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Moon's Two Faces: Near-Side/Far-Side Maria Disparity

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ABSTRACT

Any attempt to understand the origin of lunar maria must as well account for the dearth of maria on the far-side of the Moon. Various attempts have been made to explain the origin of lunar maria based solely upon obvious lunar processes, namely, volcanism and impact phenomena. Here I review a different explanation for the origin of lunar maria by analogy with observations of Earth, specifically related to its central nuclear fission georeactor. Georeactor formation is a natural consequence of density layering in oxygen-starved (highly-reduced) planetary matter and is ideally suited for magnetic field generation in planets and large moons. A portion of georeactor produced heat is channeled to Earth's surface hot-spots, e.g., Hawaii and Iceland, where its georeactor origin is indicated by the high relative $^3He/^4He$ ratios observed, and seismically imaged heat channels extending to the top of the core. Massive basalt floods, e.g., Deccan and Siberian Traps were driven by georeactor-produced heat as indicated by the high relative $^3He/^4He$ ratios of their occluded helium. These terrestrial basalt floods suggest to me that the lunar maria might have similar origins driven by the Moon's nuclear fission "lunar-reactor." Remanent magnetization of some lunar surface material is indicative of an ancient internally-generated magnetic field. That implication is consistent with the magnetic fields produced by central nuclear fission reactors in many planets and large moons. The location of the lunar-reactor at the Moon's center of mass, displaced 2 km toward the Earth-facing side, in concert with Earth's tidal pull, I posit, is principally responsible for driving the maria-basalt floods toward the Earth facing side of the Moon. In principle, it should be possible to verify the correctness of this concept by measuring the helium isotopes of maria basalt samples taken from depths sufficient to be unaffected by solar wind implanted helium.

INTRODUCTION

Much of the temporal biology of life on Earth is regulated and/or influenced by the daily, seasonal, lunar and tidal geophysical cycles [1, 2]. The Moon figures prominently in agriculture [3-5], wildlife behavior [6-9], spiritual matters [10-12], and romance [13-15] (Figure 1) and in legend. As adapted from [16]:

"Chang'E flying to the moon is a beautiful legend in ancient China. Chang'E is a lady graceful of carriage and unparalleled of beauty. After she secretly swallowed the elixir of immortality, she felt herself becoming light. She flew up in spite of herself, drifting and floating in the air, until she reached the palace of the moon. Once on the moon, Chang E became a three-legged toad, as punishment from the Queen Mother [for] going to clasp the moon in the Ninth Heaven."

Figure 1. The inextricable connection between romance and the Moon. Photo by El Salanzo, Unsplash.com.

As noted by Lihua [17]:
"The Moon has fascinated mankind throughout the ages, full of romantic and blue color. By simply viewing with the naked eye, one can discern two major types of terrains on the moon: relatively bright highlands and darker plains…. people like to put the moon into literature particularly poems to express variety of their emotions. The image of the full moon has been endowed with many symbolic meanings over the world, often out of aesthetic need."

For as long as humans have gazed at the Moon, they have seen the same two-component face, rarely if ever thinking that the opposite face might be substantially different, that the Moon might have two faces. That changed in 1959 when the Soviet Luna 3 spacecraft first photographed the Moon's far side [18].

Lunar maria, the great dark plains, and the lighter highlands are prominent features of the Earth-facing surface of the Moon. The lunar highlands are composed of Ca-Al rich anorthositic rocks, whereas the lunar maria are composed of basaltic lava flows [19, 20]. Any attempt to understand the origin of lunar maria must as well account for the fact that maria are nearly absent on the far-side of the Moon (Figure 2).

Figure 2. NASA image of the near side and far side of the Moon

Scientists have long puzzled about the origin and nature of the Moon [21-23]. In 1974, when I earned the Ph.D. degree, Moon investigations were "all the rage" in the geoscience community. But I abstained, concerned that there were still missing pieces to the puzzle. Then, in 2022, inspiration arrived in a most unexpected way.

Dorion Sagan [24] asked me a question as to the veracity of investigations about the reason for the Moon's facial disparity. Why he wanted to know was both of historical and romantic interest. His question arose while reading love letters from his father, astrophysicist Carl Sagan [25] to his mother, evolutionary biologist Lynn Margulis [26]. In the letter, his father, perhaps tauntingly, referred to the "two Marias" (i.e., Moon and Mars) he had been seeing.

Various attempts have been made to explain the origin of lunar maria based solely upon obvious lunar processes, namely, volcanism and impact phenomena [27-29]. After being asked the question by Dorion Sagan, the thought occurred to me that the two disparate faces of the Moon might be understood by considering processes on Earth.

