Planetary Charge Separation due to Tidal Force Deformation
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Abstract: Lightning is fundamentally caused by a charge separation. The source of this charge separation is proposed as a hypothesis then discussed and analyzed in great detail with very high-correlative evidence. For charge separation to occur there must be polarization of charge; piezoelectric substances polarize charge when they experience a change in pressure and Earth’s crust is composed primarily of piezoelectric material which polarizes electrons toward the core. Earth’s changing pressure (which is directly proportional to force) is caused primarily by Tidal Force Deformations from the Sun and the Moon and secondary by tectonic plate stresses. Piezoelectrically active layer compositions and Tidal Force Deformations are the two things that are believed to be required for a massive body to have a charge separation via charge polarization. Having non-homogeneous Tidal Force Deformations (resulting in non-homogeneous charge separation) has its consequences. This means that lightning should occur only at regions with high changing Tidal Force Deformations which is increased by regions of high changing tectonic plate pressures. Charge separation and lightning introduce a cycle of flowing electrons which will ultimately induce magnetic fields. Volcanoes and vents are mechanisms to return electrons to the crust from the mantle thereby
completing the cycle. Excess of electrons and lack of electrons is directly and respectively correlated with alkaline and acidic properties of naturally occurring substances. Evidence of lightning or magnetic fields will lend support to piezoelectrically active layer compositions and changing pressures for any given large mass, particularly other planets and orbiting bodies within our solar system. More information about other planets can be understood by taking this phenomenon into account.

Keywords: Electron, charge separation, voltage, ionization, piezoelectric, tidal force, pressure/stress, deformation, lightning, induction, polarization, convergent, divergent, satellites, gradient, pH, crystalline, amorphous, spontaneous, subduction, accretion, magnetic field, fault line.

Introduction: To understand the charge separation due to piezoelectric polarization it is vital to understand why, how, and where the changes in pressure occur. When reasons, mechanisms, and locations of changes in pressures are understood the piezoelectric effect plays a key role in understanding the charge separation for Earth. Lightning is known to be caused by charge separation however causes of the charge separation have remained unknown. This hypothesis offers valuable awareness of why, how, and where charge separation occurs and introduces a cycle which may induce the magnetic field of Earth and can help study and explain other large masses in our solar system.

Tidal Force Deformations:

Lightning is caused by charge separation from the piezoelectric effect of suspended piezoelectric crystals in the tectonic plates. The spin of the planet and changing Tidal Force Deformation (changing pressures) create an approximately constant voltage (charge separation) between the layers of the planet at specific regions. There are two mass systems discussed: the Earth-Sun system and the
Earth-Moon system. There is a center of mass for each mass system; since each mass system is approximately super-imposable on one another, each mass system is studied independently. The Moon contributes approximately twice as much tidal force deformation as the Sun.\textsuperscript{CITATION NEEDED} There is a dynamic bulge force gradient corresponding to the Moon’s gravitational pull acting on the Earth; this will be called the Dynamic Tidal Bulge Force Gradient (DTBFG\textsubscript{Moon}). The DTBFG\textsubscript{Moon} is pointing towards the Moon. If the change in DTBFG\textsubscript{Moon} with respect to changing time is constant (dDTBFG\textsubscript{Moon}/dt \approx \text{constant}), the maximum and minimum come from the angle at which the force is being applied. The force change is based upon direct force and ring stress, transferred elongation compression with respect to Poisson’s ratio. for the DTBFG\textsubscript{Moon}, then the piezoelectric effect will also consistently evident. The DTBFG\textsubscript{Moon} experiences maxima very near the equatorial line and decays as the gradient approaches the poles which experience a constant force since the poles themselves experience no changing tidal forces due to lack of spin. There exists a normal plane (a perpendicular plane) that is normal to the maxima of the DTBFG\textsubscript{Moon}. There is a Dynamic Force (Lateral Stress) Gradient ((DFG\textsubscript{Moon}) a gradient of changing forces (dF)) which exists on the normal plane pointing inward. The DFG\textsubscript{Moon} experiences maxima very near the equatorial line and decays as the gradient approaches the poles. It is very important to note that because Earth is spinning, DTBFG and DFG are not in the same areas and their maximas near the equatorial line oscillate between one another; maxima of DTBFG will become a maxima of DFG as the planet spins approximately 90 degrees. There is an analogous DTBFG and DFG for the Sun-Earth system. The Earth has a DFG\textsubscript{Sun} existing on the plane normal to the maxima of the DTBFG\textsubscript{Sun} which is usually not on the equatorial line (Earth is on a tilted spin with respect to the Sun). The DFG\textsubscript{Sun} experiences maxima near the equator, however because the maxima of the DTBFG\textsubscript{Sun} is not perfectly on the
equator (tilted spin), both the $\text{DFG}_\text{Sun}$ and $\text{DTBFG}_\text{Sun}$ experience maxima mostly slightly above and slightly below the equator; $\text{DFG}_\text{Sun}$ also decays as it approaches the poles. Since there are $\text{DTBFG}_\text{Moon}$, $\text{DTBFG}_\text{Sun}$, $\text{DFG}_\text{Moon}$, and $\text{DFG}_\text{Sun}$ acting on the Earth, which are each in different positions relative to one another, this introduces non-symmetry and could help explain quadripole effects on Earth. $\text{DTBFG}_\text{Moon}$, $\text{DTBFG}_\text{Sun}$, $\text{DFG}_\text{Moon}$, and $\text{DFG}_\text{Sun}$ all experience maxima near equatorial line and diminish as the gradient approaches the poles.

