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Cataclysmic Geomagnetic Field Collapse: Global Security Concerns

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Author's contribution

The author holds that technical, scientific, medical and public health representations made in the scientific literature in general, including this particular journal, should be and are truthful and accurate to the greatest extent possible and should serve to the highest degree possible to protect the health and well-being of humanity and Earth's natural environment.

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ABSTRACT

In 2015, Tyler J. Williams authored "Cataclysmic Polarity Shift: Is U. S. National Security Prepared for the Next Geomagnetic Pole Reversal?" That document provides an extremely cogent and thorough description of some of the risks to national security and infrastructure expected to result from a geomagnetic polarity reversal. However, it describes geomagnetic field generation solely as currently promoted by the geophysics community which is based upon old ideas, circa 1940s-1960s, that are taken to be factual without any attempt to understand their limitations or to evaluate their validity in light of subsequent scientific developments. Moreover, the security concerns Williams described are relevant to humanity globally. Here I have reviewed the historical development of those old ideas, pointed out their problematic nature, and reviewed subsequent published advances that overcome their inherent problems and lead to a better understanding of the geophysics related to geomagnetic polarity reversals, geomagnetic excursions, and, at some yet unknown time, the permanent demise of the geomagnetic field. Mechanisms of rapid geomagnetic field collapse, both natural and potentially human-induced, are described. The present state of nuclear georeactor activity, whether geomagnetic field collapse leads to increased georeactor output, and whether it is likely to trigger earthquakes and volcano eruptions are yet

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unknown matters of seriously troubling human security concerns. Global security preparedness, even though addressed by sovereign nations, should be predicated upon the latest and most correct scientific understanding. In some areas that may be the case, but in the scientific areas described here there are clearly problems. The inherent problems, I submit, do not result from inadequate funding, but from inadequate methodologies, expectations and responsibilities of scientists, their national and parent institutions, publishers, and respective funding-agencies.

Keywords: Magnetic pole reversal; geomagnetic reversal; magnetic pole shift; geodynamo.

1. INTRODUCTION

Earth is constantly under assault by the solar wind, an electrically conducting ionized plasma streaming from the sun at temperatures on the order of one million degrees Celsius and velocities of about 1.6 million kilometers per hour [1]. Fortunately, the geomagnetic field deflects the solar wind safely around our planet thus shielding the environment and its biological constituents from serious harm [2].

From time to time, massive pulses of charged plasma are ejected from the sun's corona [3] that partially overwhelm Earth's magnetic field, producing infrastructure-damaging geomagnetic storms that disrupt communications and navigation systems, and that damage electrical equipment by induced electric currents [4,5]. These sporadic events provide glimpses of the far more devastating consequences that will inevitably result during the next collapse of the geomagnetic field. As illustrated in Fig. 1, geomagnetic reversals have happened often in the geological past and will happen often in the geological future [6,7].

Proto-humans existed and survived the last geomagnetic polarity reversal 786,000 years ago, but were extremely limited in population and infrastructure. Now, when a reversal takes place, the consequences will be catastrophic for civilization's technologically highly-integrated infrastructure. In 2015, Williams [8] authored a document entitled "Cataclysmic Polarity Shift: Is U. S. National Security Prepared for the Next Geomagnetic Pole Reversal?" Drawing on the consequences of exceptionally great coronal mass ejections, Williams described some of the potential risks to national security and infrastructure posed by a geomagnetic polarity reversal. Such risks are generally applicable to global security.

The potential consequences of a geomagnetic reversal on global technologically-based infrastructure, include the following [8]: Widespread communications disruptions, GPS blackouts, satellite failures, loss of electrical power, loss of electric-transmission control, electrical equipment damage, fires, electrocution, environmental degradation, refrigeration disruptions, food shortages, starvation and concomitant anarchy, potable water shortages, financial systems shut-down, fuel delivery disruptions, loss of ozone and increased skin cancers, cardiac deaths, and dementia. This list is not exhaustive. It is likely that a geomagnetic field collapse would cause much hardship and suffering, and potentially reverse more than two centuries of technological infrastructure development.

William's report [8] is nonetheless based on an outmoded understanding of solid-Earth geophysics, an understanding whose foundations are comprised of ideas that date from the 1930s, 1940s, 1950s, and 1960s, where they stop. These fundamental ideas are taken to be factual decades later without any attempt to understand their limitations or to evaluate their validity in light of subsequent scientific ideas and discoveries made over the last 50 years. I have reviewed the historical development of those old ideas, described their problematic nature, and reviewed subsequent published advances that overcome their inherent problems and lead to a better understanding of the physics related to geomagnetic polarity reversals. I have also described mechanisms of geomagnetic field collapse, both natural and potentially human-induced. My intent is not to contradict Williams' [8] well-described national security implications, but to broaden and extend them globally, especially in light of fundamentally new scientific advances.

When the geomagnetic field collapses and then re-establishes in a reversed direction, it often leaves a readily traceable paleomagnetic record that can be revealed by rock-magnetism investigations. From Fig. 1 there is neither apparent periodicity with respect to the onset of magnetic reversals nor periodicity with the durations between reversals [9].

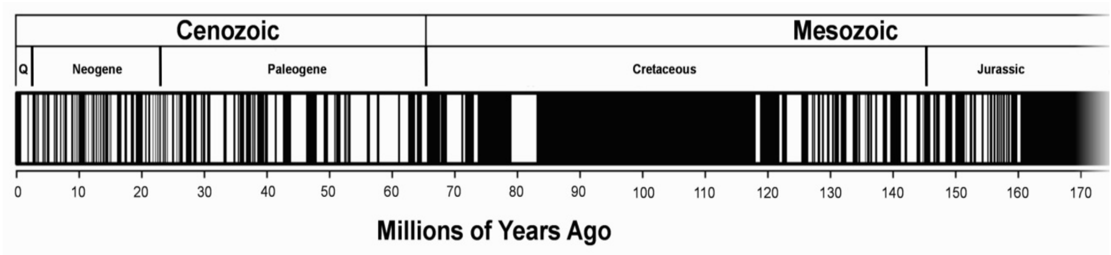

Fig. 1. Geomagnetic polarity since the middle Jurassic. Dark areas denote periods where the polarity matches today's polarity, while light areas denote periods where that polarity is reversed. Based upon published data [10,11]