Here I review the quite different, but logical, explanation for the origin of lunar maria [30] derived through analogy with observations of Earth. I describe a way to test the validity of the concept presented, and discuss some potential implications.

UNDERLYING SCIENTIFIC BACKGROUND

Phenomena in nature are rarely isolated events, but are usually connected logically and causally by a series of processes. So, it is with understanding the nature and composition of the Earth and, as well, the observed disparity of the near side and far side of the Moon (Figure 2).

The solar system and its components formed from well-mixed primordial matter having a well-defined chemical composition that resembles spectroscopically-observed matter comprising the photosphere of the sun [31-34]. Among the various types of meteorites, chondrites possess chemical compositions that are somewhat similar to the relatively non-volatile elements of the photosphere. Chondrites are comprised of three groups of meteorites that differ mainly in their states of oxidation:

- Ordinary chondrites
- Carbonaceous chondrites
- Enstatite chondrites

Since graduate school, I have investigated those three groups of chondrites, not necessarily to learn how those meteorites formed, but principally to discover the fundamental processes that operated during the early period of planetary formation.

Since the 1940s, numerous geologists and geophysicists have believed that Earth resembles an ordinary chondrite, the most frequently recovered chondrite, which consists of nickel-containing iron metal and silicates. The rare carbonaceous chondrites are so oxidized that iron does not occur as metal. The enstatite chondrites were largely ignored due to their rarity and oxygen-poor mineral composition that was unlike rocks of Earth's surface. For a general review of chondrites, see [35].

My focus on the enstatite chondrites led to the following new concepts and discoveries.

- Solar System formation occurred primarily according to the protoplanetary theory, minimally by the planetesimal theory [36, 37]
- Stored energy of protoplanetary compression as the primary energy driving geodynamics [37-39]
- Nuclear fission georeactor at Earth's center [40-45]
- Terracentric nuclear fission energy as the secondary energy driving geodynamics [38, 39, 44]
- Basis of heat transport within the Earth [37, 46, 47]
- Earth's magnetic field powered and produced by the Terracentric nuclear fission georeactor [44, 48]
- Whole-Earth Decompression Dynamics, the fundamental basis of geodynamics and geology [38, 49], not requiring physically impossible mantle convection [47], including
    1. New concept for the origin of mountains characterized by folding [50]
    2. New concept for the origin of fjords and submarine canyons [51]
- Georeactor origin of deep-Earth helium-3 [43]
- Planetocentric nuclear fission reactors as the basis for magnetic field generation in planets and large moons [52, 53]
- Whole-Mars Decompression Dynamics [54]
- Hydrogen geysers on Mercury [55] and Mars [54]

Even in light of all of these new concepts and discoveries one cannot unambiguously ascertain the Moon's origin. Pieces of the puzzle are still missing which, I suspect, might be found by better understanding details of Earth's origin.

The Moon's maria are similar to flood basalts on Earth [56], two flood basalts in particular, the Deccan Traps [57, 58] and the Siberian Traps [59, 60].

Helium data from the Deccan Traps in India [61] that formed 65 million years ago and from the Siberian Traps [62] that formed 250 million years ago bear the isotopic fingerprint of having been produced by Earth's central nuclear fission georeactor [43]. Helium trapped in contemporaneous basalt floods that form the Hawaiian Islands and Iceland likewise bear the isotopic signature of georeactor-produced helium [63] (Figure 3). Moreover, thermal structures or heat channels beneath the Hawaiian Islands and Iceland have been seismically imaged as extending all the way to the top of Earth's fluid core [64, 65].