**Figure 1: Summary of Tidal Forces Acting on a Large Object of Interest**

*Note: Figure is not to scale. Stress forces of the lateral are reactionary forces due to elongation.*

**Consequences of the Piezoelectric Effect:**
Piezoelectric materials are the true key to understanding the charge separation within the planet. When a non-zero change in pressure is applied across a piezoelectric substance within a small time interval \((dP/dt \neq 0)\) the piezoelectric material will polarize electrons (move electrons from one side to another), however, it is required to have an electron source and electron outlet; these can be metals. The Earth has metals on its surface as well as its core and mantle. The Earth’s crust is composed of many different piezoelectric substances. The Moon contributes approximately twice as much Tidal Force Deformation as the Sun, \(dDBFG_{Moon}/dt \approx \text{constant}\) and \(dDBFG_{Sun}/dt \neq \text{constant}\), and all dynamic gradients resulting from changing Tidal Force Deformations \((DBFG_{Moon}, DBFG_{Sun}, DFG_{Moon}, DFG_{Sun})\) experience maxima near the equatorial line and decay toward poles, therefore it can be inferred that total changes Tidal Force Deformations are not significantly variant which will directly cause a piezoelectric-derived voltage that should also not be significantly variant. Polarization of voltage and diffusion of ions through a crystal lattice are two phenomena that were observed in experimental samples. When a sample was under any change in pressure (force/area; area is constant for any given sample; \(P \propto F\)) with respect to time \((dF/dt \neq 0)\) polarization of charge generated a voltage \(\neq 0\). This shows that any \(dF\) will cause the piezoelectric crystal to polarize and since changing Tidal Force Deformations are always present and the Earth is always rotating, electrons are always polarize in one of two directions: outward from the core or inward towards the core. If metal deposits were stripped of electrons as a result of polarization towards the core, then this would leave behind an abundance of metal ions which could potentially turn water acidic when metal salts enter solution; it is hypothesized that there is a lack of electrons on the surface of the planet’s crust due to polarization of voltage towards the core of the planet. Metal cations on the
surface would experience slow ion diffusion through the crystal lattice (Earth’s crust) towards the core of the planet due to electrostatic forces.

Figure 2: Charge Distribution (from polarization) over a Large Mass

Note: Figure is not to scale.

Spontaneity and Potential:

When discussing the spontaneity of this process, relative positions of electron-deficiency are taken into account for before and after a lightning strike. Before a lightning strike, there is an electron-deficient area on the crust of the planet and a cloud that is theorized to be overall charge neutral, with charge separation in the cloud being of interest, such as local separation due to light ionization and other similarly studied effects; after a lightning strike, there remains
the cloud that is theorized to be after the transfer of electrons from the ice within
the cloud into the crust. The Electric Potential Energy ($U_E$) between two
oppositely charged particles is decreased as distance between the two particles is
increased. This requires the conductivity of the material in-between to change with
respect to local diffusion than convection, known as step leaders. The crust is
closer to the negative mantle and core (from polarization) than the cloud; if the
crust held the positive charge then it would be at a greater $U_E$ relative to the cloud
holding the positive charge. To result in a lower $U_E$, the system favors having the
cloud transfer electrons into the crust so that it can hold the positive charge at a
greater distance from the mantle and core and therefore result in lower $U_E$. The
consequently electron deficient ice crystals in the clouds are typically released as a
solid (hail), due to the endothermic nature of water ionizing as well as low
tropospheric temperatures. Conductivity and connectivity are all portions of
understanding when looking at the discharge of distributed partial charges. When
storms occur, usually a large abundance of ice is also generated; storms that do not
generate ice will rarely generate any lightning.\textsuperscript{1}