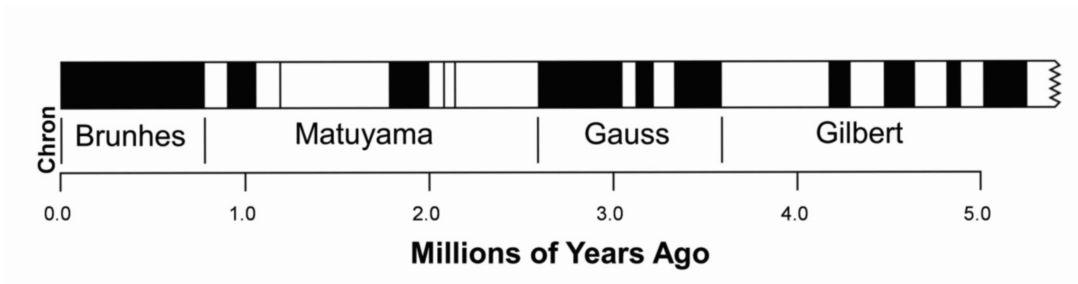

Fig. 2. Recent geomagnetic polarity from rock-magnetism investigations. Dark areas denote periods where the polarity matches today's polarity, while light areas denote periods where that polarity is reversed. Based upon an image by the U. S. Geological Survey

Fig. 2 presents a record of recent magnetic polarity reversals. The last polarity reversal event occurred about 786,000 years ago and may have occurred during a time span as short as 13±6 years [9], a time-frame consistent with other observations of rapid geomagnetic reversals [12,13].

There have been numerous instances with geomagnetic polarity durations shorter than the duration-existence of the present polarity (Figs. 1 and 2). There is presently no known way to estimate the onset of the next polarity reversal or excursion. There are indications that may show that a reversal might be imminent:

- As reported by Brown et al. [14]: "*The geomagnetic field has been decaying at a rate of ~5% per century from at least 1840, with indirect observations suggesting a decay since 1600 or even earlier.*"
- As reported by Olson and Amit [15]: "*The dipole moment of Earth's magnetic field has decreased by nearly 9% over the past 150 years and by about 30% over the past 2,000 years according to archeomagnetic measurements*".
- There has been recent accelerated movement of the North Dip Magnetic Pole, shown in Figs. 3 and 4.

2. GEOMAGNETIC FIELD PRODUCTION IDEAS

Despite the importance of understanding the nature of the geomagnetic field, especially its potential for disruption which could have devastating global consequences for modern humanity [8], almost all scientific publications about it are based upon the false assumption that the geomagnetic field is generated inside the Earth's fluid core.

Gauss [18] demonstrated that the seat of the geomagnetic field lies at or near the center of the Earth. Faraday [19] discovered that an electrical current of moving charges produces a magnetic field. Beginning in 1939, Elsasser [20-22] set-forth the idea that the geomagnetic field is produced by a current of moving charges driven by convection operating inside the Earth's fluid iron-alloy core that acts as a self-sustaining dynamo mechanism. For 80 years that concept has been widely assumed to be the case [8,23-27] without questioning the underlying scientific basis, without considering the inherent problems of the basic idea, or without citation of more recent and contradictory scientific literature.

In 1898 Wiechert [28] suggested that the Earth's whole-body density [29] could be explained if Earth has a core made of iron metal, like the iron meteorites he had seen in museums. Oldham [30] discovered the Earth's core in 1906 and by 1933 its size was precisely determined and it was understood to be fluid [31]. In 1936 Inge Lehmann [32] reasoned the existence of the inner core to explain observations of earthquake waves reflected into the 'shadow zone' (Fig. 5).

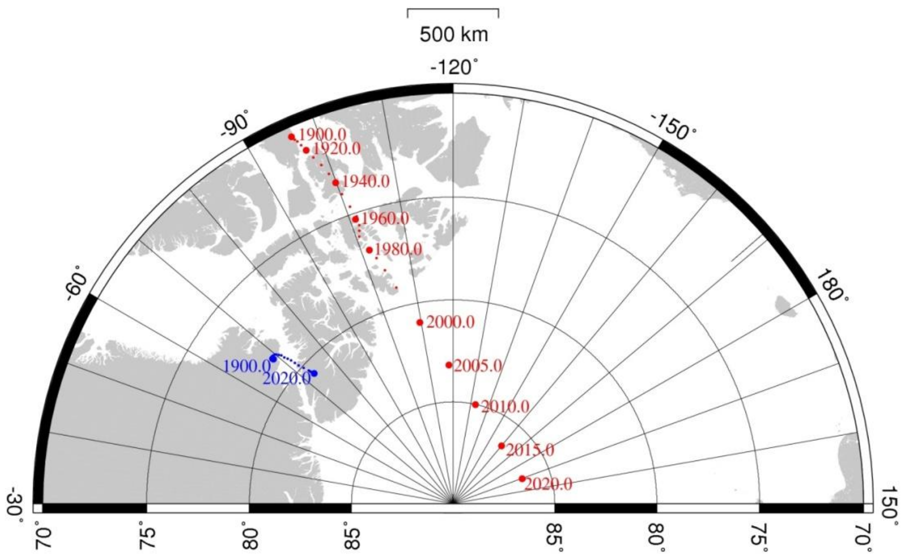

Fig. 3. Points in red show the movement of the North Magnetic Dip Pole, the position on the Earth's surface where the geomagnetic field is vertical. Points in blue show the movement of the North Geomagnetic Pole, a model result of a fictitious dipole through the Earth's center. Courtesy of the British Geological Survey

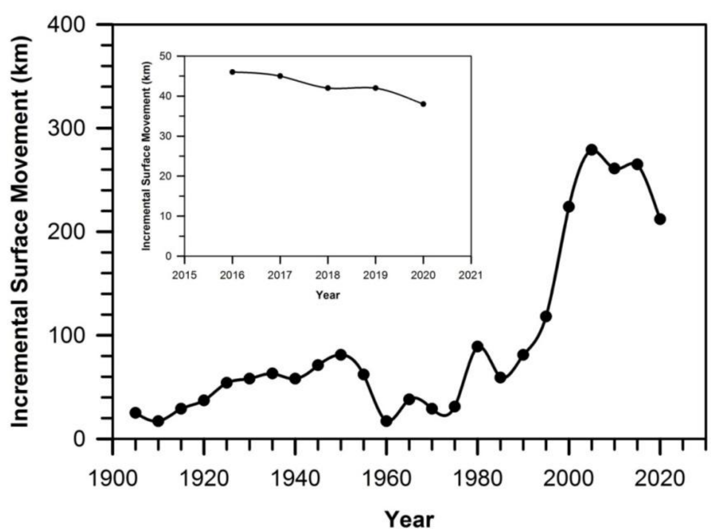

Fig. 4. Distance increment in km across the Earth's surface that the North Magnetic Dip Pole moved between dates indicated by five-year points of time. Data from [16]. Inset shows similar incremental North Magnetic Dip Pole surface movement (km) for recent one-year points of time. Data from [17]