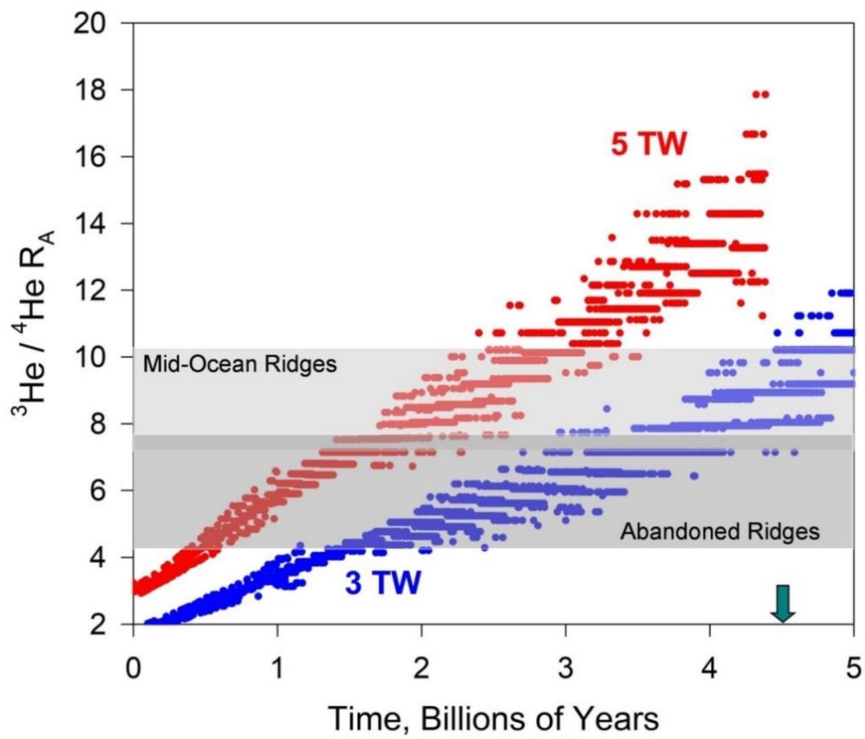

Figure 3. Fission product ratio $^3He/^4He$, relative to that of air, R_A, from nuclear georeactor numerical calculations at 5 terawatts, TW, (upper) and 3 TW (lower) power levels [43]. The band for measured values from mid-oceanic ridge basalts is indicated by the solid lines. The age of the Earth is marked by the arrow. Note the distribution of calculated values at 4.5 billion years, the approximate age of the Earth. The increasing values are the consequence of uranium fuel burn-up. Icelandic deep-Earth basalts present values that range as high as 50 times the atmospheric value [66].

Two independent lines of evidence support Earth's georeactor existence:

- Calculated georeactor nuclear fission production of $^3He/^4He$ ratios are in precisely the range of ratios observed in oceanic basalts [43].
- Geoneutrino (antineutrino) measurements, at a 95% confidence level, at Kamioka, Japan [67] and Grans Sasso, Italy [68], indicate georeactor nuclear fission output energy of 3.7 and 2.4 terawatts, respectively. These fissionogenic energy values are similar to

the 3–6-terawatt range employed in Oak Ridge National Laboratory georeactor simulations [43, 45].

Georeactor formation is a natural consequence of density layering in oxygen-starved (highly-reduced) planetary matter [40-42]. The two-component, self-regulated [69] nuclear fission georeactor assembly is capable of sustained thermal convection in its charged-particle-rich sub-shell, and is ideally suited for magnetic field generation in planets and large moons [37, 48, 52] (Figure 4).

