE* stations, suitably located in order to take into account the tectonic features that are typical of different sites.

Note that the large oscillation observed in figure 30 around the long-range seasonal trend is suggestive of a lunar modulation, associated to the time variation during the year of the lunar tide.

The argument is that the Moon is the main trigger. It has a very complicated orbit that lies in a plane that is inclined by $\sim 5°\,9'$ with respect to the ecliptic - i.e. it almost coincides with the ecliptic plane. In contrast, the spin axis of the Earth is defined by a latitudinal angle (with respect to Sun's direction) $\Lambda \sim 90° - 23°\,27'$, and by a longitudinal angle Φ, which expresses the position of the Sun along the ecliptic, i.e. it is associated with the Zodiac sign of the date (Fig. 29). In addition, the Moon orbit has the well-known Meton cycle of $\sim 18.6\ years$.

The concern is about the interference between the prevailing lunar tide ($\sim 5/6$ of the total tidal effect on the Earth) and the solar tide ($\sim 1/6$). Consider first the epoch at which the Moon has the identical Φ as the Sun. In this way, the solar and lunar oscillations must start with no phase shift. Their phase shift, however, will be subsequently accumulated in time, until the time instant when this condition is attained anew, after the minimum multiple of Metonic periods that gives an integer number of years, i.e. after $\sim 18.6 \times 5 = 93\ years$.

Independent of this interference with the solar tide, the Moon determines a temporal variation of $\sim 29\ d\ 12\ h\ 44\ min\ 3\ sec$, which is the mean lunar month. This ought to be the cause of the large oscillation in Fig. 30 of the *HF AE* signal around the long-range seasonal trend, which displays a seemingly peak-to-peak distance of this same average amount.

The Metonic period and the geocentric distance of the Moon control the intensity of the tidal action. In fact, as mentioned above, the inclination of the lunar orbit with respect to the ecliptic plane is $\sim 5°\,9' \sim 5°$ Hence, upon considering the $\sim 23.5°$ inclination of the Earth's spin axis, every day the Moon declination (i.e. latitude with respect to the Earth's equator) oscillates between a given angle varying with the date. The maximum $\sim 28.5°$ (called major lunar standstill) is found, e.g., in 2006 and 2025, the minimum $\sim 18.5°$ (called minor lunar standstill) e.g., in 2015, with a modulation according to the Metonic cycle.

The geocentric distance of the Moon controls the gravitational tidal effect. The sum of the two effects can determine emergency conditions due to exceptionally high tides, such as in 2015 it occurred on both sides of the Atlantic (*Anonymous*, 2015o). This means that this modulation is also very relevant for the loading tide, which is primarily caused by the tidal action on ocean water.

Therefore, it is reasonable to expect that the large oscillation in Fig. 30 ought to reflect these peculiarities of the Moon's orbit. Note that, if this is confirmed, *HF AE* monitoring is a tool of a unique paramount importance suited to monitor in real time the planetary effects of Earth's tides on crustal stress generation and propagation.

A map of rock stresses in main mining regions of former Soviet Union, according to measurements on sites, is shown by Kozyrev and Savchenko (2009). They found that the sub horizontal tectonic stresses exceeded the lithostatic stresses. This appears consistent with the guess here envisaged of a primary stress field associated with the westward push by the loading tide of Pacific Ocean waters.

The general pattern of the Kozyrev and Savchenko (2009) map appears consistent with a supposedly westward push, superposed over the northern stress applied by India and by Arabia, which involves an additional mainly northward stress field until the Caucasus according to *WMT*. Also, the three observed vertical stress case histories are to be pointed out, denoting an ongoing orogenetic process.

As already mentioned, the final check of the reliability of the explanation proposed by Poscolieri et al. (2006, 2006a) could be attained by installing an *HF AE* station somewhere in middle Eurasia, where the yearly and seasonal variation of the tidal pull ought to be readily recorded. By this the real propagation speed, more precise than $\sim 10\ cm\ sec^{-1}$, could be measured.

[33] Raponi site is here used to denote a location at Orchi on the outskirts of Foligno (Perugia, central Italy), "Orchi" means "ogres", and the local inhabitants frequently listen acoustic noise originated underground. The cooperation is warmly stressed and gratefully acknowledged of the family Raponi who generously hosted the experiment. Umberto Raponi (1934-2021) has been a renown painter, together with his living wife Luciana Bartella.

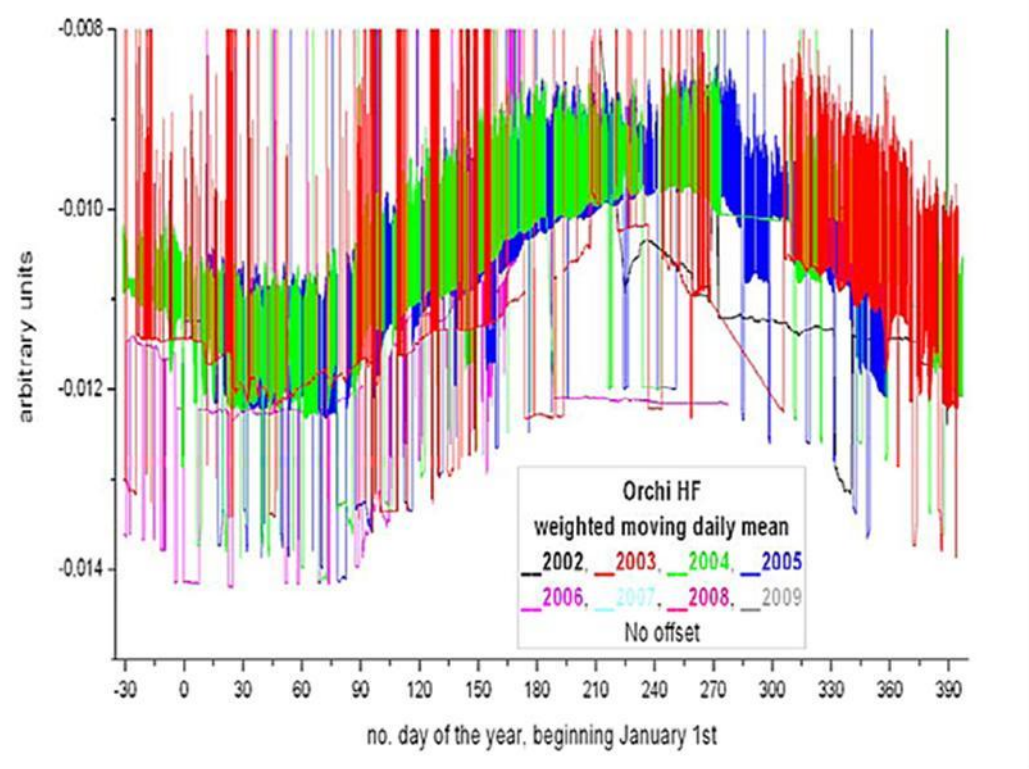

Fig. 30. *HF AE* raw signal at Orchi, superposing several years, every string beginning by its respective 1st January. The seasonal variation is clearly shown being the likely consequence of the loading tide. In addition, the figure gives clear evidence of discontinuities called *MFE*s (minor fracture events). After Gregori et al. (2010). *Natural Hazards and Earth System Sciences* is an "*Open Access*" journal. With kind *EGU* permission by CC BY 3.0 license.

The *SG* data series monitors the mass displacement of solid and/or fluid matter, which composes the Earth system. In contrast, *AE* monitor crustal stress propagation, which is an indirect consequence of mass displacement. In addition, the *AE* data series - unlike the *SG* records (see however below) - are severely perturbed by local tectonic settings and by spacetime changes of geodynamic actions exerted by the lithospheric environment. This tectonic disturbance is more pronounced on *LF AE*, which shows no clear and similar seasonal modulation.

The role of tectonic setting and of geodynamic actions is also confirmed by the fact that *LF AE* do not show synchronism, while *HF AE* sometimes show synchronism at two different sites, sometimes they do not. This is shown by Figs 31 and 32. Raponi site and Kefallinìa Island display synchronism in 2004, while in 2003 some tectonic perturbation happened, likely involving the Kefallinia Island, which is well-known to be a seismically very active area, as it is at the cross point of three active faults.

In any case, this morphological similarity of the *SG* and *AE* data series is suggestive of the potentiality of a comparison of *AE* records collected - simultaneously with the measurements of the *SG* network, plus *AG* – in an *AE* array that should monitor a large region of sub-continental or continental size: gravity measurements monitor mass displacement, while *AE* monitor crustal stress. Also, *InSAR* and/or *GRACE* records can effectively complement the aforementioned entire physical interpretation.

The crucial role of crustal stress was explicitly stressed by Zerbini et al. (2001, 2002) while comparing *GPS* and *SG* records collected at Medicina during 4 $years$ beginning in Jul 1996. The observed seasonal *SG* variation was typically in the $\sim 1.5 - 3\ \mu Gal$ range, while all environmental corrections summed up altogether to an effect with an amplitude in the order of $\sim 1\ \mu Gal$.

The two data series appeared correlated, except a sudden gravity increase of the order of $\sim 3\ \mu Gal$ occurred in July-September 1997. Zerbini et al. (2002) state that "*this has been attributed to mass/density increase associated with uprising of deep-seated salty (connate) waters, likely triggered by local stress field changes.*" Zerbini et al. (2001) also stress that "*during the second half of 1997, concurrent seismic activity occurred both in the southern Po valley and in central Italy (Umbria seismic crisis)*."

Let us stress that, as mentioned above, during the period 1998-2004, Zerbini et al. (2007) observed no similar abrupt step-like change of gravity. That is, this phenomenon is likely to be associated with a paroxysm of crustal stress, to be eventually associated with seismic activity. The concern, however, is not only about time, but also about the spatial extension of tectonic phenomena, and about their temporal evolution. These phenomena can be more easily investigated by means of *AE* arrays (see below).

Zerbini et al. (2002) carried out a specific detailed analysis of this July- September 1997 anomalous event. They considered measurements of electrical conductivity σ carried out in the piezometric well at Medicina. Anomalous values ($\sigma \sim 4{,}000\ \mu S\ cm^{-1}$) were measured already at $\sim 3\ m$ depth below the topographic surface, suggesting the occurrence of a mixing between fresh shallow waters and brackish deep-seated waters. "*... The depth at which the boundary between fresh waters and brackish salty waters lies in this area is* $\sim 450\ m$. *Anomalous values of* σ. *are known to occur in the area.*".

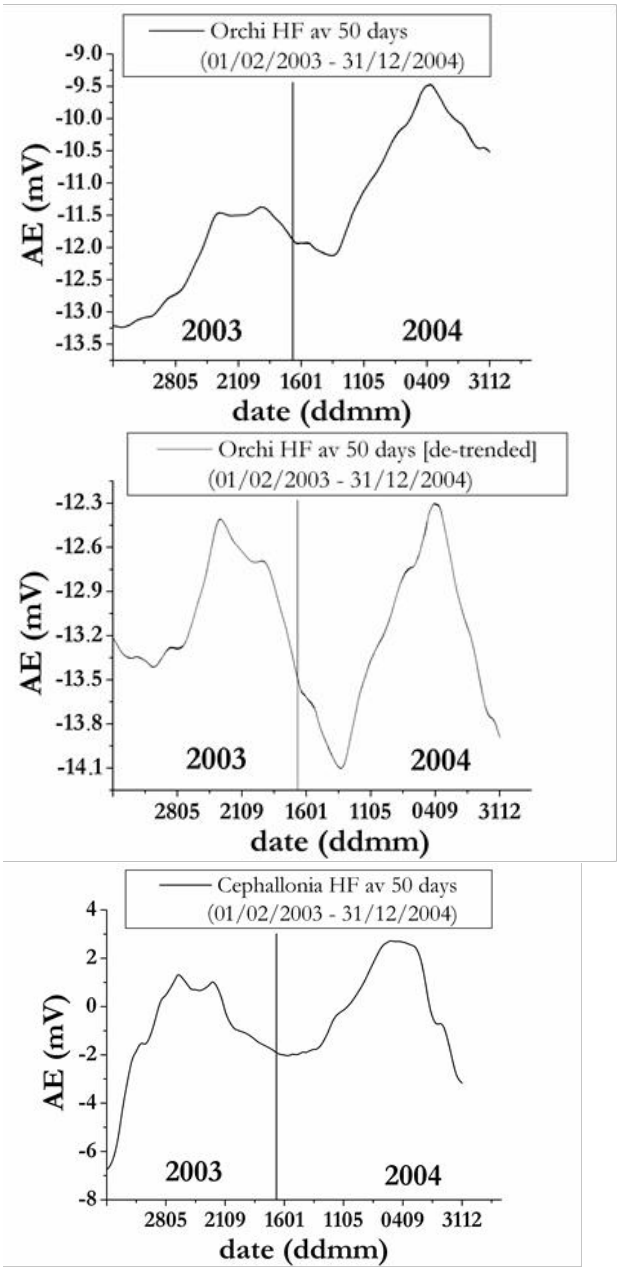

Fig. 31. *(a)* Moving average, weighted by a triangular weight, over 50 $days$, for the *HF AE* records at the Raponi site. The acronym "*ddmm*" denotes, respectively, day and month of that year. *(b)* The same as figure *(a),* after applying a linear de-trending; *(c)* The same as figure *(a)* but applied to the data series referring to Kefallinìa Island. After Poscolieri et al. (2006). *Natural Hazards and Earth System Sciences* is an "*Open Access*" journal. With kind *EGU* permission by CC BY 3.0 license.