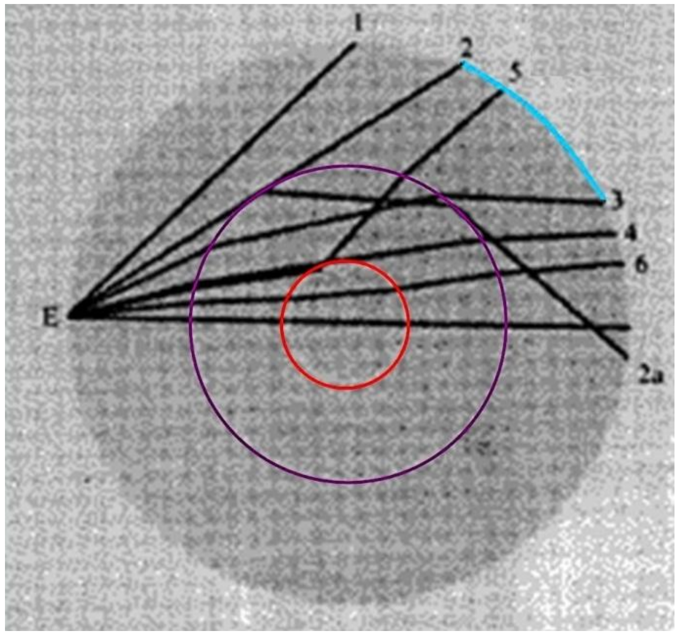

Fig. 5. A scan of Inge Lehmann's original diagram showing discovery of the Earth's inner core [32]. For improved clarity, the circles representing the inner core and the fluid core have subsequently been traced over in red and purple, respectively. The shadow zone, not specifically marked on her original diagram, is indicated in blue. Note the reflection of ray #5 into the shadow zone [33]

Explaining the composition of Lehmann's inner core began a progression of misunderstanding that confused generations of geophysicists, especially those concerned with the geomagnetic field, including its origin, energy source, and reversals.

The discovery of the inner core necessitated understanding its composition. At the time of its discovery and for decades thereafter, the composition of the Earth was imagined to be similar to that of an ordinary chondrite meteorite. In ordinary chondrites, nickel is always observed alloyed with iron metal [34,35]. Elements heavier than iron and nickel are insufficiently abundant, even when aggregated, to comprise a mass as great as the inner core. To explain the composition of the inner core, in 1940 Birch [36] assumed that the inner core was partially crystallized iron metal.

Eighty years later, geoscientists, nearly without exception, continue to assume that the inner core is partially crystallized iron metal. That assumed inner core composition informs obsolescent thinking about the generation of the geomagnetic field inside Earth's fluid core. Some even assume – without substantive evidence – that the inner core is growing [37,38]. No one seems to be aware of the problematic, unresolvable underlying assumptions. For example, does the Earth's core really resemble the alloy of an ordinary chondrite meteorite? If not, then what *is* the composition of the inner core, and what does the theoretical composition imply about the generation of the geomagnetic field, the potential causes for its disruption, and concomitant global security concerns?

Metal-bearing chondrite meteorites mainly consist of nickel-iron alloy, iron sulfide, and silicates. Upon heating in a gravitational field, iron metal and iron sulfide meld, liquefy, and settle by gravity beneath the less-dense silicate portion, similar to the way steel settles beneath slag on a steel-hearth [39,40]. Earth is like a spherical steel-hearth, its entire core or alloy part comprising 32.5% of the planet's mass [41]. As shown in Fig. 6, some enstatite chondrites have a sufficiently high percentage of iron-alloy to make such a massive core. Ordinary chondrites do not [42-44].

The fact that the Earth's core *does not* resemble the metal alloy of an ordinary chondrite calls into question the oft-quoted *assumption* that the inner

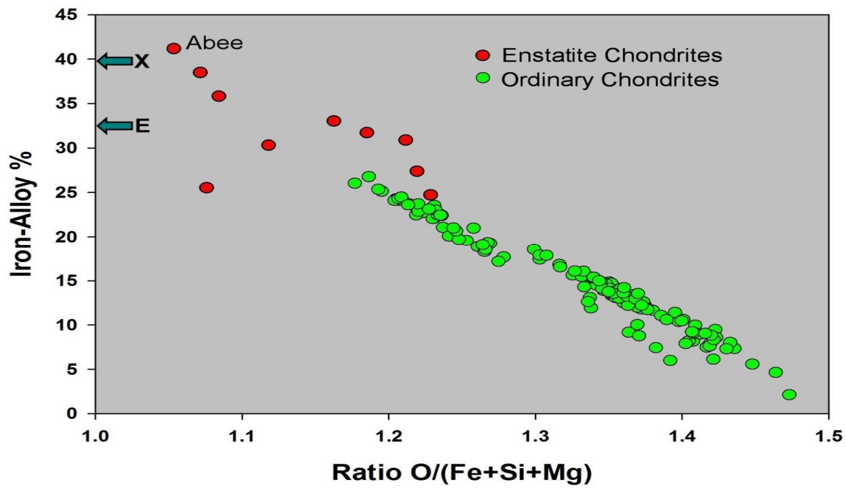

Fig. 6. Evidence that Earth resembles an enstatite chondrite. The percent alloy (iron metal plus iron sulfide) of 157 ordinary chondrites (green circles) and 9 enstatite chondrites (red circles) plotted against oxygen content. The core percent of the whole-Earth, “arrow E”, and of (core-plus-lower mantle), “arrow X”, shows that Earth resembles an Abee-type enstatite chondrite and does not resemble an ordinary chondrite. Data from references [45-48]