Magnetic Field of Earth:

Magnetic Fields are fundamentally caused by the movement of electrons. Generated Magnetic Fields are perpendicular with respect to the axis of electron
movement. All of the Tidal Force Deformations are greatest near the equatorial
line, consequently the piezoelectric effect is also greatest near the equatorial line,
and therefore the polarization is greatest near the equatorial line. The strength of
the magnetic field of the planet is generally greater near the poles and lowest near
the equatorial line (Figure 3).\textsuperscript{6}

\textbf{Figure 3:} Magnetic Field Strength
Volcanos and Vents

There remains the problem that if polarization of electrons is always towards the core then the entire surface of the planet should be acidic everywhere; this does not happen because there is a mechanism to return electrons to the surface of the planet but this only occurs at specific regions. Based on the hypothesis that the mantle and core are very negatively charged (from polarization), magma from the mantle therefore also carries negative charge. Volcanos occur at convergent plate boundaries; volcanos are a mechanism for magma (and negative charge) to be brought back to the surface of the planet as negatively charged lava (once magma

Note: Magnitude is in \( \mu T \).
reaches the surface it is called lava). Volcanos cannot be conclusively said to occur because charge must be returned to the surface, however, volcanos will transport negative charges back to the surface as a side effect. Magma vents occur at top of volcanos but also occur at divergent plate boundaries where negatively charged magma flows up in-between plate boundaries and cools to form new crust. Lightning at the very beginning of a volcano eruption has also been previously documented but unexplained. Before a volcanic eruption, the surface of the planet surrounding the volcano is under high stress (convergent plate boundary) and is therefore lacking electrons from polarization; the magma is still negatively charged from the negatively charged mantle. When the eruption occurs, magma is now called lava and still holds its negative charge but because the lava is negatively charged and the surrounding surfaces are positively charged, a near instantaneous, spontaneous charge transfer will occur (volcano lightning). This is a spontaneous event because opposite charges are in very close proximity of one another resulting in a high $U_E$ (Electric Potential Energy); the volcano lightning is a mechanism for the system to reduce the $U_E$ and result in a lower energy system during a volcanic eruption. Once enough charge has been transferred, the system no longer has enough $U_E$ to cause lightning. There is not enough information to conclusively determine what occurs for magma vents at divergent plate boundaries since they are at lower elevation than convergent plate boundaries and are all covered by water; they are at the bottoms of oceans. Deep sea vents should carry negative charge back to the crust and therefore be a region of less hydronium ions (less acidic). The question would remain, why is there acid found in pools around magma vents, and the solution lays in the chemistry. As a sulfate ion interacts with the atmosphere it will go through acid base chemistry.
“Oxidation/reduction (redox) reactions are key to supporting chemosynthesis. The atmosphere and hydrosphere are relatively oxidizing with an abundance of potential electron acceptors (O₂, SO₄²⁻, and NO₃⁻). In contrast, the basaltic rocks that form the oceanic crust are relatively reduced because of the abundance of ferrous iron. High-temperature fluid/rock interaction forms reduced gases (H₂S, H₂, and CH₄) that dissolve in hydrothermal fluid. Representative redox reactions that produce H₂S include:

\[
\begin{align*}
\text{Mg₅.₅Fe₀.₅Si₂O₆} + 0.083\text{H}^+ + 0.0416\text{SO}_4^{2-} + 0.5\text{H}_2\text{O} &= \text{Mg₅.₅Si₂O₅}[\text{OH}] + 0.167\text{Fe}_3\text{O}_₄ + 0.0416\text{H}_₂\text{S} \\
\text{(Pyroxene)} &\quad \text{(Talc)} &\quad \text{(Magnetite)}
\end{align*}
\]

\[
\begin{align*}
\text{Fe}_₂\text{S₈} + 2\text{H}^+ + \text{SO}_4^{2-} &= \text{FeS}_₂ + \text{H}_₂\text{S} + \text{Fe}_3\text{O}_₄ \\
\text{(Pyrrhotite)} &\quad \text{(Pyrite)} &\quad \text{(Magnetite)}
\end{align*}
\]