After carrying out some modelling they stress "… *the importance of collecting continuous high accuracy, multi-parameter data series for an appropriate interpretation of signals related to environmental variability"*. AE records and continuous monitoring seem to be excellent additional parameters for the interpretation of these tiny though crucial environmental effects.

Crustal deformation and ground displacement can be effectively monitored by two other techniques.

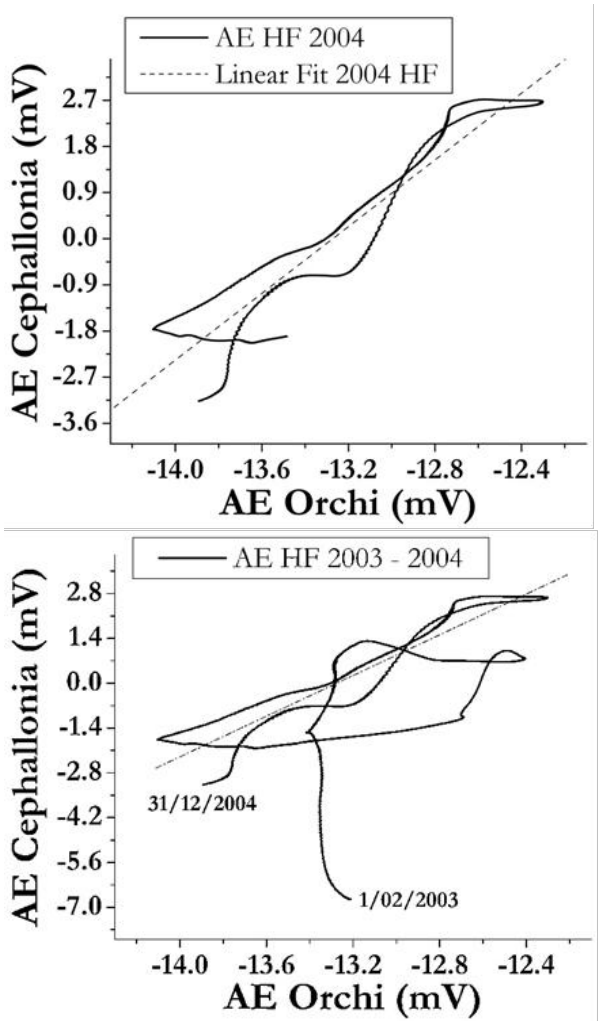

Fig. 32. The data plotted in Fig. 31 are used for drawing the Lissajous figure for 2004 in figure *(a)*, with de-trended data of Raponi site on abscissæ, Kefallinìa Island on ordinates. The same for 2003-2004 is shown in figure *(b).* The almost perfect synchronism is observed in 2004, not in 2003. See text. After Poscolieri et al. (2006). *Natural Hazards and Earth System Sciences* is an "*Open Access*" journal. With kind EGU permission by CC BY 3.0 license.

GPS arrays are an increasingly applied tool. However, they are suited to monitor real time ground displacement, and up to some more limited extent also ground deformation.

Other well-known techniques rely on satellite-borne remote sensing devices. Mostly, the *InSAR* technique is frequently reported concerning observations of ground deformation associated with some earthquakes, or dealing with some volcanic edifice. Compared to *GPS* monitoring, this technique seems more sensible. There is no need to review the several papers dealing with this approach. See, e.g., Furuya et al. (2010).

Satellite methods, however, have the drawback of a limited time resolution, as the available monitoring of a given area is discontinuous in time and/or in space coverage. In addition, some techniques (such as *InSAR*) need to compare observations of the same area carried out at different instants of time that differ by a small-time lag etc. Sometimes the use of an expensive cluster of identical

satellites is available, and - in some way - it is thus possible to mitigate this drawback.

Some examples of satellite monitoring are shown in a series of several figures by Tronin (2010). Consider, however, that several case histories considered by these figures refer to the occurrence of strong earthquakes, although the same techniques can be applied also to monitor smooth phenomena. The sensitivity and spacetime resolution, however, must be ascertained. In this respect, *SG* appears effective as it provides a high-precision and high-time-resolution monitoring of ground deformation, even although, owing to high cost, a comparatively sparse array of *SG* stations is available.

AE monitoring stations are certainly much cheaper. Thus, dense arrays can be implemented, at least over land, while submarine *AE* stations require some additional care. On the one hand, water is an excellent conductor for *AE*, and this makes it easier to carry out *AE* monitoring. On the other hand, environmental disturbances could be, perhaps, amplified, and the signal-to-noise ratio could eventually result worsened. Hard thinking is required.

Earth's tides, variation of l.o.d.*, earthquakes, volcanism*

An indication - of the uncertainty that characterizes the present understanding of these phenomena - is represented by the controversial evidence pro or con the correlation between solid Earth's tides *vs.* earthquakes (or volcanism).

We just remind about the *4*-level approach to earthquake precursors and "forecast", extensively discussed by Gregori et al. (2018), including specific examples and references that illustrate the practically efficiency of this approach.

Level 1 monitors planetary scale irregularities inside some large areas (see e.g. Parrot, 2025 and references therein, but a huge number of investigations is presently reported in the literature).

Level 2 is to monitor crystal stress propagation by continental arrays of *AE* recorder aimed to monitor "*crustal storms*" that cross through a given area.

Level 3 is to focus on some known active fault that can be the potential source of a forthcoming earthquake, and to put a local dense array of *AE* recorders. The purpose is to monitor the occurrence and evolution of "*crustal substorms*"

Level 4 is to consider the local lunar time (*LLT*), i.e. time reckoned not to the Sun, but to the Moon. An earthquake – if it is going to occur – will always occur almost exactly at the local $06\ 00\ 00\ LLT$, or at the local $18\ 00\ 00\ LLT$, i.e. at these time instants the maximum of the local tidal deformation occurs.

This is not a "prediction", which is impossible, but this is a reliable objective forecast of the ongoing hazard.

Concerning the more general problem, a detailed discussion is not pertinent for the present study, and no specific items are here discussed.[34]

The evidence appears, however, somewhat controversial. In fact, all volcanoes cannot be likened to one another, depending on several physical factors, including the primary energy source and its intensity, the depth of the melting process, the thickness of the overlying lithosphere, the tectonic setting of the area, the regional faulting and its direction relative to the volcano, etc.

In addition, smooth phenomena - such as geothermal heat flow, or fumarolic activity - eventually correlate with the Earth's tides. In contrast, a volcanic eruption is a phenomenon that responds to a calorimetric accumulation of endogenous energy, which is eventually released, almost like from the security valve of a pressure cooker. However, the time resolution provided by such a "valve" has the order of magnitude of the time interval between two subsequent volcanic eruptions of a given volcano.

On the other hand, carry out an analysis by considering the hour of the day when the Earth tide has a given phase. Assume that, if a volcano is ready to erupt, the eruption ought preferentially to occur when the Earth tide has a suitable phase. Even in this case, the concern remains about whether such a tiny phenomenon as the Earth's tide can be eventually sufficient to overwhelm the leading role, and timing, of the major energy driver of an eruption.

In any case, every "blind" correlation analysis - which simply searches for a linear dependence of Earth's tides and the time instant of eruptions - is not expected to give unquestionable and clear evidence.

Concerning volcanic *vs*. seismic activity, Delle Donne et al. (2010) carried out an analysis from two *NASA* satellites. They scanned their available database and searched for every increase of volcanic heat, during 2000-2006. They investigated the resulting observed correlation and considered more than *40,000* earthquakes with a magnitude greater than 4.5. They found *37* instances of volcanic responses to regional earthquakes. "*Each response is expressed by an increase in heat flux within* $1-21\ days$ *of the triggering earthquake. Whether a volcano responds depends on earthquake magnitude, distance to the epicenter, and orientation of the earthquake focal mechanism in respect to the volcano: the focal mechanism has to align with the responding system. Of the* 7 *global major increases of seismic energy during 2000-2006,* 4 *were followed by a global volcanic heat flux increase. The largest response involved a* 300% *increase and followed the largest earthquake in the period, the 2004 Sumatra-Andaman (Indonesia) earthquake, moment magnitude,*

[34] As a sample reference-list see e.g. Knopoff (1964), Johnston and Mauk (1972), Hamilton (1973), Mauk and Johnston (1973), Dzurisin (1980), Talley (1980), Heaton (1982), Hartzell and Heaton (1989), Weems and Perry (1989), Bottari et al. (1992), Sun (1992), Gao Wei et al. (1996), Public Information Office UCLA (1998), Hinderer et al. (2002), Iwata and Katao (2002), Kasahara (2002), Tanaka et al. (2002), Tolstoy et al. (2002), Beeler and Lockner (2003), Biagi et al. (2003), Lin Cheng-Horng et al. (2003), Pesicek (2003), Cochran et al. (2004), Kennedy et al. (2004), Tanaka et al. (2004a), M´etivier et al. (2005), Venkatanathan et al. (2005), Gackstatter (2007), Belyakov et al. (2008), Gusev (2008), Rubinstein et al. (2008), Kasahara et al.(2009), Thomas (2009), Thomas et a l. (2009), Delle Donne et al. (2010), Tanaka (2010), …

$M_w = 9.3.$*"* However, only about one-third of volcanoes with increased activity were reacting to specific earthquakes.

As a general comment, two key items, however, have been seemingly "forgotten" by several authors who tackled this problem.

A *first* concern deals with the fact that the loading tide effect is a planetary scale phenomenon, which causes conspicuous stress through the planetary crust, although by different amounts at different times and locations, depending *(i)* on the morphology of the crust, *(ii)* on the distribution of continental *vs.* oceanic regions, *(iii)* on the thickness of crust and lithosphere, etc.

In addition, consider the role of the "*domino effect*" in the propagation of crustal stress on the planetary (Gregori, 2013a), or the stress propagation through the serpentosphere (Gregori and Hovland, 2025).

Speculating, as it has been generally made in the literature - that a local "crisis" or "paroxysm" of crustal stress is determined by the local tidal deformation alone of the crust - appears unrealistic, even naïve. An *AE* local instant monitoring of the time variation of the local stress and strain can give a realistic record of the state of external actions that are locally operative on the crust, and that are likely to be eventually associated - under suitable circumstances - to a possible trigger of either a seismic or a volcanic event.

The *second* concern is that a simple and straightforward two-variate linear correlation analysis can be misleading. In fact, a huge number of *d.o.f.*s characterize them. In contrast, several papers often appear to claim and believe, rather, that one simple linear correlation analysis ought to be capable to discriminate - with no possible doubt - about a reliable "proof" or "disproof" of the guessed control of Earth's tides on seismicity and/or volcanic activity.

In this same respect, the investigation by Sun (1992) appears noteworthy. It is focused on the statistical latitude dependence alone - i.e. integrating over longitude, hence achieving a planetary scale analysis - of global seismic-energy distribution. Two peaks are thus found, one in the Northern and one in the Southern Hemisphere, with axis of symmetry at $\sim 10°$ N. *"The two peaks for shallow earthquakes have an interval of* $90°$*, while those for intermediate and deep ones concentrate in low latitudes. The twin peak distribution in energy of intermediate and deep earthquakes becomes more apparent with increasing depth. Almost no energy is released in the North and South Pole areas. The energy released in the Northern Hemisphere is* $\sim 30\%$ *greater than that in the Southern Hemisphere, except for the focal depths from* 100 *to* $150\ km$*. Through a study of the shear stress component caused by the corresponding long-period lunisolar potential, it is found that the shear stress distribution due to lunisolar constant flattering wave* (M_0S_0) *coincides with some of the above phenomena."* Thus they "*conclude that the long-period tidal shear stress may be one of the possible causes for the seismic energy release; or a triggering effect.*"

This seems to be, indeed, a confirmation of the aforementioned loading tide effect. The prevailing effect in the Northern compared to the Southern Hemisphere can be explained by a different amount of crustal stress propagation, westward. This depends *(i)* on the different extension of continents, *(ii)* on the fact that the impact of the loading tide on Africa is reduced due to the hydrodynamic "screening" against ocean water flow – a real breakwater - represented by Australia, and *(iii)* mostly (and likely) by the fact that Africa seems to be the best "rooted" continent over its underlying mantle.

Sometimes this effect will be eventually measured. The present frontier is the detection of regular tidal deformations of the planet Earth, depending on season. For instance, Han (2016) reports about a skillful analysis resulting from a comparison between *GPS* and *GRACE* records. The maximum detected effect amounts to $\sim 1\ mm$.

"*As atmosphere, ocean, ice, and terrestrial water are redistributed, the center of mass (*CM*) of the Earth's system moves and the accompanying loading yields global surface deformation. In Australia, when* GPS *surface displacements were corrected for local mass change (hydrology, atmosphere, and ocean) with* GRACE *data, the residual* GPS *data reveal a peculiar seasonal mode of continental deformation.*

During the southern summer, the entire continent coherently shifts NW by $\sim 1\ mm$ *and the southeastern part is uplifted, while the northwestern part is subsided by* $\sim 12 - 3\ mm$ *and the opposite patterns of deformation are observed during the southern winter. Such characteristic deformation could be understood to be a result of the Earth's elastic response to globally averaged surface mass load, generally heavier in Europe during southern summer and in the South Pacific Ocean during southern winter.*

It was found that such deformation is even larger than local hydrology-induced loading effects in horizontal motion over Australia. A simple method of determining locations of the CM *was developed by combining* GPS *and* GRACE *data; the latter being insensitive to the* CM *motion but sufficiently accurate to remove the local hydrologic and atmospheric effects in* GPS *data. The* CM *signals are pronounced over systematic errors in* GPS *and* GRACE *data.*

The CM *coordinates estimated by inversion of the Australian* GPS *data set and* GRACE *agree with the geocenter motions determined by satellite tracking analysis. This study suggests an independent way of monitoring the* CM *motion entirely based on two distinct geodetic measurements of* GPS *and* GRACE*."*

In addition, the loading tide effect must progressively decrease until vanishing on the poles. A combination of this decreasing trend *vs.* latitude towards to poles, and of the distribution of continents in the two hemispheres, is thus responsible for the observed double peak feature. The different response when dealing with earthquakes having different hypocenter depth depends on the varying thickness of lithosphere and crust.