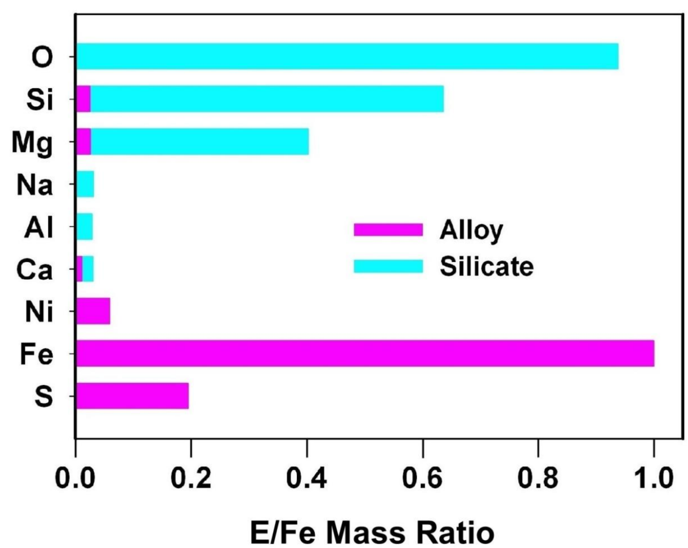

Fig. 7. Relative abundances of the major and minor elements in the Abee enstatite chondrite, normalized to iron, showing their relative amounts in the alloy and silicate portions. Note that calcium (Ca), magnesium (Mg), and silicon (Si), normally lithophile elements, occur in part in the alloy portion of enstatite chondrites, but not ordinary chondrites. Data from references [41,59,60]

core is partially crystallized iron metal. Why? The partially crystallized inner core idea was based upon the *false assumption* that the Earth’s core resembles the alloy of ordinary chondrite meteorites. Thus, the idea of the inner core growing [37,38], for which there is no independent corroborating evidence, cannot be assumed to be the energy source that produces the geomagnetic field.

In 1940, when Birch [36] propounded the idea of the inner core’s composition as partially crystallized iron metal in the process of freezing from the liquid iron core, he ignored the possibility of rare enstatite chondrites whose unusual mineral chemistry was then largely unknown, except for the mineral oldhamite, calcium sulfide (CaS) [49], which is not found naturally on Earth's surface. Subsequent discoveries related to components of the alloy portion of enstatite chondrites were necessary to understand the constituents of the Earth's enstatite-chondrite-like core. These crucial discoveries, however, were not made until the 1960s and 1970s: Silicon in the metal of enstatite chondrites [50]; niningerite, magnesium sulfide (MgS) [51] and, perryite, nickel silicide (Ni_2Si) [52-57]. Subsequently, in 1982, two important trace elements, uranium and thorium, were discovered in the alloy portion of the Abee enstatite chondrite [58]. These data provide a basis for understanding the chemistry of the Earth's core, which would have been impossible for Birch to have known in 1940.

Fig. 7 shows the relative proportion of high-oxygen-affinity elements present in the alloy portion of enstatite chondrites unlike as in ordinary chondrites.

3. EARTH'S INNER CORE AND ITS PRECIPITATES

While studying the mineralogy of enstatite chondrites, I realized the possibility that, if silicon exists within the Earth's fluid core, then in principle the silicon would combine with nickel to form a solid precipitate *more dense than the fluid core* and that it would have virtually the same mass as the actual inner-core mass. My new inner-core concept, derived logically, was published in 1979 in the *Proceedings of the Royal Society of London* [61]. The abstract in its entirety states: "From observations of nature the suggestion is made that the inner core of the Earth consists not of partially crystallized nickel iron metal but of nickel silicide."

Elements that have a high affinity for oxygen tend to be incompatible in iron-based alloys. Incompatible elements, like calcium and magnesium, in a cooling liquid iron alloy will seek a thermodynamically feasible way to come out of solution in a cooling liquid iron alloy. Industrially, to remove sulfur from high-quality steel, magnesium or calcium is injected into the molten iron which then combines with sulfur and floats to the surface [62-64]. In the Earth's core, calcium sulfide (CaS) and magnesium sulfide (MgS) can form solids at temperatures well above the melting point of iron, and float to the top of the core.

Dahm [65] and Bullen [66] first discussed the seismic irregularity at the boundary between Earth's core and its lower mantle. Subsequent investigations confirmed the existence of "islands" of matter at the boundary of the core [67,68] that accounts for the seismic "roughness" observed. Rather than being an artifact from the lower mantle, I showed that the "islands" of matter at the core-mantle boundary are understandable as low-density, high-temperature CaS and MgS precipitates from the Earth's enstatite-chondrite-like core [69-71] (Table 1).

Table 1. Fundamental mass ratio comparison between the endo-Earth (lower mantle plus core) and the Abee enstatite chondrite. Above a depth of 660 km, seismic data indicate layers suggestive of veneer, possibly formed by the late addition of more oxidized chondrite and cometary matter, whose compositions cannot be specified with certainty at this time [44]

Fundamental earth ratio	Earth ratio value	Abee ratio value
lower mantle mass to total core mass	1.49	1.43
inner core mass to total core mass	0.052	Theoretical 0.052 if Ni_3Si 0.057 if Ni_2Si
inner core mass to lower mantle **+** total core mass	0.021	0.021
D″ mass to total core mass	0.09***	0.11*
ULVZ** of D″ CaS mass to total core mass	0.012****	0.012*

** = avg. of Abee, Indarch, and Adhi-Kot enstatite chondrites, D" is the "seismically rough" region between the fluid core and lower mantle, ** ULVZ is the "Ultra Low Velocity Zone" of D", *** calculated assuming average thickness of 200 km, **** calculated assuming average thickness of 28 km data from [41,59,72]*

4. PROBLEMATIC EARTH CORE GEO-MAGNETIC DYNAMO

In the circa 1940 understanding of the Earth's core, assumed to be an iron alloy similar in composition to the iron metal of ordinary chondrites, there is no obvious source of energy in the fluid core to power the geomagnetic field. In 1950 Elsasser [22] realized that problem and suggested uranium and thorium oxides (UO_3 and ThO_2) might be incorporated in the core because of their high densities. Urey [73] disputed that idea believing that Earth resembled an ordinary chondrite. In ordinary chondrites, uranium tends to concentrate in CaO-rich mineral assemblages [74], which are not expected to occur in Earth's fluid core.