where talc serves as a proxy for a Mg hydroxide component of alteration minerals such as chlorite and amphibole. Sulfur is a particularly important component in the subseafloor redox cycle because there is a transfer of eight electrons (derived from oxidation of Fe²⁺ to Fe³⁺) in the reduction of seawater sulfate to sulfide. Microbial reoxidation of H₂S near the seafloor releases the stored energy and drives biochemical reactions. Serpentinization reactions also may be important in supporting chemosynthetic communities (2), especially at off-axis sites. Serpentinization reactions are not limited to the high-temperature portions of seawater circulation systems, and the H₂ provided by reactions such as 3 is readily metabolizable by a variety of microbes.

\[
\begin{align*}
2\text{Mg₅.₅Fe₀.₅Si₂O₆} + 2.933\text{H}_₂\text{O} &= \text{Mg}_{₂.₇}\text{Fe}_{₀.₃}\text{Si}_₂\text{O}_₆[\text{OH}]₄ \\
\text{(Olivine)} &\quad \text{(Serpentine)}
\end{align*}
\]

\[
\begin{align*}
+0.9\text{Mg}[\text{OH}]₂ + 0.033\text{Fe}_3\text{O}_₄ + 0.033\text{H}_₂ \\
\text{(Brucite)} &\quad \text{(Magnetite)}
\end{align*}
\]

Reduced magmatic gases (H₂ and H₂S) also are released directly during intrusion and eruption of basaltic magma. Seafloor hydrothermal systems undergo cyclic variations in temperature, vent fluid composition, and biological activity in response to magmatic episodes (3, 4). Volcanic events initially are followed by relative increases in vent fluid temperature and magmatic gases, often accompanied by decreased salinity in hydrothermal fluids as a result of supercritical phase separation of seawater in the subsurface (5) and faster migration of the vapor-like component to the seafloor. Later in the cycle (on the order of a few years) the high-salinity component of the phase-separated fluids reaches the seafloor. The higher chloride content of these fluids enhances
metal solubility, but H$_2$S content drops, consistent with solubility control by metal sulfide minerals. Microbial blooms are observed at the initiation of the magmatic cycle, suggesting that the upper oceanic crust is inoculated with microbial communities poised to exploit the chemical energy carried by hydrothermal fluids.” Robert A. Zierenberg*†, Michael W. W. Adams‡, and Alissa J. Arp§ 40

**Figure 4: Ocean pH**

![Ocean pH Map](image)

*Note: Most of the ocean is basic.* 18

Summary of Hypothesis: Earth’s crust is made of several piezoelectric materials and piezoelectric materials polarize electrons toward the core when force deformations act on them. Tidal Force Deformations are the main cause of the polarization towards the core (planetary charge separation) and occur more strongly near the equatorial line. Movement of plate tectonics causing regions of high stress is another significant contributor of polarization towards core. Lightning occurs as a side effect in regions of high charge separation (high polarization) due to changing pressures (high deformations and high stresses).
Precipitations are typically acidic due to the transfer of electrons from pH-neutral, evaporated water within clouds to the surface of the Earth as well the equilibrium between carbon dioxide and carbonic acid in the atmosphere. Volcanos and vents establish the mechanism that completes the cycle of electron flow. Electrons are polarized toward the core via piezoelectric effect which cause lightning and electrons are returned to the surface via volcanos and vents. Geographical Evidence: Analyzing and correlating maps lends valuable support for this hypothesis.

Geographical Figures:

**Figure 5a:** High Occurrence of Lightning (High Stress) Region Correlation to Converging Plate Tectonic Region in Asia

![Image of Asia showing correlation between lightning and tectonic plate boundaries]

*Note:* More lightning occurs in the zones that are more red and dark (left).\(^7\) Red lines are convergent tectonic plates; light purple lines are transform boundaries (right image).\(^8\)

**Figure 5b:** High Occurrence of Lightning (High Stress) Region Correlation to Converging Plate Tectonic Region in South America
Note: More lightning occurs in the zones that are more red and dark (top image). Red lines are convergent tectonic plates (bottom image).

Areas of large pressure (or stress) experience more lightning strikes which is consistent with the notion that high pressures will cause high piezoelectric responses which will cause more polarization (charge separation within crust) which should ultimately result in more lightning strikes. Evidence of this is circled in Figures 5a and 5b.