Consider also that, according to *WMT*, the huge megasyncline spanning from Gibraltar through Japan is located in the Northern Hemisphere, and it is certainly the site of a comparatively more intense seismic activity.

In addition, the correlation, as per the discussion above, of earthquake occurrence *vs.* abrupt variations of the *l.o.d.* or of pole position, could be interpreted as evidence of a local crustal paroxysm, which triggers a local catastrophe of the system (some references are given below). However, the catastrophe was formerly caused by a planetary scale phenomenon. This phenomenon can be associated with every possible cause, including either *(i)* a regular and steady effect such as the lunar and seasonal variation of the loading tide, or also *(ii)* an occasional and transient event, such as the torque originated by temporary Foucault currents.

A relevant drawback, however, is that a precise monitoring of the anomalies of the astronomical motion of the Earth became available only in comparatively recent times. In addition, time resolution is very important, in order to assess the timing of the sequence crustal paroxysm-earthquake-Earth's motion anomaly, in order to assess what comes first, what second, and what the cause and what the effect, or whether different phenomena share a common primary driver.

In summary, the key point is to assess whether *(i)* a crustal stress paroxysm on the planetary scale - which was determined by an abrupt variation of the astronomical motion of the Earth - was the cause of a local natural catastrophe, or rather *(ii)* the local natural catastrophe was the cause of the anomalous planetary behavior of the astronomical motion of the Earth.

This second possibility is discussed in detail below.

In any case, it seems crucial to monitor by *AE* arrays - operated on an instant basis, and with a high time resolution - the planetary synoptic distribution of crustal stress, and its time variation. This appears to be, maybe, the most straightforward and easiest way of obviating to the lack of a sufficient time resolution in monitoring the anomalies of the astronomical motion of the Earth. The purpose is to assess the instant of time, and how far, local crustal paroxysms are important as a trigger for natural catastrophes.

On the other hand, the present "generally agreed" model searches for effects associated to isostatic rebound after deglaciation, to convection in the mantle, and to climate variation (e.g. Adhikari et al. 2018). According to the general rationale of the present whole study, climate variation is one facet of the evolution of the whole Earth's system, although it is difficult to assess what is the cause, and what the effect (Gregori et al., 2025w; Gregori and Gregori, 2025). In contrast, the existence is contended of the other two effects.

In any case, all aforementioned investigations are generally concerned with comparatively short time lags, and with limited spatial ranges. The next concern is rather to be here devoted to the long-range trend of *SG* records.

Loading tide and Antarctica

One additional preliminary comment deals with a related phenomenon, concerned with the evidence of the loading tide on the coasts of Antarctica.

The Antarctic Circumpolar Current (*ACC*) flows eastward, due to strong westerlies. However, the tidal action, which is active on a much lower frequency compared to atmospheric circulation drivers, pulls westward the water masses.

This huge mass displacement finds no obstacle capable to represent a "dam" that opposes it, except the Antarctic Peninsula. Hence, the bulge of water, which is thus displaced by the tide, enters the Weddell Sea, where it generates a periodic tidal vertical oscillatory motion of $\sim 3\ m$ of the Ronne and Filchner ice shelves that float on it (Han et al., 2005). Fig. 33 shows the twice-daily lunar tide *(a),* and the solar tide *(b).* This effect also causes erosion and melting on the underside of the ice sheet.

Gravity changes and volcanic activity

For completeness's sake, we recall that temporal changes of gravity were also investigated, which are associated either to volcanic activity (e.g. Greco et al., 2008), or to large earthquakes (e.g. Imanishi et al., 2004, 2009; Xu et al., 2008; Tronin, 2010).

The crucial aspect, however, mostly deals with the skill in the subtraction of the indirect unwanted effects, which are strictly concerned with the tectonic phenomenon alone. This is shown in Fig. 34, dealing with the $M_w = 9.1$ Sumatra-Andaman December 26, 2004, earthquake, where the results are compared - of the *GRACE* monitoring before and after the event – with or without subtraction of non-tectonic effects. This achievement was possible due to the particular skill and know-how exploited for data handling.

Fig. 35 is a similar figure, including a comparison with the pattern that is found by an astute numerical model. Tronin (2010) comments that "*coseismic deformation produces sudden changes in the gravity field by vertical displacement of Earth's layered density structure and by changing the densities of the crust and mantle.* GRACE*'s sensitivity to the long spatial wavelength of gravity changes resulted in roughly equal contributions of vertical displacement and dilatation effects in the gravity measurements. The* GRACE *observations provide evidence of crustal dilatation resulting from an undersea earthquake.* GRACE *is more sensitive (*$\sim 50\%$ *signal retained) to the dilatation effect than to the vertical gravity change (*$a\ few\%$*) from the Sumatra earthquake co-seismic signals. The negative effect is due to density changes in the crust and the mantle, largely due to expansion of the crust*."

de Linage et al. (2009), with reference to Fig. 34, use the *PREM* Earth's model, and comment as follows. "... *a complete modeling of the elasto-gravitational response of a self-gravitating, spherically layered, elastic Earth model is carried out using a normal-modes summation for comparison with the observed coseismic gravitational change. Special attention is paid to the ocean mass redistribution. Special care is paid during the inversion of the data to avoid contamination of tectonic gravity changes by ocean tidal model errors, seasonal and interannual signals originating from continental hydrology and oceanic circulation as well as contamination of the coseismic gravity change by the postseismic relaxation. We use a* $4.6\ year$ *-long time-series of global gravity solutions including* $26\ months$ *of postseismic data …* "

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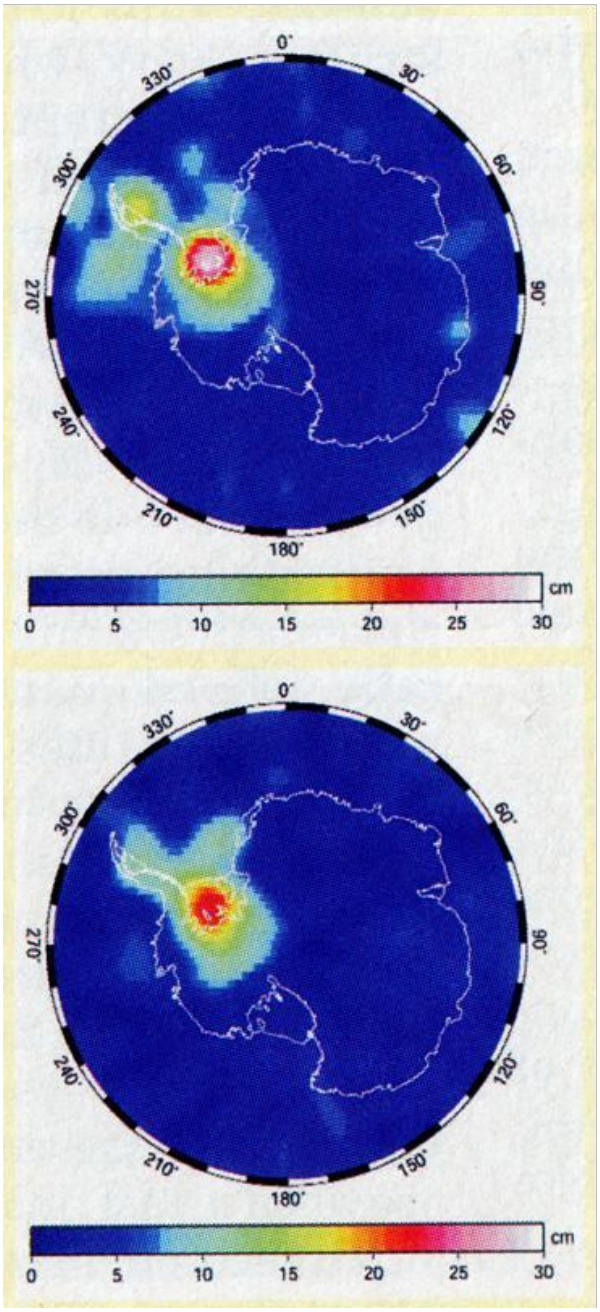

Fig. 33. "*The observations of ocean tides from* GRACE (a) *amplitudes of samples (aliased)* M_2 *and* (b) *those of* S_2 *tides ...* " Figure and captions after Han et al. (2005). *AGU* copyright free policy.

They compare different solutions, by considering different models derived from other complementary observations, and further comment that "*different gravity solutions are globally similar, although their spatial extent and amplitude depend on the type of filter used in the processing of* GRACE *fields ... The coseismic signature consists mainly of a strong gravity decrease east of the Sunda trench, in the Andaman Sea. A gravity increase is also detected at a smaller scale, west of the trench. ... Coseismic gravity changes are followed by a postseismic relaxation that are well fitted by an increasing exponential function with a mean relaxation time of* $0.7\ years$. *The total postseismic gravity change consists of a large-scale positive anomaly centered above the trench and extending over* $15°$ *of latitude along the subduction. After* $26\ months$, *the coseismic gravity decrease has been partly compensated by the postseismic relaxation, but a negative anomaly still remains south of Phuket. A dominant gravity increase extends over* $15°$ *of latitude west of the trench, being maximal south of the epicenter area. By investigating analyses of two global hydrology models and one ocean general circulation model, we show that our* GRACE *estimates of the coseismic and postseismic gravitational changes are almost not biased by interannual variations originating from continental hydrology and ocean circulation in the subduction area and in the central part of the Andaman Sea, while they are biased by several μGal in the Malay Peninsula.*"

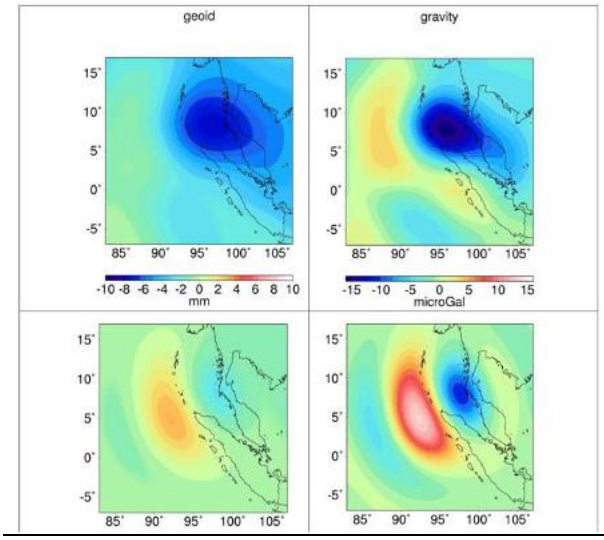

Fig. 34. Coseismic effect of the Sumatra-Andaman December 26, 2004, earthquake according to *GRACE* monitoring (top maps) and modeled (lower maps), expressed either like geoid height (left) and like gravity anomaly (right). After de Linage et al. (2009). With kind permission of *Geophysical Journal International.*

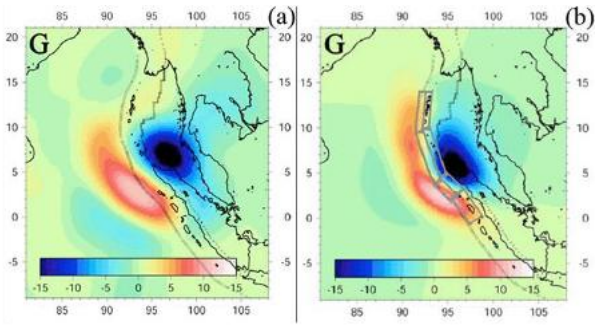

Fig. 35. "*Satellite data showing the gravity changes for the Sumatra earthquake (* $M = 9.0$ *, 26 December 2004, Indonesia).* (a) *A composite image from* GRACE *observed gravity change (* $\pm 15\ \mu gal$ *).* (b) *Seismic model predicted gravity change at* GRACE *resolution (Hashimoto et al., 2006).*" Figure and captions after Tronin (2010). *MDPI* journals and articles are licensed under "*Open Access*" CC BY 4.0.

The coseismic signature resulted in the order of $20\ \mu Gal$ peak-to-peak, displaying a negative anomaly of $-16\ \mu Gal$

in the Andaman Sea, and a positive anomaly of $+4\ \mu Gal$ west of the subduction region. The geoid anomaly results strongly negative, amounting up to $-8.0\ mm$ in the Andaman Sea, while west of the subduction region it is only slightly negative. They guess that the $0.5 - 0.7\ years$ relaxation time is likely to be associated with a viscous process.

Conclusion

According to the operative approach here highlighted, it is possible to measure and monitor - in principle even on an instant basis - the geometrical shape, size, orientation, kinetic energy and density of the *IC*. In addition, upon considering the time variation of these parameters, it is possible to monitor the dynamics of the *IC*, and its "*breathing*". Let us use this intuitive term "*breathing*" to denote the "*battery*" effect implied by transformation of *magpol* state of the *IC* into the "*metallic*" state of the *OC*, or viceversa.