For 80 years geoscientists, have subscribed to the view that the Earth's inner core is made up of partially crystallized iron metal, and have either ignored the absence of a dynamo-powering energy source in the fluid core [75] and relied on fictive energy production or assumed "compositional" convection that results from hypothetical growth of the inner core [76,77]. These are no longer scientifically justified assumptions.

There are periods of time when the geomagnetic field has operated without reversals for millions of years (Fig. 1). Geoscientists [78-80] have not yet understood that sustained thermal convection, necessary for geomagnetic field production, is *physically impossible in Earth's core* [71,81].

In addition to the absence of a dynamo-driving-energy source, there are two reasons why convection is physically impossible in the core [71]. First, the core is 'bottom heavy', i.e. its density at the bottom is about 23% greater than at its top due to compression by the weight above. The potential decrease in density caused by thermal expansion, <1%, is insufficient to make the core 'top heavy' and result in convection [82]. Further, for stable thermal convection, heat brought to the top of the core must be efficiently removed to maintain the adverse temperature gradient required for convection [82]. But that is not possible because the core is wrapped in a thermally-insulating silicate blanket, the mantle, which has lower thermal conductivity, lower heat capacity, and higher viscosity than the core [71].

5. NUCLEAR GEOREACTOR GEO-MAGNETIC FIELD GENERATION

In 1982 Murrell and Burnett [58] discovered that uranium in the Abee enstatite chondrite resides in its alloy component. A decade later I published the justification that uranium in the Earth's core would be a high temperature precipitate and would settle to the planet's center [69]. In a series of publications beginning in 1993 through 2006 [43,69,83-87], I demonstrated the feasibility of the planetocentric uranium maintaining a self-sustaining nuclear fission chain reaction. The georeactor, as it came to be known, provides both the energy source for geomagnetic field generation, and a location, not in the fluid core (Fig. 8), but in the georeactor itself, wherein the geomagnetic field could be generated by Elsasser's [20-22] dynamo mechanism. To date no one has refuted this theory's validity.

The following is part of the abstract of the first georeactor review article published in 2014 [44]: The background, basis, feasibility, structure, evidence, and geophysical implications of a naturally occurring Terracentric nuclear fission georeactor are reviewed. For a nuclear fission reactor to exist at the center of the Earth, all of the following conditions must be met*: (*1) There must originally have been a substantial quantity of uranium within Earth's core; (2) There must be a natural mechanism for concentrating the uranium; (3) The isotopic composition of the uranium at the onset of fission must be appropriate to sustain a nuclear fission chain reaction; (4) The reactor must be able to breed a sufficient quantity of fissile nuclides to permit operation over the lifetime of Earth to the present; (5) There must be a natural mechanism for the removal of fission products; (6) There must be a natural mechanism for removing heat from the reactor; (7) There must be a natural mechanism to regulate reactor power level; and; (8) The location of the reactor must be such as to provide containment and prevent meltdown. Herndon's georeactor alone is shown to meet those conditions. Georeactor existence evidence based upon helium measurements and upon antineutrino measurements is described. Geophysical implications discussed include georeactor origin of the geomagnetic field, geomagnetic reversals from intense solar outbursts and severe Earth trauma, as well as georeactor heat contributions to global dynamics.

From a global security standpoint, the relevance of the georeactor bears directly upon the causes of geomagnetic reversals and *the rapidity with which they might occur*, as well as the possibility that geomagnetic collapse might be initiated by human activity. And there are uncertainties about georeactor output, specifically potential increases in output as georeactor convection declines, as well as the possibility of the georeactor triggering earthquakes and volcano eruptions.

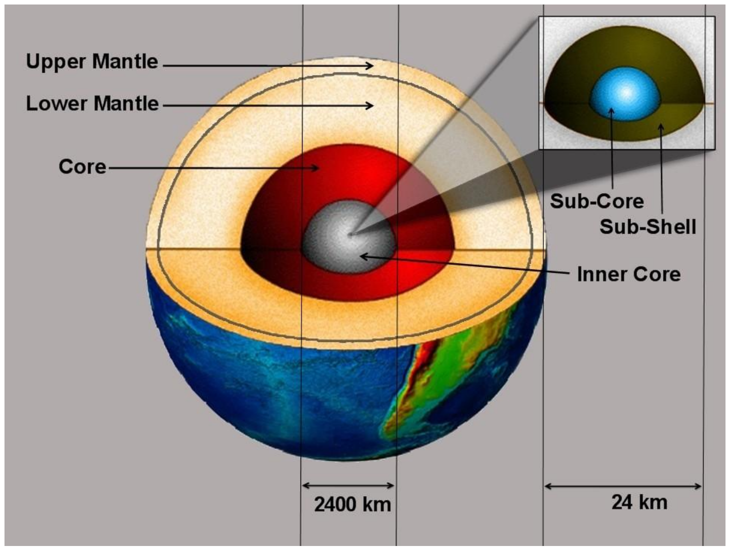

Fig. 8. Earth's nuclear fission georeactor (inset) shown in relation to the major parts of Earth. The georeactor at the center is one ten-millionth the mass of Earth's fluid core. The georeactor sub-shell is the liquid (or slurry) repository for nuclear fission-products. The georeactor sub-shell, situated between the nuclear-fission heat source and inner-core heat sink, assures stable thermal convection. That stable thermal convection is necessary for sustained geomagnetic field production by convection-driven dynamo action in the georeactor sub-shell [84,86,88]

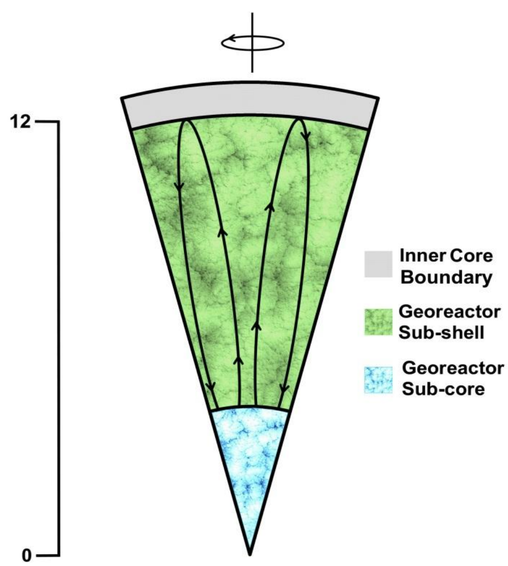

Fig. 9. Schematic representation of the georeactor. Planetary rotation and fluid motions are indicated separately; their resultant motion is not shown. Stable convection with adverse temperature gradient and heat removal is expected. Scale in km [44]