This region is known for an everlasting lightning storm. Known as the Catatumbo Lightning, it has been theorized that methane evaporation from fresh water meeting salt water was hypothesized for being responsible. The current hypothesis is that water vapor and heat cause changes in electric states. However, given that this is a region of high plate stress due to maximizing both the sun and moon tidal force.

Figure 6.a:
Note: The red lower line is a subduction zone on the water basin side. This region also has some interesting properties to the west of the fresh water bay.

Figure 6.b:

Note: the Nazca plate is pushing the Guiana shield toward the fresh water bay.

Showing this is due to the tidal forces is a bit more straightforward knowing that the lightning storm as stopped at certain points. This was a mystery, but given
the periodicity of the moon has been charted by NASA, the periodicity of the orbit can be looked at.

It was reported that, “For a several months starting January 2010, not one lightning bolt was seen, sparking concern it was gone forever. Then, as mysteriously as it had stopped, it began again, as proven from NASA satellite data.”

Figure 6.c: Orbit of moon with elliptical motion.

Note: The elliptical motion of the moon is noted by the apogee line.

Figure 6.d:
Note: this figure shows that the beginning of 2010 the mean difference of perigee and perihelion are at a minimum. As well as difference from mean lunation.\textsuperscript{37}

Figure 6.e:
Note: this figure shows the difference in the inclination of the orbit of the moon and the sun.\textsuperscript{37}

Fred Espizet at NASA had this to say, “Figure 4-10 plots the instantaneous inclination of the lunar orbit over the 3-year period 2008-2010. The mean angle between the Sun and the ascending node (i.e., difference in mean longitude) is also plotted. The largest inclination of 5.30° occurs when the difference in longitude is either 0° or 180°. In other words, the inclination is always near its maximum value for both solar and lunar eclipses. The smallest inclination of 5.00° occurs when the difference in longitude is either 90° or 270°. Note the small monthly oscillations in the inclination when near its minimum. The figure also plots the longitude of the instantaneous ascending node. Its westward motion draws to a near standstill
whenever the Sun aligns with either of the nodes. This corresponds to a difference in longitude of either 0° or 180°.”

This figure shows the inclination of the moon was at a maximum in the beginning of 2010. This means that the relative tidal force deformation was at an absolute minimum.

Figure 6.d: Global Lightning Map

Note: More lightning occurs in the zones that are redder and dark.15

When viewing a Lightning Map, one can clearly see that lightning strikes generally occur most strongly near the equatorial line and rate of occurrence is diminished towards the north and south poles (Figure 6). This is also consistent with the hypothesis because all of the Tidal Force Deformations (which are directly proportional with piezoelectric response) experience maxima near the equatorial line and diminish towards the north and south poles.

Figure 7 shows an area on the African Continent; it is one of the areas of the planet that has a high rate of lightning occurrence and is a high stress region. The area is known for producing diamonds due to the massive stresses that occur in the crust. The region has an average amount of precipitation. There is low occurrence
of lightning at the northern part of the African continent because it does not have the layering composition to create a piezoelectric polarization effect; that region is a large desert.

**Figure 7:** Correlation of High Stress, High Occurrence of Lightning, High Hydration, and High Precipitation in Africa.

![Image of Africa with correlation data](image)

*Note:* Green lines are divergent tectonic plates (top left image). More lightning occurs in the zones that are more red and dark (top right image). More soil hydration are in the zones that are more green (bottom left image). More precipitation are in the zones that are more blue and dark (bottom right image).
Figure 8: Correlation of Precipitation and Soil Hydration with High Elevation per Year and High Lightning Occurrence

Note: More precipitation are in the zones that are more green (top left image). More soil hydration are in the zones that are more blue (top right image). Higher elevation per year are in the zones that are more purple (bottom left image). More lightning occurs in the zones that are more red (bottom right image).

Soil hydration and conductive paths have to be taken into account to get a more accurate larger picture. As the soil becomes saturated with water, ions are
able to travel through the soil via water paths and this effect expedites the diffusion of ions to the earth’s surface. A significant factor is that there must be clouds available in the area that can produce precipitation, however, precipitation clouds are not a causation for lightning. Figure 8 shows that zones of precipitation in the southeast may be well correlated with the zones of higher lightning occurrence (as well as higher changes in elevation (high stress)) but are badly correlated in the northwest region. The top right image show that soils of the central-north and northeastern coast may be more hydrated but do not have high occurrence of lightning (bottom right image). These images of Figure 8 lend support to the notion that precipitation, soil hydration, and lightning are poorly correlated and that changes in elevation (high stress regions) play a more significant correlation to lightning occurrence.