This whole information ought to be derived first by consideration of extreme and sporadic occurrences of very strong earthquakes. It is unfortunate, however, that adequate precise measurements of the astronomical motion of the Earth are available only for very few recent case histories.

As a first observational fact we must clearly assess whether the anomaly of the astronomical motion of the Earth precedes or follows the time instant of the earthquake, as stressed) here above. Let us suppose that it is thus proven that the seismic shock precedes the anomaly in the astronomical motion.

If it is assessed that this hypothesis is incorrect, the cognitive approach must be different, because a driver applies a torque to the Earth, and generates crustal stress that eventually triggers an earthquake. This case history requires a different approach and viewpoint. In contrast, when this hypothesis is correct, the event is an important hunch for the investigation of the geometrical figure of the *IC*.

Additional constraints and inferences can be derived when dealing with the planetary scale - and also when considering the time range of the *SV* either of the geomagnetic field or of the gravity field models.

Over the time range of the last $\sim 6\ centuries$, two observational sources of information are:

(i) the *WD*) of the geomagnetic *SV* - which has been known since over *~4 centuries* although presently unexplained; and

(ii) the latitudinal drift of the same *SV* - which was only very seldom investigated, although it can be effectively monitored.

In addition, consider the possibility of carrying out an independent computation of the figure of the *IC* according to the rationale illustrated in previous sections.

The network of *SG* stations - but also the network of *AG* stations – could give a precise - both in space and time - monitoring, almost in real time, of some minor details of phenomena, while they are in progress, and that can be framed into the long-range trend inferred by the aforementioned observational database.

Compared to planetary scale phenomena to be possibly associated with *IC* effects, the separation of local or regional tectonic effects can be achieved by investigating the correlation between the observations carried out by *GRACE* and the records of an array of *HF AE* recorders (this array should be as dense as it ought to be required by the spatial resolution that one wants to achieve).

A reminder is also deserved about the possibility to compute, at an instant time resolution, the vector torque - and the total resultant force - applied to the planet Earth and originated by the e.m. induction by the solar wind. This computation can be carried out by means of ground based geomagnetic records measured in the international network of observatories, plus by monitoring the induced electric potentials inside a network of submarine communication cables.

This whole information can be relevant concerning the definition of a suitable reference frame for geodynamic processes, even though we cannot enter here in the discussion of this difficult and intricate problem.

As an additional comment consider that geomagnetic records, *AE* records, *SG* and *AG* measurements, and *GPS* monitoring, have a high spatial and temporal resolution, unlike the more conventional astrometric *l.o.d.* and pole motion measurements. However, in principle, Sagnac effect's and Josephson effect's recorders could be much more precise.

In addition, Table 3 - unlike the often-reported studies based on statistical correlations - deals with deterministic occurrences. When crustal stress propagation - including its trigger and origin, and the relation between different areas - will be clarified, it is possible that some catastrophic event can be forecasted or justified as a consequence of presently non-understood specific physical drivers. In this respect, the 4-level approach to seismicity seems particularly effective (Gregori et al., 2018).

This entire strategy is, however, only a possible, and maybe likely, future perspective of research, which requires a long time, both for implementing and operating the observational arrays, and for exploiting the algorithms needed for data handling, and error-bar optimization, etc.

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B. A. Leybourne is a semi-retired, self-funded independent researcher.

Author's Contributions

Conceptualization began with a proposal of G. P.

Gregori, who also exploited the physical data interpretation, and wrote the draft of the present paper. A. Incoronato has actively operated as referee for M. Marino, during the implementation of his thesis. M. Marino carried out an impressive amount of data handling and computations, which are the true heart of the present study, and - owing to this reason - he is warmly acknowledged as second author of the present paper. The deceased G. Paparo played a crucial role in the exploitation of the *AE* technique in cooperation with G.P. Gregori. M. Poscolieri gave an important contribution in the exploitation of the Kefallinìa experiment, in addition to several studies on *AE* precursors of earthquakes in the Italian peninsula. B. A. Leybourne contributed with discussion on several items concerning the overall approach to the whole perspective that is the backbone of the present study.

Ethics

No particular ethical issues are related to the paper.

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Acronyms

ACC - Antarctic Circumpolar Current
AE – acoustic emission
AG - absolute gravimeter or absolute gravity
AGU – American Geophysical Union
ALB – asthenosphere-lithosphere boundary
BGI - (Bureau Gravimétrique International, Toulouse
BKG - Bundesamt für Kartographie und Geodäsie, Frankfurt a.M.
CGPS - continuous GPS,
CM - center of mass of the Earth's system
CMB - core mantle boundary
CMT - Harvard centroid moment tensor
CNR – Consiglio Nazionale delle Ricerche
d.o.f. – degree of freedom
e.m. - electromagnetic
ECCO - Estimating the Circulation and Climate of the Ocean (project)
ED – Eastward Drift
EGF - empirical Green's functions
EGU – European Geophysical Union
FR -field reversal (geomagnetic)
GCM - General Circulation Model
GGFC - Global Geophysical Fluids Center (of *IERS*)
GGOS - Global Geodetic Observing System
GGP - Global Geodynamics Project
GPS - Global Positioning System
GRACE - Gravity Recovery and Climate Experiment, a twin satellites system of a joint mission of *NASA* and the *German Aerospace Center* (*DLR*).
HF AE – high-frequency AE
HWA - Hawai'i anomaly
IC – inner core
ICB – inner core boundary
IERS - International Earth Rotation and Reference Systems
IGFS - International Gravity Field Service
IIC - innermost inner core
InSAR - Interferometric Synthetic Aperture Radar, a satellite-based remote sensing technique
INTERMAGNET - International Real-time Magnetic Observatory Network
JPL – Jet Propulsion Laboratory
l.o.d. - length of the day
LASA - Large Aperture Seismographic Array

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LF AE – low frequency AE
LID - the outermost solid, cool silicate shell, equivalent to the lithosphere that overlies a supposedly convecting mantle
LLT - local lunar time
LN - Lowes-Nevanlinna's (law, or plot)
magpol - magnetic polarization (a state if matter)
MDPI - Multidisciplinary Digital Publishing Institute, publisher
MFE - minor fracture events
MHD – magneto-hydro-dynamics, either dynamo, or Larmor's dynamo, or Larmor-Elsasser-Bullard dynamo
MOR – mid- ocean ridge
NASA – National Aeronautics and Space Administration
NCGT – New Concepts in Global Tectonics
OBP - ocean bottom pressure
OC - outer core
OIC . outer inner core.
PREM - preliminary reference Earth model
SA - tidal solar semiannual constituent
SCL - sunspot cycle length
ScriW - supercritical water
SG - superconducting gravimeters
SHE – spherical harmonic expansion
SLR - satellite-laser ranging technique."
ss - spherical surface
ssc - sudden storm commencements
SV - secular variation (either geomagnetic or else)
TD- tide driven dynamo or geodynamo
TR - time-reversal (algorithm)
USNO – United States Naval Observatory
VLBI – very long baseline interferometry
WD - Westward Drift (of the geomagnetic field or else)
WDMAM - World Digital Magnetic Anomaly Map
WMT - warm mud tectonics
WOCE - World Ocean Circulation Experiment

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Could high- energy neutrinos trigger earthquakes? The case of deep and simultaneous earthquakes

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Abstract: There are earthquakes that occur almost simultaneously, almost always with the same magnitude, despite being several thousand kilometers apart in different geological settings. These earthquakes occur with time lags ranging from a few seconds to less than a minute apart. If we rule out coincidence or chance, it is necessary to investigate the possible triggering mechanisms, which are proposed in this study and are useful for formulating hypotheses. Candidates for this research are neutrinos, which are hypothesized to play a role in the energy balance of the lithosphere by interacting with electrons accumulated in areas subjected to tectonic stress. As is known, the interaction of neutrinos with electrons is a fundamental process in subnuclear physics mediated exclusively by the weak nuclear force. Since neutrinos are particles with no electrical charge, they do not interact through the electromagnetic force and are not subject to strong interactions. This study suggests a correlation between cosmic rays and earthquakes, as there is a clear relationship between the intensity of cosmic rays and the magnitude of earthquakes. Neutrinos and muons, created when cosmic rays enter the atmosphere, are believed to trigger earthquakes. The mechanism is as follows: electrons rise from the Earth's interior and accumulate in rocks. Rocks are dielectric and store large numbers of electrons. Cosmic rays scatter neutrinos and muons across the Earth's surface, and when these penetrate underground, they trigger electrical discharges. The intensity of cosmic rays expands the area irradiated by neutrinos and muons, and a larger discharge area translates into greater earthquake intensity.

Keywords: Olivine, neutrinos, electrons, cosmic rays, earthquakes

Introduction

The simultaneous occurrence of earthquakes on a global scale, with hypocenters sometimes deep, thousands of kilometers apart, in different geological settings, represents an ongoing challenge for geologists and geophysicists and a question to be answered for a better understanding of earthquakes. In this context, in addition to "simultaneous" earthquakes, deep earthquakes are also included, that is, those that occur at depths greater than approximately 300 kilometers and up to nearly 700 kilometers and represent one of the most complex problems in modern seismology. The two questions, that of simultaneity of occurrence and deep earthquakes, may have a common answer and the same causes, which will be discussed in this study. Deep earthquakes are generated under very different conditions from superficial earthquakes in the Earth's crust, with pressure and temperature levels theoretically making fracturing according to traditional models impossible. These characteristics leave open the question of the triggering mechanism. At those depths, pressures exceed 20 GPa and temperatures can reach 1,500°C. Under these conditions, rocks should deform ductilely, gradually dissipating stress rather than breaking suddenly. This question has not yet provided a satisfactory and solid answer, but it has led to the formulation of at least three hypotheses currently considered by the scientific community.

The metastable phase of olivine

The first concerns the metastable phase of olivine (Green and Burnley, 1989), olivine being the main mineral constituent of the upper mantle, the environment where deep earthquakes are generated. The triggering energy of deep earthquakes could derive from the transformation of olivine into denser crystalline structures such as wadsleyite and subsequently ringwoodite. In the mantle transition

zone, which extends between 410 km and 660 km, structural transformations of silicates occur due to extreme pressures. The mantle transition zone can also retain significant quantities of water included in the crystalline structure. And under these conditions, ringwoodite can retain OH^- and hydrogen ions, which reduces viscosity and facilitates convective motion. Other cases show that in the hydrothermal phase, peridotite loses iron, generating oxides and magnetite, while magnesium silicate promotes rock foliation, which contributes, in tectonic stresses, to dislocation. A similar situation can be observed in the Manubiola Valley (Italy) in the formation environments of Jurassic-age accretionary prisms (Boschetti, Toscani, 2008). A second model, proposed by Kirby, Durham, and Stern (1991), attributes the trigger to the dehydration of hydrated minerals present in the subducting slab. The release of fluids would reduce the strength of the rocks, favoring sudden mechanical instabilities even at great depths. Another theory is that of thermal shear instability, according to which the heat produced during localized deformation can trigger a rapid loss of strength, favoring fracture propagation (Prieto et al., 2013). Frohlich (1989) describes these earthquakes as occurring within subducting plates and investigates the physical triggering mechanisms, including mineral dehydration and thermal instabilities, distinguishing between intermediate depths and deep mantle foci. Frictional heating in a shear zone reduces viscosity, triggering a self-healing localization of deformation that can cause earthquakes at medium and large depths (Margott et al., 2016).

Neutrinos and cosmic rays

The interaction between neutrinos and earthquake triggers is, at the current stage of research, still at the hypothetical level, as direct testing is not possible. The hypothesis pursued in this study is that neutrinos exert an ionization effect on electrons accumulated underground in tectonically active zones. However, neutrinos do not usually cause ionization directly because they have no electrical charge and interact only through the weak force. High-energy neutrinos cause ionization indirectly: they collide with nuclei or electrons in the medium, generating secondary charged particles such as electrons, muons, or tracing protons, which ionize the material in bubble chambers or scintillators. In bubble chambers and modern particle detectors, what is typically observed is not the passage of the neutrino itself, but rather that of the charged particles generated when a rare interaction occurs with an atomic nucleus or electron in the sensing material (Glaser, 1952; Cowan & Reines, 1956). Subsequently, in the 1970s, greater precision was achieved with the ionizing tracks produced by secondary particles (Danby et al., 1962; Fukuda et al., 1998). When a neutrino interacts with an electron or a nucleon, as in the case under study, it can transfer part of its kinetic energy to a charged particle. In the case of elastic neutrino-electron scattering, the recoil electron passes through the material, ionizing it according to the Bethe-Bloch relationship, depositing energy through collisions with the atoms in the medium (Bethe, 1930; Formaggio & Zeller, 2012).