Fig. 9 is a schematic representation of the georeactor at Earth's center which consists of two components: The nuclear fission sub-core where sustained nuclear fission chain reactions take place, and the nuclear waste sub-shell where the products of radioactive decay and nuclear fission collect which is where convection takes place. Heat produced by the nuclear fission sub-core is transported by convection to the heat sink that is the inner core which is surrounded by a much more massive heat sink, the Earth's core. Planetary rotation twists the convecting fluid which produces dynamo-action to generate the geomagnetic field. This is a self-regulating mechanism that is generally applicable to planetary and planetary-moon nuclear fission reactors [88,89].

6. GEOREACTOR GEOMAGNETIC FIELD COLLAPSE

There are profound differences between georeactor geomagnetic field production and the 1930s idea [20] of its production in Earth's core, which has a mass almost one-third that of our planet. The georeactor mass is one ten-millionth the mass of the fluid core. Consequently, disruption in georeactor convection can occur quite quickly.

As noted above, there is evidence from ancient lava flows of instances of rapid geomagnetic field change, six degrees per day during one reversal and one degree per week during another [12,13], and the last reversal possibly occurring in 13.6 years [9]. These brief instances point to the likelihood of a magnetic reversal occurring on a time scale as short as one month or several years, which is consistent with the relatively small mass of the georeactor. Humanity is wholly unprepared to deal with such a rapid collapse of the georeactor-generated geomagnetic field. Moreover, one cannot reasonably assume that the next polarity reversal and its recovery will be as rapid as these scattered data indicate. That is simply unknown.

Reversals are usually thought to represent geomagnetic field collapse with subsequent re-establishment of stability. In addition to natural radioactive decay, nuclear fission consumes uranium fuel. At some yet unknown point in time, the georeactor will essentially run out of its nuclear fuel and will be unable to re-establish convection. At that point, Earth will forever be without a geomagnetic field [85].

Geomagnetic field collapse is expected to occur when stable convection in the nuclear waste sub-shell is disrupted, for example, by trauma such as an asteroid collision, or the eruption of a super-volcano (perhaps Yellowstone), or by a major continental fragmentation attempt driven by whole-Earth decompression [43,90].

Disruption of convection in the nuclear waste sub-shell may also result from extreme coronal mass ejections from the sun as previously described [44]: The geomagnetic field deflects the brunt of the solar wind safely past the Earth, but some charged particles are trapped in donut-shaped belts around the Earth, called the Van Allen Belts. The charged particles within the Van Allen Belts form a powerful ring current that produces a magnetic field that opposes the geomagnetic field near the equator. If the solar wind is constant, then the ring current is constant and no electric currents are transferred through the magnetic field into the georeactor by Faraday's induction. High-intensity changing outbursts of solar wind, on the other hand, will induce electric currents into the georeactor, causing ohmic heating in the sub-shell, which in extreme cases might disrupt convection-driven dynamo action and lead to a magnetic reversal.

A frightening potentiality is that human efforts to cause an EMP, electromagnetic pulse, for hostile purposes, for example, by detonating hydrogen bombs in the Van Allen Belts, might intentionally or unintentionally lead to georeactor-convection disruption and geomagnetic field collapse.

Initially, I applied Fermi's nuclear reactor theory [91] to demonstrate the feasibility of a nuclear fission reactor at Earth's center [69,83,84]. Subsequent calculations were made using the nuclear reactor software developed at Oak Ridge National Laboratory [85,87,92]. These numerical simulations demonstrated that the georeactor could function over the lifetime of our planet as a fast fission breeder reactor. The numerical simulations also provided data on fission products that were not available from Fermi's nuclear reactor theory calculations.

One notable fission-product result was that the ^{3}He and ^{4}He are produced in the same range of ratios observed in volcanic material [85], which previously had been inexplicable except by *ad hoc* speculations [93,94]. The observed helium ratios in volcanic material [93,95,96] provided the first evidence of georeactor existence. Further georeactor-existence evidence was later obtained from geoneutrino measurements [97] as the geoneutrino spectrum from georeactor

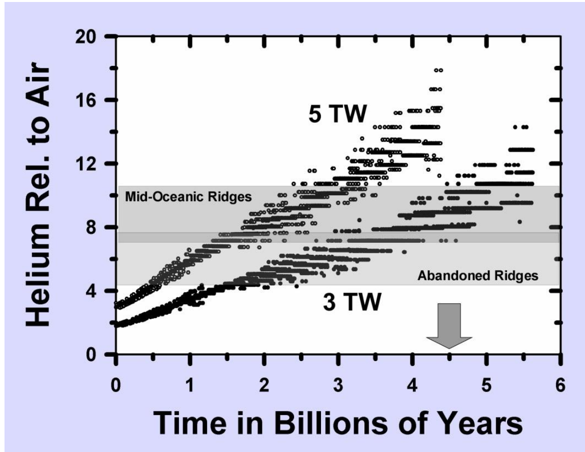

Fig. 10. Fission product ratio of $^3He/^4He$, relative to that of air, RA, from nuclear georeactor numerical calculations at 5 TW (upper) and 3 TW (lower) power levels[85]. The band comprising the 95 % confidence level for measured values from mid-oceanic ridge basalts (MORB) is indicated by the solid lines. The age of the Earth is marked by the arrow. Note the distribution of calculated values at 4.5 Gyr, the approximate age of the Earth. The increasing values are the consequence of uranium fuel burn-up. Iceland deep-source ‘‘plume’’ basalts present values ranging as high as 37 RA [95] [98]

nuclear fission differs from the spectrum of radioactive decay.

Georeactor helium isotope production varies over time. If the georeactor operates at a constant energy level, the tritium production, which decays to ^3He, is constant. The level of ^4He production, however, decreases over time as much of it comes from the radioactive decay of the uranium fuel, which is constantly being diminished by nuclear fission and by radioactive decay. Thus the ratio $^3He/^4He$ increases over time as shown in Fig. 10.