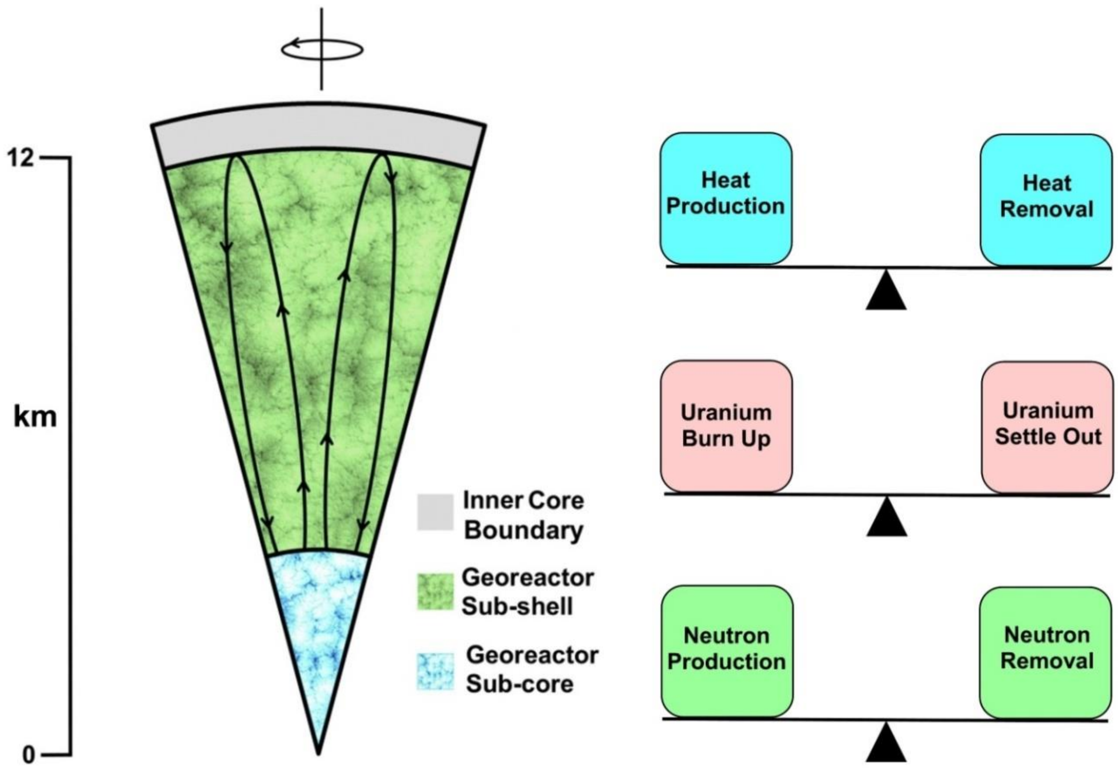

Figure 4. Schematic representation of Earth's georeactor, not to scale, with non-resultant planetary and fluid motions indicated separately (left) and (right) representations of the balances that must be maintained for stable georeactor operation. From [69].

Fissionogenic heat produced by the georeactor's nuclear sub-core is transferred via convection in the nuclear waste sub-shell to the inner-core heat sink and then to the larger fluid-core heat sink [44]. A portion of the georeactor produced heat is channeled to Earth's surface hot-spots [47], e.g., Hawaii and Iceland, where its georeactor origin is indicated by the high relative $^3He/^4He$ ratios observed [70] and seismically imaged heat channels extending to the top of the core [64, 65].

ORIGIN OF LUNAR MARIA

As noted above, the massive basalt floods, the Deccan Traps and the Siberian Traps were driven by georeactor-produced heat as indicated by the high relative $^3He/^4He$ ratios of their occluded helium [61, 62]. These terrestrial basalt floods suggest to me that the lunar maria might have similar origins driven by the Moon's nuclear fission "lunar-reactor."

Although the Moon currently has no internally generated magnetic field, remanent magnetization of some of its surface material is indicative of an ancient internally-generated magnetic field [71, 72]. That implication is consistent with the magnetic fields produced by central nuclear fission reactors in many planets and large moons [36, 52].

Earth's formation at high temperatures and high pressures from within a giant gaseous protoplanet resulted in its inner 82%, i.e., the core and lower mantle, being oxygen starved (highly reduced) [36, 37, 73]. Consequently, some of the elements that have a high affinity for oxygen were partially occluded in the iron-alloy core [47, 74]. When thermodynamically feasible, these elements precipitated and separated from the alloy [75]. Uranium, presumably as a sulfide, settled to Earth's center. Silicon combined with nickel settled to form Earth's nickel silicide inner core. Calcium and magnesium combined with sulfur floated to the top of Earth's core [76, 77].

In 1993, I employed Fermi's nuclear reactor theory [78] to demonstrate the feasibility of a nuclear fission georeactor at Earth's center [40-42]. In 2001, Dan Hollenbach and I published the results of nuclear georeactor simulation results performed at Oak Ridge National Laboratory [45]. These results showed that the georeactor could operate over Earth's lifetime as a fast neutron breeder reactor. Moreover, subsequent measurements showed that georeactor-produced helium isotope ratios matched helium from terrestrial deep source lavas [43], as pointed out above.

Thus, it is reasonable to suspect that, when the Moon's nuclear fission reactor was in operation, it would provide the heat channeled to the lunar surface to produce the Moon's flood basalts, i.e., the maria.

The location of the lunar-reactor, however, is not at the Moon's center, but at the Moon's center of mass, which is displaced 2 km toward the Earth-facing side [79]. That displacement toward the Earth-facing side in concert with Earth's tidal pull [80], I posit, is principally responsible for driving the maria-basalt floods toward the Earth facing side of the Moon [30].

In principle, it should be possible to verify the correctness of this concept as an explanation for near-side maria bias by measuring the helium isotopes of maria basalt samples taken from depths sufficient to be unaffected by solar wind implanted helium.

CONCLUSIONS

When first inspired to look into the problem of the Moon's near-side/far-side maria disparity by Dorion Sagan's question, I was fortunate to have already related, logically and causally, much understanding of Earth's origin, composition, and concomitant geological behavior. This understanding was crucial, because in nature events are rarely independent, but usually are connected to other events and circumstances. Thus, many scientific discoveries can result from a logical progression of understanding, connecting step-by-step events in nature that are related logically and causally, and securely anchored to the properties of matter and radiation. Despite all of the insights and discoveries made so far, there are more details to understand about Earth's formation which, when made, will presumably lead to an understanding of the Moon's origin.

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