The study of ionizing tracks has also allowed us to demonstrate the phenomenon of neutrino oscillations, measure their cross sections, and investigate fundamental properties of the Standard Model. It also provides a tool for observing solar, atmospheric, and supernova neutrinos (Fukuda et al., 1998; Ahmad et al., 2002). Neutrinos interact with electrons and atomic nuclei, and indirect data indicate that this mechanism may be possible at the level of the Earth's crust. It has always been thought that an earthquake was a piezoelectric phenomenon caused by the electric charge stored in rocks. Earthquakes frequently occur near magma, which tends to accumulate electricity. However, there are still many questions about the timing of earthquakes. What causes the charge to build up in rocks? Neutrinos penetrate deep into the ground and have an electrical effect. In particular, neutrinos generated by high-energy cosmic rays have extremely high energy when they enter the atmosphere. High-energy neutrinos in bubble chambers and solid scintillators cause ionization. High-energy neutrinos cause ionization when they pass through liquids and solids. A similar behavior, therefore, could occur when neutrinos pass through the interior of rock, resulting in the formation of a low-resistance electrical circuit within it. Most neutrinos come from the Sun, and their density is 66 billion per second per square centimeter. Atmospheric neutrinos, which have relatively high energy, pass through about 100 neutrinos per square meter per second. And it is on the latter that this study focuses its research and on a potential link between atmospheric neutrinos and earthquakes.

A possible connection between neutrinos, cosmic rays and earthquakes

This study, as mentioned, hypothesizes a new alternative mechanism involving the interaction between electrons trapped in rock cracks and cosmic rays, which, at certain energies, act as a trigger. This mechanism may explain both the phenomenon of concurrent earthquakes and deep-seated earthquakes. Indeed, unlike shallow earthquakes, which are caused by brittle failure of rocks along well-defined faults, deep-seated events develop under pressure and temperature conditions that make fracturing theoretically impossible according to traditional models. It is well known that modern seismic tomography techniques have significantly improved our understanding of the Earth's internal structure but have not yet provided a definitive answer. Observations show that deep earthquakes with very similar characteristics can occur in different geological environments, suggesting that no single universal mechanism exists. The candidate area for these mechanisms is the mantle, which is largely composed of olivine. It is

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hypothesized that significant quantities of non-biological methane may be contained within the mantle, which can react chemically with forsterite according to the following reaction:

producing water and carbon dioxide and separating O_2 from SiO_4 via a phase transition. Under these conditions, the rock expands in volume, and the electrons released in the reaction concentrate in fractures and crevices within the rocks (Straser, Miura, 2020). Abiotic methane is present on Earth in various environments: from magmatic processes to volcanic and geothermal areas, or from low-temperature gas-water-rock reactions. The isotopic composition of C and H is a first step in distinguishing abiotic from biotic CH_4 (Etiope and Sherwood Lollar, 2013). Large quantities of methane can form during progressive metamorphism in a cold subduction zone, which, in subduction zones globally, is estimated at approximately 10.8 million tons per year (Zhang et al., 2022). The dielectric properties of rocks have the ability to capture electrons within their crystalline structure. Since gravity acts weakly within the Earth, SiO_2, water, carbon dioxide, and electrons, which have undergone the phase transition, move toward the surface due to centrifugal force, but the speed of movement decreases with the presence of gravity. It can be assumed that the depth at which electron transfer decreases is approximately 10 km.

Methods

The method used for this study is based on comparing data collected daily from websites such as the USGS and INGV. Since the study is theoretical, the methodology used is circumstantial, based not on direct evidence, but rather on evidence deductible from available data.

Data

The data used are those reported by websites that update the list of global events in real time. Specifically, we used data provided by https://earthquake.usgs.gov/earthquakes/ and https://www.ingv.it/, http://ds.iris.edu/sm2/eventlist/index.phtml

We examined earthquakes that occurred worldwide and searched for a pair of earthquakes that occurred twice in a short period of time (Fig.1). As an example, we show the "twin" earthquakes detected globally from November 22 to 30, 2020.

N	Day hh:mm:ss (UTC)	Lat.	Long.	M	Deep (Km)
1	22-Nov-2020 11:28:12	17.93	-66.85	4.3	16
	22-NOV-2020 11:27:26	-2.59	127.47	5.3	11
2	24-NOV-2020 03:51:05	-22.46	-68.69	4.2	114
	24-NOV-2020 03:49:00	17.38	-93.95	4.5	175
3	24-NOV-2020 22:18:16	32.55	29.70	4.0	10
	24-NOV-2020 22:17:38	30.44	138.45	4.6	438
4	30-NOV-2020 22:54:59	-24.38	-67.05	6.3	148
	30-NOV-2020 22:54:34	48.26	140.81	6.4	587

Table 1. Four cases of pairs of earthquakes that occurred with time lags ranging from a few seconds to a minute after the occurrence

Fig. 1. Neutrinos penetrated from the eastern Mediterranean to southern Japan on November 24, 2020, 22:18:16 and 22:17:38, according to data reported in the table 1.

Discussion

The hypothesis presented in this study can be articulated in two aspects. The first concerns the potential interaction between neutrinos and electrons trapped in rocks in tectonically active zones, but not only, and the second considers the metastable conditions of olivine in the Earth's mantle, which in this context generates electrons. The first case.

If we consider data from the Japan Meteorological Agency on earthquake epicenters and the related graph, based on the statistical relationship between an earthquake's magnitude (M) and its frequency (N), known as the Gutenberg-Richter

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equation: logN = a – bM. In the graph, M is plotted on the horizontal axis and logN on the vertical axis, so it appears as an approximately straight line from M2 to M7 (with some slight bends). This slope is what is called the b value. The number of earthquakes announced by the Japan Meteorological Agency between 1997 and 2019 was as follows (Fig.2):

Magnitude 8 or greater - 4 (0.2/year)

Magnitude 7 - 90 (4/year)

Magnitude 6 - 1665 (72/year)

Magnitude 5 - 12702 (552/year)

Magnitude 4 - 33141 (1441/year)

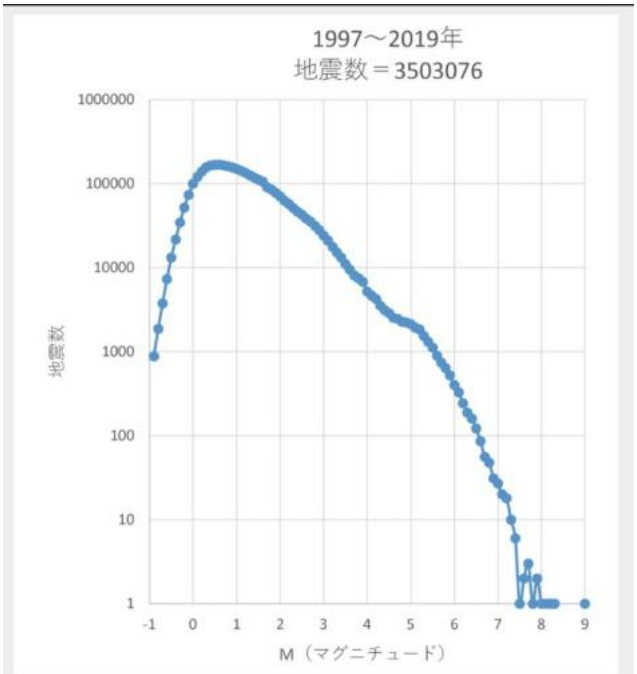

Fig. 2. The number of earthquakes between 1997 and 2019 (Japan Meteorological Agency)

For every 1-degree decrease in magnitude, the number of earthquakes increases by approximately one order of magnitude. Similarly, considering the graph of cosmic rays in relation to their energy, it emerges that there may be a potential relationship between the intensity of cosmic rays and the magnitude of earthquakes.

The frequency of earthquakes shows a characteristic curve between magnitudes 4 and 5. A similar curve is also observed for cosmic ray frequencies (Fig.3). This suggests that neutrinos and muons, created when cosmic rays enter the atmosphere, are the triggers of earthquakes.

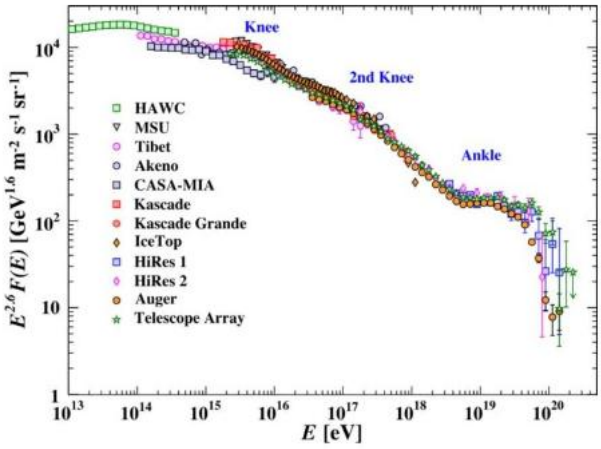

Fig. 3. Graph from Kheirandish (2020). Energy-weighted cosmic ray flux at energies above 10 TeV and the three main features of the cosmic ray spectrum: the knee, the second knee, and the ankle. The knee refers to the sharpening of the spectrum at energies above ~3 PeV, and galactic cosmic rays are thought to be the main contributors to this energy. The second knee has been identified around ~300 PeV and marks the sharpening of the flux. The "ankle" refers to the flattening of the spectrum at energies above ~500 PeV. Figure from Particle Data Group (Tanabashi et al. 2018)

Very high-energy cosmic rays rarely reach the atmosphere. Large earthquakes of magnitude 8 or higher, therefore, may have a close cause-and-effect relationship with very high-energy cosmic rays. If we consider the data reported in this study, we can observe that each pair of these four earthquakes occurs at very short intervals. However, neutrinos penetrating the Earth do not necessarily cause a pair of earthquakes. The piezoelectric phenomenon that causes an earthquake is due to the passage of neutrinos through places where electricity is stored in rocks, while they have no effect if neutrinos pass through areas where electricity is not stored. In this regard, considering the devastating earthquake that struck Japan on March 11, 2011, several characteristics emerge. One is that the location of the epicenter is unclear. At least three epicenters have been reported, and ISC data (http://www.isc.ac.uk/) lists eight. This is consistent with the generation of dozens of particularly dense regions of atmospheric neutrinos by high-energy cosmic rays. The piezoelectric effect of electric charge in these regions occurred almost simultaneously in

a wide range of rocks.

In the 24 hours following the main shock of March 11, 2011, 530 aftershock events occurred. This not only demonstrates that the earthquake was not caused by rock deformation but also suggests that the high-energy neutrinos were exceptionally powerful. Approximately 100 atmospheric neutrinos are emitted per square meter per second. When the rock is solarized by the first charge, the second neutrino triggers a large, though not particularly intense, generation. It is therefore believed that the charge-polarization-piezoelectric effect chain may have generated the more than 530 aftershock events over a large area.

Another characteristic is that the earthquake's intensity is high on the side affected by the neutrinos. From this, it can be deduced that the neutrino energy is correlated with the earthquake's magnitude. This is because it is known that, as neutrinos penetrate the Earth, their number decreases due to neutrino oscillations.

The second case. If we consider the formula

$2Mg_2SiO_4 + CH_4 \text{ - > } 2Mg_2SiO_2 + 2H_2O + CO_2 + 4e^-$,

we can make the following observations. The formula is, stoichiometrically, possible, but it does not correspond to a stable and known compound in silicate chemistry. The reason lies in the instability of this particular silicate which is linked to the oxidation states of magnesium (Mg^{2+}), silicon (Si^{4+}), and oxygen (O^{2-}). The total would be +4, and therefore the formula would not be electrically neutral, and for a stable ionic compound this is not possible. However, Mg_2SiO_2 could occur as a transient molecular cluster, for example during the condensation of vapors at high temperatures, but it would not be a stable mineral. Under conditions of extreme pressure and temperature, where electronic states and bonds can differ from ordinary ones, things can be different. Ultrahigh-pressure chemistry has shown that compounds with unusual stoichiometries can exist, although a stable silicate with the formula Mg_2SiO_2 has not yet been demonstrated. Instead, it is hypothesized that the silicate in question can assume a metastable phase, that is, a structure that exists for very short periods before transforming into more stable compounds such as Mg_2SiO_4 or $MgSiO_3$. In the Earth's mantle, up to a depth of about 2,900 km, the main magnesium silicates are Mg_2SiO_4, olivine and its high-pressure phases, $MgSiO_3$, bridgmanite and other phases, and periclase MgO, but a stable phase with the composition Mg_2SiO_2 has not been observed. However, at the extreme pressures of the lower mantle and core, solid-state physics calculations show that compounds with unusual stoichiometric ratios, different from those predicted by ordinary chemistry, can form, and Mg_2SiO_4 may be compatible with the conditions of the Earth's mantle. From a theoretical standpoint, therefore, there is nothing to prevent studying a hypothetical crystalline structure of Mg_2SiO_2 using quantum mechanical calculations. And, if it exhibited a minimum energy and the absence of vibrational instabilities, it could be classified as a metastable phase, even if not yet observed experimentally.

Conclusion

We conclude that the electrons stored in subsurface rocks come from the Earth's mantle. Olivine, the main component of the mantle, reacts with methane to undergo a phase transition into silicon oxide, the main component of granite.

$2SiO_4 + CH_4 \text{ -> } SiO_2 + CO_2 + 2H_2O + 2e^-$

Electrons rise from the Earth's interior and accumulate in rocks. Rocks are dielectric and store large numbers of electrons. Cosmic rays scatter neutrinos and muons at the Earth's surface, and when these penetrate underground, they trigger electrical discharges. The intensity of cosmic rays expands the area irradiated by neutrinos and muons, and a larger discharge area translates, from this perspective, into greater earthquake intensity. As mentioned, this is a study that hypothesizes that neutrinos can trigger earthquakes. Is it possible to test this hypothesis? One possibility is to inject neutrinos, which can be generated at high-energy facilities like KEK (https://www.kek.jp/en/), into the rock to trigger an earthquake, but this could pose significant challenges. Further studies may confirm or deny this hypothesis.