Thermal structures beneath the Hawaiian Islands and Iceland, imaged by seismic tomography [99,100] are two high $^3He/^4He$ hotspots. These thermal structures, which extend to the interface of Earth's core and lower mantle, appear to be heat channels [71], conduits for heat removal from Earth's core. The high mobility of helium apparently allows it to move to the surface through these channels.

As indicated by the data shown in Fig. 10, the high $^3He/^4He$ ratios measured in hotspot lavas appear to be the signature of ‘recent’ georeactor-produced heat and helium, where ‘recent’ may extend several hundred million years into the past. Catastrophic events in the geological past have sometimes, but not always, been associated with both high $^3He/^4He$ ratios and geomagnetic reversals. The Siberian Traps, massive flood basalts 250 million years ago, is one example [101,102] that occurred about the time of the End-Permian [a.k.a. Permian-Triassic] mass-extinction [103,104]. Another example [105,106] is the Indian massive flood basalt, the Deccan Traps that took place 65 million years ago about the time of the Cretaceous–Paleogene [a.k.a. Cretaceous–Tertiary] mass-extinction [103,104]. From the helium data [102,106], energy from the georeactor figured prominently in these and in other cataclysms.

Currently, volcanos of the East African Rift System, which is slowly splitting apart the African continent [98], are spewing lava that is characterized by the high $^3He/^4He$ ratios [107] indicative of georeactor-produced heat [85].

The Yellowstone volcano, potentially a super-volcano [108], is fed by georeactor energy as indicated by the observed high $^3He/^4He$ ratios [109]. Although the time-frame for the next eruption is unknown, its magnitude will likely be extreme. A previous explosive eruption about 640,000 years ago ejected about 1,000 km^3 of volcanic-material [110].

Although rare, from time to time in science a paradigm-shift occurs that necessitates a universal revision of understanding [111]. Occasionally, the transition into a new understanding proceeds quickly and smoothly, as in the case of DNA [112]. Geological science, however, is especially resistant to change. For example, Wegener [113,114] displayed considerable evidence supporting the idea of continental displacement, but the idea of continent-mobility was frequently ignored for half a century until plate tectonics was envisioned [115]. But, particularly for reasons of global human security, the geological community should open itself to new ideas. Prudence dictates having global security monitoring and preparedness for a geomagnetic disaster that could potentially devastate our highly vulnerable technological infrastructure, and rapidly transport a 21st century population into a realm of 18th century infrastructure with great suffering and loss of life.

7. GEOREACTOR CONSIDERATIONS, LIMITATIONS AND UNKNOWNS

There are two primary energy sources for major geodynamic activities that are typically not discussed in the geoscience literature, georeactor nuclear fission energy [44] and the much greater stored energy of protoplanetary compression [43,89,90,116]. An intrinsic connection between the two fundamental planetary energy systems exists and manifests in Earth's surface dynamics.

There is evidence to indicate that Earth initially formed as a Jupiter-like gas giant, its rocky kernel surrounded by 300 Earth-masses of gases and ices [89]. The violent solar winds, associated with the thermonuclear ignition of the sun, stripped the gases and ices from the proto-Earth leaving a rocky kernel, compressed to about two-thirds the diameter of our present planet, enclosed by a contiguous rocky shell without ocean basins. Over time, heat from georeactor nuclear fission and radioactive decay began to replace the lost heat of protoplanetary compression, pressures began to build, the planet's outer surface began to crack, and the process of decompression began, as described by the theory of Whole-Earth Decompression Dynamics (WEDD) [43,90,116].

During whole-Earth decompression two fundamental processes necessarily must take place:

- New surface area must be created to accommodate the expanding diameter of Earth.
- Curvature of Earth's surface must change.

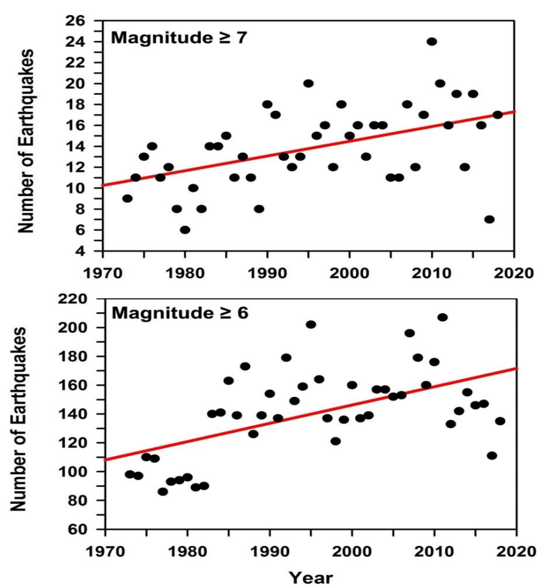

Fig. 11. The annual number of global earthquakes, magnitudes ≥ 6 and ≥ 7, from the U. S. Geological Survey database [119] shown with linear regression fit lines. This figure clearly shows that there has been a dramatic increase in the annual number of global earthquakes in the indicated magnitude ranges over the time interval 1973-2018. For earthquakes of magnitude ≥ 6, the average increase is 51.0%; for earthquakes magnitude ≥ 7, the average increase is 59.3%

Table 2. Statistics from Fig. 11

	Earthquake magnitude ≥ 6	Earthquake magnitude ≥ 7
Linear Regression	y = 1.2693x – 2392.3 R^2 = 0.3117	y = 0.1408x – 267.11 R^2 = 0.2421
Percent Increase	from 1973 to 2018 51.0%	from 1973 to 2018 59.3%

Whole-Earth decompression causes cracks to form in Earth's surface as it expands. Cracks underlain by heat sources extrude basalt; cracks without heat sources serve as sinks into which extruded-basalt eventually falls and infills as it flows by gravitational creep. This is the origin of ocean basins and seafloors [43,90].

Whole-Earth decompression necessitates changes in surface curvature which takes place primarily by the formation of surface tucks. The surface tucks bend, fall over, and break thus forming chains of mountains characterized by folding [117]. Secondarily, tension fractures around the continental edges explain the primary origin of fjords and submarine canyons [118].

The association of major volcanism and/or continent-splitting events with georeactor heat, as indicated by high $^3He/^4He$ ratios, begs the question whether georeactor variations can trigger decompression-driven volcanism, such as the Siberian Traps [101,102], Deccan Traps [105,106], and the East African Rift System [98] among others. This is simply not known. Also unknown: Could a major pulse in georeactor energy trigger eruption of the Yellowstone super-volcano whose georeactor-supplied heat is strongly indicated by high $^3He/^4He$ ratios [108]?