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Author's Contributions

The authors worked in synergy to create this article.

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A Geometrical Radial Evolution Model for Earth: (MGREM) model Investigating the Role of Variable Planetary Radius in Continental Separation

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Abstract: The separation and long-term evolution of Earth's continents have been traditionally explained within the framework of plate tectonics, which describes lithospheric motion on an approximately constant-radius planet. This study introduces the Maleki Geometrical Radial Evolution Model **(MGREM)** as a complementary geometric framework for investigating continental separation through possible long-term changes in Earth's mean radius.

The model is based on the fundamental relationship between the surface area and radius of a sphere, A=4\pi R^2, indicating that an increase in the total surface area of a spherical body requires a corresponding increase in mean radius. Using this geometric principle, the study examines whether progressive evolution of Earth's surface geometry could provide an additional perspective on the increasing separation of continental blocks.

The proposed Apple Model illustrates how expansion of a spherical body may generate additional surface area and produce fragmentation of an initially continuous outer shell. Furthermore, a three-continent geometric analysis is introduced to investigate the implications of variable planetary radius for continental divergence.

MGREM does not seek to replace established geological mechanisms such as seafloor spreading and subduction. Instead, it proposes a testable geometric hypothesis in which long-term radial evolution and surface-area expansion may have contributed to Earth's geological development. Future numerical modelling and comparison with geological and geophysical observations are required to evaluate the validity and limitations of this framework.

Keywords: Earth radius evolution; continental separation; spherical geometry; surface area expansion; geodynamics; plate tectonics; geoid; planetary evolution.

1. Introduction

The origin and separation of the Earth's continents have remained among the most fundamental questions in Earth science for more than a century. Continental drift, originally proposed by Wegener (1915), suggested that the present continents were once joined as a single landmass before gradually separating through geological time. This concept later evolved into the modern theory of plate tectonics, which explains continental motion through lithospheric plate interactions, seafloor spreading, and subduction (Morgan, 1968; Le Pichon, 1968; Kearey et al., 2009; Turcotte & Schubert, 2014).

Plate tectonics successfully explains numerous geological observations, including seafloor spreading, transform faults, earthquake distribution, and many aspects of global tectonic activity. Nevertheless, several geometric aspects of large-scale continental separation continue to invite further investigation, particularly regarding the long-term evolution of the Earth's surface geometry.

This study proposes the Maleki Geometrical Radial Evolution Model (MGREM) as an alternative geometric framework for interpreting continental separation. Unlike conventional models that assume a nearly constant planetary radius, MGREM investigates whether long-term evolution of the Earth's mean radius can provide a complementary geometric explanation for the increasing separation of continental blocks.

The proposed model is founded on a simple geometric principle. For a spherical body, total surface area is related to radius by

[A = 4\pi R^2]

Consequently, any sustained increase in the total surface area of a sphere requires an increase in its mean radius. This study examines whether this geometric relationship can provide an alternative interpretation of continental separation while remaining consistent with established geological observations.

The purpose of this work is not to reject the observational foundations of modern geology, but rather to evaluate whether a variable-radius geometric model offers an additional perspective for understanding the long-term evolution of the Earth's surface.

2. Geometrical Basis of the Variable-Radius Earth Model

The proposed Maleki Geometrical Radial Evolution Model (MGREM) is founded on a fundamental geometric relationship between the radius and surface area of a sphere. The total surface area of a spherical body is expressed as

[A = 4\pi R^2]

where A represents the total surface area and R denotes the mean radius. Consequently, any sustained increase in the total surface area of a sphere necessarily requires an increase in its mean radius.

The Earth, however, is not a perfect sphere with an identical radius at every location. Owing to gravitational equilibrium, planetary rotation, topography, crustal thickness variations, and heterogeneous mass distribution, the Earth's solid surface exhibits local radial variations relative to its mean reference radius (Hofmann-Wellenhof & Moritz, 2006; Torge & Müller, 2012).

Removing ocean water would reveal substantially larger variations in solid-surface elevation and radial distance. Nevertheless, the overall geometry of the Earth remains governed by gravitational and rotational equilibrium rather than by a perfectly constant radius (Fowler, 2005; Turcotte & Schubert, 2014).

Within the MGREM framework, it is essential to distinguish between local radial variations and long-term evolution of the Earth's mean radius. Geological processes such as tectonic uplift, crustal thickening, sediment accumulation, erosion, volcanism, and subsidence continuously modify the radial distance of the Earth's surface at numerous locations. Individually, these processes represent local geometric changes; collectively, when integrated over geological timescales, they may contribute to the long-term evolution of the Earth's mean radius.

From a purely geometric perspective, continental separation requires the generation of additional surface area between diverging continental blocks. If this increase represents a genuine long-term expansion of the Earth's solid surface, the geometric relationship A = 4\pi R^2 implies that an increase in the planet's mean radius must also be considered. This geometric consequence constitutes the central hypothesis of the MGREM proposed in this study.

The following sections examine the implications of this hypothesis and compare its predictions with those of the conventional constant-radius plate tectonic model.

3. The Apple Model: A Geometrical Analogy for Continental Separation

To illustrate the geometric concept underlying the proposed model, this study introduces the Apple Model as a conceptual analogy for long-term continental separation.

Consider a small apple whose peel forms a continuous, unbroken outer shell. The peel represents the Earth's early continental lithosphere, while the apple itself represents the planetary body. As the apple grows, its volume and radius increase. Because the surface area expands according to the geometric relationship.

[A = 4\pi R^2,]

The outer peel experiences increasing tensile stress. Once this stress exceeds the mechanical strength of the peel, fractures develop naturally, dividing the previously continuous surface into separate segments. Continued growth progressively increases the distances between these segments while preserving their overall geometric relationships.

Within the MGREM framework, this analogy represents a hypothetical early Earth in which continental crust initially formed a more continuous outer shell. Progressive long-term increase in the Earth's mean radius would increase the available surface area, allowing continental blocks to separate without requiring large-scale horizontal migration across an unchanged planetary surface.

The Apple Model is intended as a geometric representation rather than a direct mechanical description of lithospheric deformation. It does not attempt to reproduce the detailed rheology of the Earth's mantle or lithosphere. Instead, it demonstrates how progressive radial growth alone naturally produces increasing separation between initially continuous continental fragments while maintaining the overall geometry of the planetary surface.

A key implication of the Apple Model is that increasing separation between continental blocks arises primarily from

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the expansion of the available surface area rather than from extensive lateral displacement over an unchanged spherical surface. In this interpretation, the increase in mean planetary radius provides the geometric space required for continental divergence.

It should be emphasized that the Apple Model is not presented as a replacement for all geological processes described by plate tectonics. Instead, it serves as a conceptual geometric framework for investigating whether long-term radial evolution can account for aspects of continental separation from an alternative perspective.

The principal objective of the Apple Model is therefore to establish a simple and physically intuitive geometric analogy that connects radial evolution, surface-area expansion, and continental separation. The following section develops this concept further by examining the geometric behavior of three continental blocks on spherical surfaces of different radii.

The Apple Model also highlights an important distinction between local deformation and global geometric evolution. In a real planetary system, surface features such as mountain belts, ocean basins, and sedimentary regions represent local responses of the lithosphere to internal and external forces. However, the cumulative effect of widespread surface modifications over geological time may influence the overall geometry of the planetary surface

In this analogy, the initial state of the apple represents a smaller-radius Earth with a more compact surface configuration, whereas the expanded apple represents a later evolutionary stage with increased radius and surface area. The development of cracks in the peel illustrates how a continuous outer shell may become fragmented when the available surface area changes relative to the original shell geometry.

The analogy does not imply that the Earth's crust behaves exactly like an apple peel. Earth's lithosphere is a complex mechanical system influenced by mantle convection, thermal evolution, gravity, and plate interactions (Fowler, 2005; Turcotte & Schubert, 2014). Rather, the Apple Model isolates a fundamental geometric principle: when the radius of a spherical body increases, the surface area available to accommodate a rigid outer shell also increases.

Therefore, the Apple Model provides a conceptual framework for evaluating whether long-term radial evolution could have contributed to the separation of continental blocks. The model establishes the geometric foundation for the subsequent analysis of continental configurations and spherical surface relationships.

3.1 : The Apple Model

A simple apple-growth experiment can be used as a conceptual illustration of the geometric principle. Lines representing initial continental boundaries may be drawn on the firm outer surface of a young apple. As the apple naturally increases in size, the outer surface expands and the marked lines become progressively separated, creating gaps between initially connected regions.

This analogy illustrates the relationship between expansion of a spherical surface and separation of surface blocks. Within the MGREM framework, the Apple Model is not intended to represent the exact mechanical behaviour of Earth's lithosphere, but rather to demonstrate how an increase in the radius of a spherical body can generate additional surface area and provide a geometric basis for increasing separation between surface regions.

4. The Three-Continent Geometric Problem A, B, C

A central geometric question addressed by the **MGREM** framework concerns the simultaneous separation of multiple continental blocks on a spherical surface.

Consider three continental blocks, referred to as A, B, and C, which were previously connected or located in close proximity on an earlier Earth configuration. During geological evolution, these blocks become progressively separated. The key geometric question is whether the observed increase in distances among all three blocks can be represented solely by lateral motion on a sphere with a constant radius, or whether an increase in the planetary radius provides an additional geometric explanation.

In a constant-radius spherical model, the total available surface area remains fixed. Therefore, continental separation requires a redistribution of existing surface space, with deformation occurring through mechanisms such as seafloor spreading, subduction, and horizontal plate motion (Morgan, 1968; Le Pichon, 1968; Kearey et al., 2009).

However, from a purely geometric perspective, if multiple continental blocks simultaneously increase their mutual distances in different directions, the available surface area between them must also increase. In the MGREM framework, this increase in available surface area is examined as a possible consequence of long-term evolution of the Earth's mean radius.

For a spherical body, the distance relationships between surface points depend on both angular separation and

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planetary radius. The surface distance between two points can be expressed as:

[d = R\theta]

where d is the surface distance, R is the planetary radius, and \theta is the angular separation between the two points.

This relationship demonstrates that, even without a change in angular position, an increase in R produces an increase in the physical distance between surface points. Therefore, a variable-radius Earth provides a geometric mechanism by which continental blocks may become progressively farther apart as the planet expands.

The purpose of this analysis is not to replace observed tectonic mechanisms, but to investigate whether changes in planetary geometry may provide an additional explanation for large-scale continental separation.

5. Surface Area–Radius Relationship and Quantitative Evaluation

The fundamental geometric of relationship **MGREM** framework is based on the dependence of spherical surface area on planetary radius. For a spherical body, the total surface area is expressed as:

[A = 4\pi R^2]

where A represents the total surface area and R represents the mean radius of the planet.

Because surface area increases with the square of radius, even relatively small changes in planetary radius can produce significant changes in the total available surface area. This geometric relationship provides a quantitative basis for evaluating whether long-term radial evolution could generate additional surface space during Earth's geological history.

Using the present mean Earth radius of approximately:

[R_{present}=6371 \ km]

The current surface area of the Earth is approximately:

[A_{present}=510 \ million \ km^2]

If the Earth had a smaller mean radius during earlier geological periods, the corresponding surface area would have been significantly smaller. For example, a hypothetical radius of approximately:

[R=5100 \ km]

would correspond to a surface area of approximately:

[A=327 \ million \ km^2]

The difference between these two spherical surfaces is approximately:
[
[\Delta A \approx 183 \ million \ km^2]

This value represents the additional geometric surface area associated with the difference between these two radii.

Within the MGREM framework, this increase in available surface area is interpreted as a potential geometric factor contributing to the progressive separation of continental blocks. As continental fragments occupy positions on an expanding spherical surface, increasing radius naturally increases the physical distances between points located on the surface according to:

[d=R\theta]

where d is the surface distance and \theta is the angular separation.

It should be emphasized that these calculations represent a geometric evaluation of surface-area consequences under a variable-radius assumption. They do not by themselves determine the physical mechanism responsible for any possible change in planetary radius. The purpose of this analysis is to quantify the geometric implications of such a hypothesis and provide a framework for further investigation.

5.1 Addition to Surface Area–Radius Relationship: Geological Radius Scenario (Table A&B)

To investigate the geometric consequences of possible long-term radial evolution, hypothetical radius scenarios can be evaluated using the spherical surface-area relationship.
Geological Interval

Example Mean Radius (km)
Relative Radius
Estimated Surface Area (million km²)
Early Precambrian (hypothetical)
3200
~50%
~129
Paleozoic (hypothetical)
4000
~63%

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~201
Mesozoic (hypothetical)
4500
~71%
~254
Late Geological History (hypothetical)
5100
~80%
~327
Present Earth
6371
100%
~510

These values represent geometric scenarios for evaluating the relationship between radius and surface area. They do not represent direct measurements of Earth's past radius and require further testing through geological and geophysical constraints.

6. Local Radial Variations and Mean Radius Evolution

The Earth's solid surface is not characterized by a single identical radius at every location. Instead, the distance between the Earth's center and its surface varies spatially due to topography, crustal thickness variations, sediment accumulation, tectonic uplift, subsidence, and differences in mass distribution (Hofmann-Wellenhof & Moritz, 2006; Torge & Müller, 2012).

In geophysical and geodetic terms, the Earth is better represented as a dynamic, equipotential surface rather than a perfect sphere. The geoid and topographic variations demonstrate that the radial distance of the solid surface is continuously modified by geological processes (Fowler, 2005; Turcotte & Schubert, 2014).

These local radial changes can be expressed conceptually as:

$$R_i = R_0 + \Delta r_i$$

where R_0 represents a reference radius and Δr_i represents the local radial variation at a specific location.

Individual local changes, such as mountain building or sediment accumulation, do not by themselves demonstrate a global increase in the Earth's mean radius. However, the cumulative effect of numerous radial modifications distributed across the Earth's surface over geological timescales provides a geometric basis for examining possible long-term changes in the mean radius.

Within the MGREM framework, planetary radius evolution is therefore not considered as a perfectly uniform outward expansion of every surface point. Instead, long-term radial evolution is interpreted as the integrated result of widespread local geometric modifications occurring throughout Earth's geological history.

Because the surface area of a sphere is directly related to its radius:

$$A=4\pi R^2$$

A sustained increase in the total solid-surface area of a spherical planet would necessarily be associated with an increase in its mean radius.

This distinction between local radial variation and global mean-radius evolution is essential for evaluating the MGREM hypothesis. The model does not rely on any single geological process but investigates whether the cumulative geometric consequences of long-term surface evolution can contribute to the observed large-scale separation of continental blocks.

7. Comparison with Plate Tectonics

The theory of plate tectonics provides the dominant framework for explaining modern observations of lithospheric motion, including seafloor spreading, subduction, transform boundaries, earthquake distribution, and volcanic activity (Morgan, 1968; Le Pichon, 1968; Kearey et al., 2009). The MGREM framework does not seek to dismiss these observations or replace the established mechanisms of lithospheric deformation.

Instead, MGREM addresses a different aspect of continental evolution: the long-term geometric consequences of increasing separation between continental blocks on a spherical planet. Conventional plate tectonic models generally consider the Earth as a body with an approximately constant radius, where continental motion occurs through the redistribution of lithospheric plates across the existing surface.

In contrast, the MGREM hypothesis investigates whether changes in the geometry of the planetary surface, specifically possible long-term evolution of the Earth's mean radius, could provide an additional contribution to understanding continental separation.

A constant-radius model requires that new oceanic surface created at divergent boundaries must be balanced by the consumption of lithosphere at convergent boundaries. This dynamic equilibrium is a central component of plate tectonics (Turcotte & Schubert, 2014). From a geometric

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perspective, however, the question remains whether the increasing distances among widely separated continental blocks can also be examined through changes in the total available surface area.

The fundamental difference between the two approaches can be summarized as follows:

Aspect| Plate Tectonics| MGREM Framework
Planetary radius| Approximately constant| Variable-radius hypothesis
Main mechanism| Horizontal plate motion and recycling| Long-term geometric surface evolution
Surface area| Conserved globally through creation and destruction of crust| Potential long-term increase in available surface area
Continental separation| Primarily explained by plate interactions| Examined through radius and surface-area relationships

The purpose of this comparison is not to claim that one framework automatically replaces the other. Rather, MGREM proposes an additional geometric perspective that can be evaluated alongside existing geological models. Future quantitative tests, including numerical simulations and comparisons with geological observations, are required to determine the extent to which radial evolution may have contributed to Earth's long-term surface development.

8. Discussion

The MGREM framework presents a geometric interpretation of continental separation based on the possible long-term evolution of the Earth's mean radius and surface area. The central concept is derived from the fundamental relationship between the radius of a sphere and its surface area, where an increase in available surface area requires a corresponding increase in mean radius.

The model provides an alternative geometric perspective on continental divergence by considering that increasing distances between continental blocks may be influenced not only by horizontal displacement mechanisms but also by changes in planetary geometry. In this context, the separation of continents is examined as a problem involving the evolution of a spherical surface through geological time.

However, the proposed framework does not assume that all geological observations can be exrdplainedq1 by radial evolution alone. Modern plate tectonics successfully describes many processes, including seafloor spreading, subduction, earthquake generation, and volcanic activity (Kearey et al., 2009; Turcotte & Schubert, 2014). These processes represent well-established components of Earth's dynamic behavior.

The primary contribution of MGREM is therefore not a replacement of established geodynamic mechanisms, but the introduction of a geometric hypothesis that examines whether changes in planetary radius and surface area may have played a role in the long-term evolution of continental configurations.

Several important questions remain open for further investigation. These include the possible physical mechanism responsible for any long-term change in planetary radius, the relationship between radial evolution and internal mass redistribution, and the compatibility of a variable-radius model with geophysical observations.

Future development of this framework requires quantitative numerical modelling, comparison with paleogeographic reconstructions, and evaluation against independent geological and geophysical datasets. Such tests will determine whether the variable-radius hypothesis provides a measurable contribution to understanding Earth's long-term evolution.

The strength of the MGREM approach lies in presenting a clearly defined geometric hypothesis that can be tested, modified, or rejected through future observations and modelling. In this sense, the model represents a scientific framework for investigation rather than a final explanation of all aspects of planetary evolution.

8.1 Additional Discussion:

Several important questions remain for the further evaluation of the MGREM hypothesis. The physical properties and internal structure of Earth impose constraints on any proposed long-term change in planetary volume or radius. Therefore, any variable-radius model must be consistent with the known mechanical behavior of the crust, mantle, and planetary interior.

Modern geodetic measurements provide precise constraints on present-day Earth dimensions and do not indicate large short-term changes in Earth's radius. Consequently, any possible radial evolution proposed by MGREM must be investigated primarily on geological timescales and evaluated using independent geological and geophysical evidence.

In addition, a complete physical explanation for the possible mechanism and energy source responsible for long-term radial evolution remains necessary. Future development of the model requires numerical simulations, mass-balance analysis, and comparison with observational constraints to determine whether such a mechanism is physically plausible.

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8.2 More Additional Discussion:

Testable Predictions of the MGREM Framework

The MGREM hypothesis generates several testable predictions that can be evaluated through independent geological and geophysical observations. These include numerical simulations of variable-radius spherical geometries, comparison with paleogeographic reconstructions, and analysis of whether changes in continental separation are compatible with predicted variations in available surface area.
Further evaluation may include comparisons between model predictions and ocean basin development, continental configurations through geological time, and global plate reconstruction datasets. The validity of the model depends on whether it can produce measurable geometric consequences consistent with observational constraints.

9. Conclusions

This study introduces the Maleki Geometrical Radial Evolution Model (MGREM) as a geometric framework for investigating the long-term evolution of Earth's surface and continental separation.

The model is based on the fundamental relationship between the surface area and radius of a sphere, expressed as A=4\pi R^2, which indicates that any sustained increase in the total surface area of a spherical body requires an increase in its mean radius.

The proposed framework does not assume uniform expansion of every point on Earth's surface. Instead, it considers the cumulative effect of widespread local radial variations and their possible contribution to the long-term evolution of Earth's mean radius.

The Apple Model provides a conceptual analogy illustrating how increasing radius and surface area could generate additional space for the separation of initially connected surface blocks. The three-continent geometric analysis further explores the implications of variable planetary geometry for continental divergence.

MGREM is not presented as a replacement for plate tectonics, which remains the established framework for explaining many geological processes. Rather, it proposes an additional geometric hypothesis that can be tested through numerical modelling, geological reconstruction, and comparison with independent geophysical observations.

Future investigations should focus on developing quantitative simulations of variable-radius scenarios and evaluating their compatibility with geological, geodetic, and geophysical constraints. The validity of the model will ultimately depend on its ability to generate testable predictions and withstand comparison with observational evidence.

10. Relationship with Seafloor Spreading, Subduction, and Magnetic Anomalies

One of the strongest geological pieces of evidence supporting plate tectonics is the pattern of symmetrical magnetic anomalies observed on both sides of mid-ocean ridges. These magnetic stripes record reversals of Earth's magnetic field preserved in newly formed oceanic crust and provide direct evidence for seafloor spreading (Vine & Matthews, 1963; Heirtzler et al., 1968).

The **MGREM** framework does not dispute the existence of magnetic anomalies or the occurrence of seafloor spreading. These observations demonstrate that oceanic lithosphere is continuously created and transported away from spreading centers. Instead, MGREM examines a broader geometric question: whether the long-term increase in separation between continental blocks may also involve changes in the geometry of the planetary surface.

In conventional plate tectonic interpretation, new oceanic crust generated at divergent boundaries is balanced by the destruction of older lithosphere at subduction zones, maintaining an approximately constant planetary radius (Turcotte & Schubert, 2014). Subduction zones provide an essential mechanism for recycling lithosphere into the mantle and explaining global plate motion patterns.

Within the MGREM framework, subduction and seafloor spreading are considered observed geological processes that describe local and regional lithospheric behaviour. The proposed model investigates whether these processes occur within a larger geometric framework in which the available surface area of the planet may have changed over geological time.

The presence of magnetic stripes there fore represents strong evidence for horizontal motion of oceanic plates, but it does not independently determine whether Earth's mean radius has remained absolutely constant throughout its entire geological history. A variable-radius hypothesis requires separate evaluation using geophysical constraints, mass balance considerations, and numerical modelling.

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Consequently, **MGREM** does not attempt to replace the mechanisms responsible for magnetic anomalies, seafloor spreading, or subduction. Rather, it proposes that planetary geometry and lithospheric dynamics may be investigated together as complementary aspects of Earth's long-term evolution.

Future studies should examine whether a variable-radius model can remain compatible with paleomagnetic reconstructions, ocean-floor age distributions, plate kinematics, and mantle dynamics.

Figures:

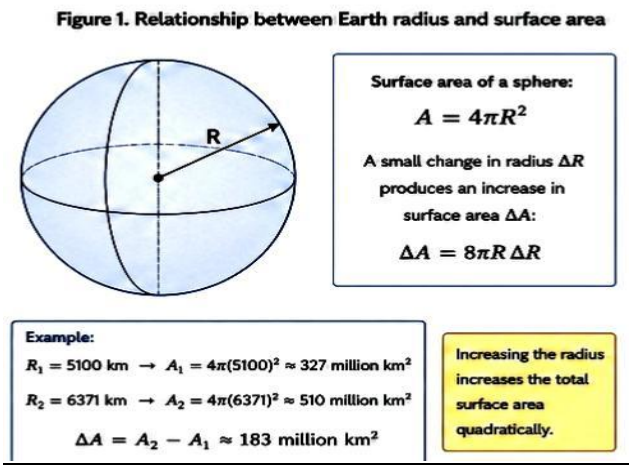

Figure 1. Conceptual illustration of the variable-radius Earth hypothesis.

Schematic representation comparing an earlier smaller-radius Earth configuration with the present Earth geometry. The figure illustrates the relationship between planetary radius, spherical surface area, and the increasing space available for continental separation. The illustration represents a geometric hypothesis and does not imply a specific mechanism of planetary expansion.

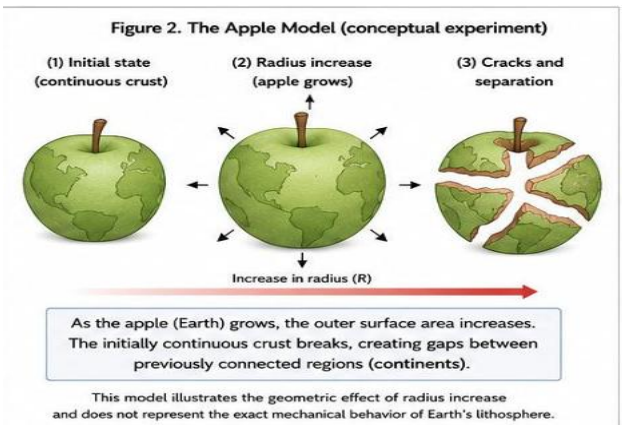

Figure 2. The Apple Model analogy for continental separation.

Conceptual analogy showing a growing spherical body with an initially continuous outer shell. As the radius increases, the surface area expands and tensile stresses develop within the outer layer, leading to fragmentation. The model illustrates the geometric relationship between surface-area increase and separation of surface blocks.

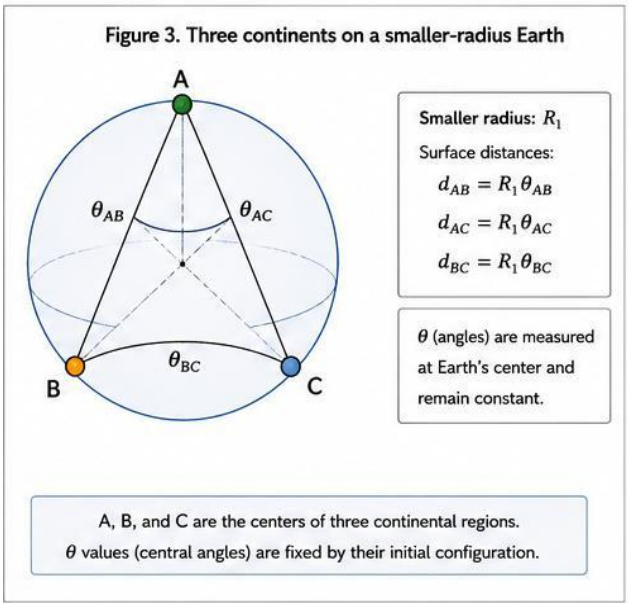

Figure 3. Three-continent configuration on a smaller-radius spherical Earth.

Schematic representation of three initially connected continental blocks (A, B, and C) positioned on an earlier smaller-radius Earth. The angular relationships between the blocks are maintained while the available surface area is reduced.