Although not often discussed in the scientific literature, the frequency of major earthquakes appears to be increasing, based upon tabulations published by the U. S. Geological Survey (Fig. 11). Statistical data are presented in Table 2. A fundamental unknown is whether the current increase in earthquakes is related to changes in georeactor output.

Although the georeactor numerical simulations were calculated assuming constant georeactor energy production, there is evidence that Earth's georeactor may possess some degree of variability. Mjelde and Faleide [120] discovered a periodicity and synchronicity through the Cenozoic in lava outpourings from Iceland and the Hawaiian Islands. These are georeactor-fed hotspots on opposite sides of the globe that Mjelde et al. [121] suggest may arise from variable georeactor heat-production.

There is much to learn about the nature and operation of Earth's georeactor, but there are also some stringent constraints. The georeactor must be able to maintain stable operation for periods measured in millions of years (Fig. 1). During that time the fissioning-portion must be able to rid itself of fission-product reactor poisons. Presumably, fission-fragments can be separated by density in the micro-gravity environment because fission fragments are roughly half the mass of the uranium atom. The georeactor self-regulatory mechanism must also be able to maintain a more-or-less constant energy output even though over time there is great variation in the amount of fissionable ^{235}U [44,87]. Further, the georeactor must be able to function as a fast-neutron breeder reactor; otherwise fissionable ^{235}U would have been depleted 2,000 million years ago. Moreover, the georeactor must be a naturally occurring configuration as planetocentric nuclear reactors are common occurrences in planets and large moons [88,122].

Among the georeactor unknowns is whether uranium is mixed with the decay-products of the convecting sub-shell fluid, and whether, when convection is disrupted, uranium will settle out and cause a sudden nuclear-fission flare-up that might trigger further whole-Earth decompression and concomitant earthquakes and volcanic eruptions.

8. REVIEW SUMMARY

- The inevitable collapse of the geomagnetic field during the next polarity reversal or excursion will have dire consequences for humanity. Williams [8] cogently described some of the potential harm to the infrastructure, but he relies on scientific theories developed in the 1930s, 1940s, 1950s and 1960s that constrict his understanding of potential consequences that derive from subsequent scientific advances.
- Old ideas about the generation of the geomagnetic field are based upon the following *incorrect* concepts: Earth resembles an ordinary chondrite meteorite; the inner core is composed of partially

crystallized iron metal; the inner core is growing; Earth's fluid core is convecting; the geomagnetic field is produced by convection-driven dynamo action within the fluid core; and, growth of the inner core provides energy to power the geomagnetic field.

- The following are *more-correct* concepts related to the generation of the geomagnetic field: The inner 82% of Earth resembles an enstatite chondrite meteorite; the inner core consists of fully crystallized nickel silicide; the inner core is not growing; stable thermal convection in Earth's fluid core is physically impossible; there exists a planetocentric nuclear fission reactor, called the georeactor; the geomagnetic field is produced by convection-driven Elsasser-dynamo action within a portion of the georeactor; and, georeactor nuclear fission energy powers the geomagnetic field.
- The georeactor mass is one-ten millionth that of the fluid core. Consequently, geomagnetic reversals can potentially occur more quickly than previously thought. Geomagnetic field disruptions occur as a consequence of convection disruption in the convecting decay-products sub-shell portion of the georeactor. Georeactor convection disruption can potentially occur as a consequence of trauma to the Earth or by an intense solar coronal outburst that induces electrical currents into the georeactor.
- Human efforts to cause an electromagnetic pulse, EMP, for hostile purposes, for example, by detonating hydrogen bombs in the Van Allen Belts, might lead to georeactor-convection disruption and geomagnetic field collapse, intentionally or unintentionally.
- At some yet unknown point in time, the georeactor will essentially run out of its nuclear fuel and will be unable to re-establish convection, marking the end of the geomagnetic field.
- Virtually all solid-Earth geodynamic activity is driven by the stored energy of protoplanetary compression, radioactive decay and georeactor nuclear fission energy. There is a historical association of some instances of major flood basalt eruptions, e.g. Siberian and Deccan Traps, with georeactor heat, magnetic reversals, and the stored energy of protoplanetary compression. That association begs the question of whether the present inevitable geomagnetic field collapse might trigger some devastating geological events such as the eruption of the Yellowstone super-volcano.
- Global security preparedness for a geomagnetic collapse is presently non-existent.

9. CONCLUSIONS

Williams [8] provided a thorough description of some of the risks to United States' national security and infrastructure that could be expected to result from a geomagnetic polarity reversal. His descriptions were based on a scientific literature that is founded on old, problematic ideas.

My review of the historical development of those old ideas, their problematic nature, and the subsequent published advances that overcome their inherent problems leads to a better understanding of the geophysics involved in Earth's geomagnetic polarity reversals and, at some yet unknown time, the permanent demise of the geomagnetic field. The global security concerns that logically follow do not contradict the concerns described by Williams [8], but clarify the science underlying the threats and extend them to a global context.

The extended global security concerns related to reasonable certainties of geomagnetic field collapse pertain to:

- Potential rapidity of geomagnetic collapse, the georeactor being one ten-millionth the mass of the fluid core;
- Potential georeactor convection disruption from trauma to the Earth by virtue of the low georeactor mass;
- Potential of massive solar flare induced georeactor heating disrupting georeactor convection;
- Potential human-caused georeactor convection-disruption by an EMP weapon.

The extended global security concerns related to yet unknown aspects of georeactor geomagnetic field collapse include:

- Questions of whether geomagnetic field collapse might lead to georeactor bursts of energy;

- Whether the present inevitable geomagnetic field collapse might trigger some devastating geological events such as earthquakes and volcano eruptions, potentially including triggering the eruption of the Yellowstone super-volcano.

Global security preparedness should be predicated upon the latest and most correct scientific understanding.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ETHICAL APPROVAL

The author holds that technical, scientific, medical, and public health representations made in the scientific literature in general, including this particular journal, should be and are truthful and accurate to the greatest extent possible, and should serve to the highest degree possible to protect the health and well-being of humanity and Earth's natural environment.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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