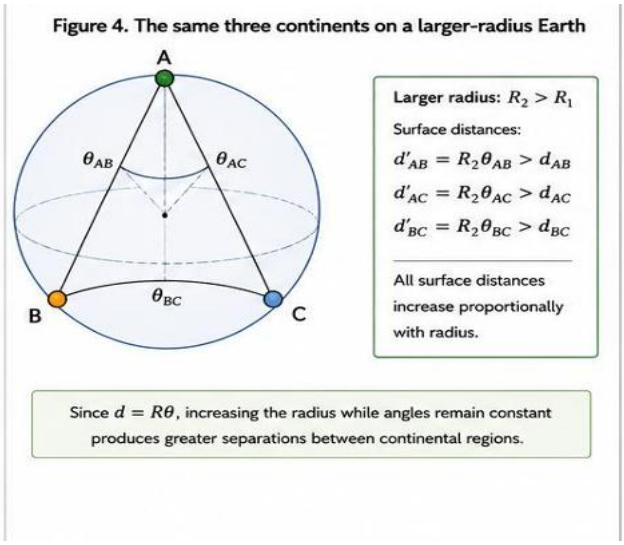

Figure 4. Three-continent configuration on an expanded spherical Earth.

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The same continental configuration after an increase in planetary radius. According to the relationship d=R\theta, increasing radius increases the physical surface distance between equivalent angular positions, producing greater separation between continental blocks.

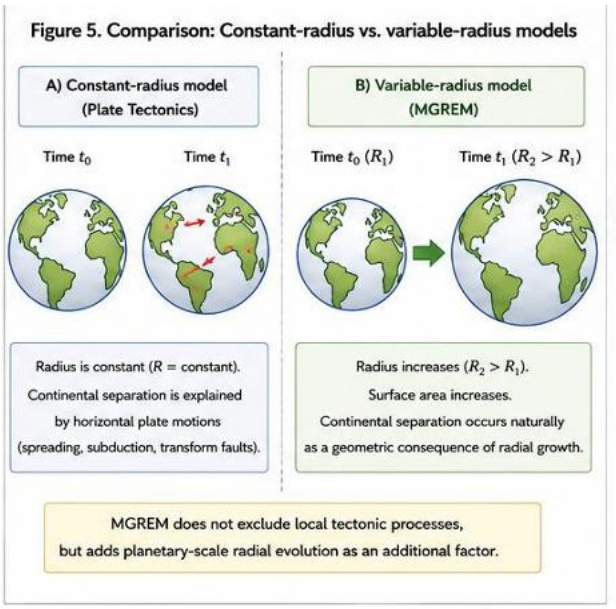


Figure 5. Comparison between constant-radius and variable-radius geometric interpretations.

Comparison of two conceptual models. In the constant-radius model, continental separation occurs through redistribution of existing surface area by plate motion mechanisms. In the variable-radius model, increasing radius provides additional spherical surface area that may contribute to increasing separation between continental blocks.

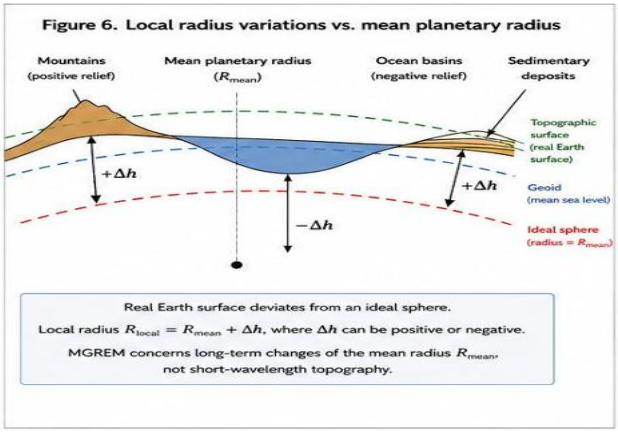


Figure 6. Local radial variations and global mean-radius concept.

Schematic representation of Earth's non-uniform surface geometry. Mountain belts, sedimentary basins, oceanic regions, and crustal thickness variations produce local changes in radial distance, while the mean radius represents the integrated planetary geometry.

Table 1. Comparison between MGREM and Plate Tectonics

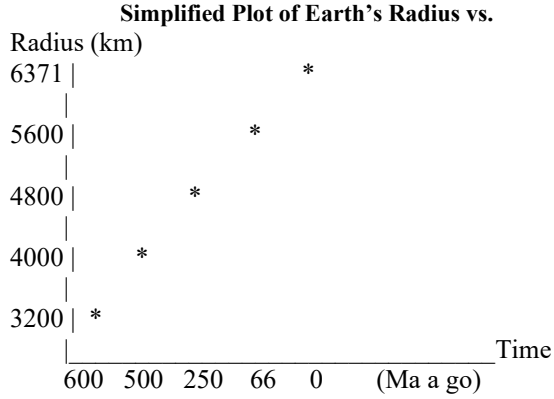
Aspect	Plate Tectonics (Constant-Radius Model)	MGREM (Variable-Radius Model)
Planetary radius	Constant over geological time	Increases over geological time
Driving mechanism	Mantle convection, slab pull, ridge push	Planetary expansion (radial growth)
Main cause of continental separation	Horizontal plate motions	Increase in surface area due to larger radius
Surface area	Constant	Increases with $A = 4\pi R^2$
Three-continent problem	Requires complex plate kinematics	Natural increase in all inter-continental distances
Ocean basins	Formed by seafloor spreading and subduction	Additional space created by increased surface may facilitate basin development
Testable prediction	Seafloor age pattern, magnetic stripes, etc.	Radius-linked increase in separations and surface area through time
Status	Well-established framework	Hypothesis requiring further testing

Table 2. Earth surface area for different radius scenarios

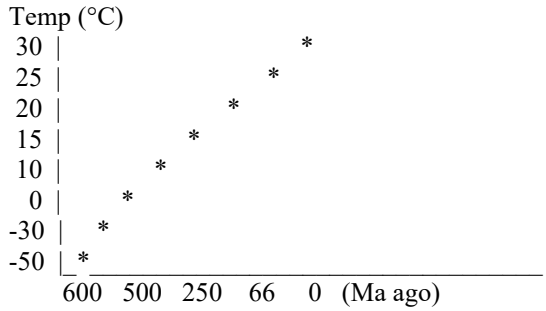
Geological interval (example)	Mean radius R (km)	Relative radius (R/R_{now})	Surface area $A = 4\pi R^2$ (million km^2)	Increase in area from previous stage (million km^2)
Early Precambrian (hypothetical)	3,200	0.50	129	-
Paleozoic (hypothetical)	4,000	0.63	201	+72
Mesozoic (hypothetical)	4,500	0.71	254	+53
Late Geological History (hypothetical)	5,100	0.80	327	+73
Present Earth	6,371	1.00	510	+183

Values are geometric estimates to illustrate the relationship between radius and surface area.
They do not represent direct measurements of Earth's past radius.

Simplified Plot of Earth's Radius vs.



Simplified Plot of Average Global Temperature vs. Time



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Questions & Answers

(Apple model) Radial-Growth) Earth

Q1 – Where does the additional mass come from if Earth expands?
A1: The model does not prescribe a specific mass-generation mechanism. Potential sources include deep-mantle phase transitions, core expansion, or early cosmic accretion. The key point is that geometric consequences of radial growth are testable and do not rely on mass assumptions.

Q2 – Why don't GPS measurements show Earth's radial expansion?
A2: GPS networks are ~30 years long. Geological-scale radial growth is extremely slow (~0.3 mm/yr), below GPS detection. Reference frames assume a fixed-radius ellipsoid, filtering out uniform radial components.

Q3 – How does the Apple model differ from plate tectonics?
A3: Plate tectonics explains horizontal motion, earthquakes, and subduction. The Apple model provides a higher-level geometric framework in which horizontal motions emerge as a consequence of radial growth.

Q4 – Is the ABC mechanism a replacement for conventional kinematics?
A4: No. ABC provides a geometric rationale for simultaneous continental divergence. Horizontal plate dynamics still operate, but the radial model reframes the underlying cause.

Q5. How does Earth's pear-shaped geometry support radial growth?
A5: A rigid, constant-radius sphere cannot maintain hemispheric mass asymmetry. Radial growth introduces new surface area, reducing geometric tension and explaining mass asymmetry.

Q6 – How can low-latitude glaciations be explained?
A6: Smaller ancient Earth radius increases Sun–surface distance at the equator, reducing surface energy absorption and permitting tropical ice formation.

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Q7 – Can the radial-growth model be tested?
A7: Yes. Long-term geodetic datasets (SLR, VLBI, GPS, GRACE) can detect minute, systematic radial signatures. Fossil depth and tectonic extension correlations are also testable.

Q8 – What are the main limitations of the model?
A8: Physical mechanisms are incompletely quantified, growth rate is small, and separating radial vs horizontal effects in GPS/tectonic data is challenging.

Q9 – How does the model reconcile with ocean-floor spreading and subduction?
A9: Radial expansion provides additional surface area, permitting new oceanic crust formation. Subduction zones still operate, but their dynamics are reframed as responses to volume growth.

Q10 – Why has this model not been widely accepted?
A10: Historical bias toward fixed-radius models, lack of long-term precise geodetic datasets, and conventional reliance on horizontal tectonics have limited recognition. However, ongoing satellite and paleogeographic reconstructions provide testable opportunities.

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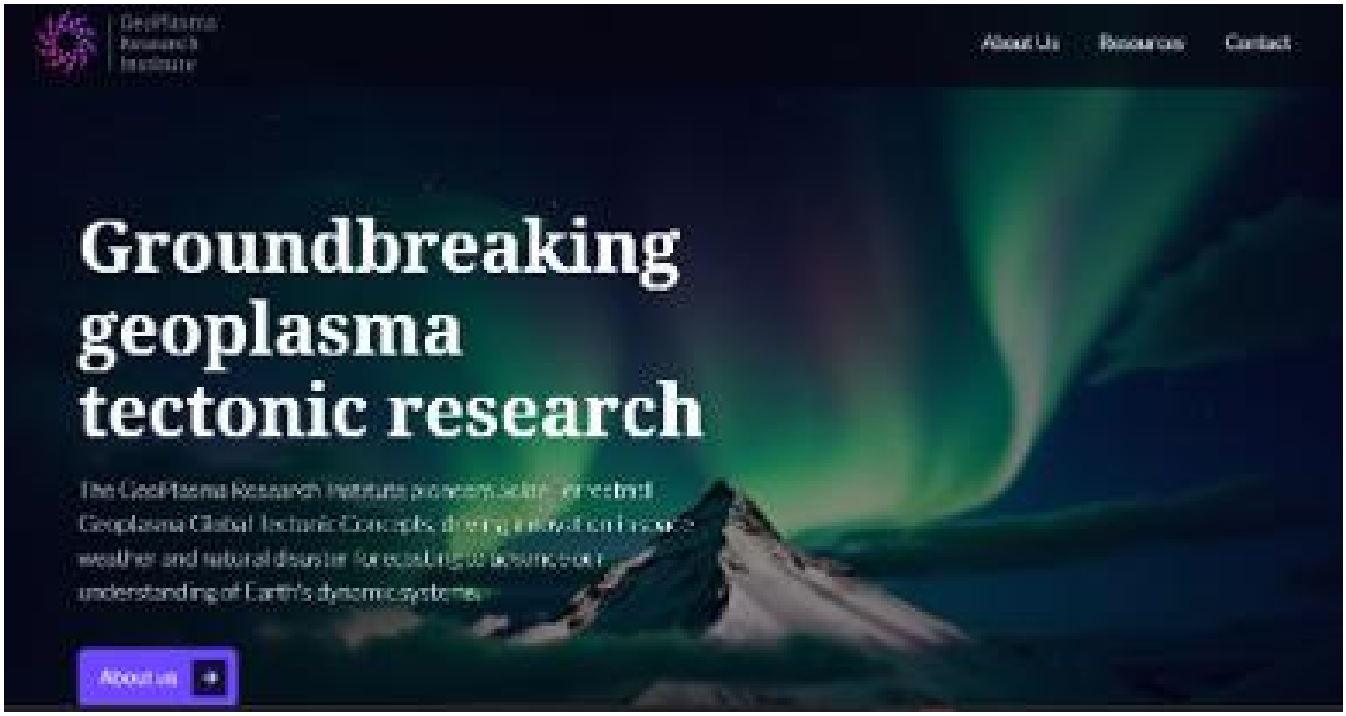
ABOUT THE NCGT JOURNAL

The NCGT Newsletter, the predecessor of the NCGT Journal, was begun as a result of discussions at the symposium "Alternative Theories to Plate Tectonics" held at the 30th International Geological Congress in Beijing in August 1996. The name is taken from an earlier symposium held in association with the 28th International Geological Congress in Washington, D. C. in 1989. The first issue of the NCGT Newsletter was December 1996. The NCGT Newsletter changed its name in 2013 to the NCGT Journal. Aims of the NCGT Journal include:

1. Providing an international forum for the open exchange of new ideas and approaches in the fields of geology, geophysics, solar and planetary physics, cosmology, climatology, oceanography, electric universe, and other fields that affect or are closely related to physical processes occurring on Earth from its core to the top of its atmosphere.
2. Forming an organizational focus for creative ideas not fitting readily within the scope of dominant tectonic models.
3. Forming the basis for the reproduction and publication of such work, especially where there has been censorship or discrimination.

https://www.GeoplasmaResearchInstitute.org/