Analysis of Other Orbiting Masses: Analysis of Tidal Force Deformation and composition effects on Piezoelectric Effect, Polarization, Magnetic Field Response, and Lightning of other orbiting masses in our solar system lends valuable support for the hypothesis. Based on the hypothesis, the two necessary components that fundamentally cause the piezoelectric effect, polarization, and magnetic field are Tidal Force Deformations and compositions that allow for piezoelectric effects to occur. Basic compositions that should allow for a piezoelectric effect to occur are: metal core (to polarize to), some sort of metals or electron source on the surface (to polarize from), and piezoelectric substances somewhere in-between the crust and the core.

**Our Moon:** Our Moon is tidally locked and thus has very small Tidal Force Deformations acting on it. The layer compositions should be sufficient to produce a piezoelectric response however there is not enough Tidal Force deformation acting thus there are low amounts of polarization (no lightning), low magnetic fields. It is believed that the solid metal core of the Moon was rotating
on a different axis than its mantle in the past which produced a dynamo effect that explains how some of the rocks brought back by Apollo astronauts were magnetic. The angle between rotational axes of the solid core and the mantle has decreased over time while the distance from the Earth has increased causing tidal forces to decrease over time; these forces were once great enough to cause a significant magnetic field but are not sufficient anymore. There is most likely some truth to the dynamo hypothesis and now that the angle between rotational axes has decreased, it is possible that a piezoelectric effect is causing the small magnetic field (via small Tidal Force Deformations from the Sun) that is still present on the Moon.

**Mercury:** Mercury is the closest planet to the Sun, has a core that is mostly solid iron, and a crust of silicate. Mercury has an approximate distance of 0.387 AU (Earth is standardized at 1 Astronomical Unit (AU)) from the Sun, has a sidereal rotation that is 58.65 days, and an orbital period of 88 days. This means that Mercury is almost tidally locked with the Sun in a ratio of roughly 3 rotations for every 2 revolutions. It has been shown that the magnetosphere is at an axial tilt of 169°.

**Venus:** Venus has an approximate distance of 0.72 AU meaning that it is closer to the Sun than Earth; one would think Venus should have more changing Tidal Force Deformation, however Venus spins very slowly. Venus’ day is approximately 116 Earth days which essentially means that Venus is barely spinning at all. Venus also spins retrograde (opposite spin of Earth). The entire surface of Venus shows evidence of volcanic resurfacing which diminishes its ability to possess a piezoelectric effect. Venus is also the hottest planet in our solar system due to its atmosphere being over 90% Carbon Dioxide resulting in a greenhouse effect which traps large amounts of heat from the Sun. Venus has the
most volcanic activity, and the volcanic activity is believed to be attributed to its high planetary temperature. It is believed that Venus does not possess any notable magnetic field due to low amounts of Tidal Force Deformation, piezoelectric inactive layer compositions, and multiple volcanos causing a dynamo effect that results in magnetic fields that cancel each other out.

**Mars:** Mars has very small orbiting moons that cause very small Tidal Force Deformations. Mars also has a semi-major axis of approximately 1.524 AU. Mars is further away from the Sun. This means that Mars will experience less Tidal Force Deformation from the Sun and overall less Tidal Force Deformation. Mars has layer compositions that are sufficient to allow a piezoelectric effect on a portion of the planet. Mars is only partially piezoelectrically active because it has indication of an impact that resulted in large amounts of crust removal. This impact removed most of the metals on the surface of the northern hemisphere which diminishes the piezoelectric effect of the northern hemisphere and results in lower total magnetic fields (lower total polarization) and might explain the strange magnetic field patterns that Mars currently has.

**Figure 9:** Theorized Outer Layer Compositions of Jupiter and Saturn
**Note:** Figure shows theorized layers of metallic Hydrogen for both Jupiter and Saturn.\textsuperscript{27}

**Jupiter\textsuperscript{5}**: A measurement of Jupiter’s magnetic field shows that it has approximately ten times the strength of the Earth’s magnetic field. It is hypothesized that Jupiter is primarily Hydrogen and Helium.\textsuperscript{26,27} Jupiter has a layer of metallic Hydrogen below the atmospheric layer of Hydrogen and Helium.\textsuperscript{27} Jupiter is also theorized to have a core that is made of rocks, metal, and hydrogen compounds.\textsuperscript{28} Jupiter is believed to have piezoelectrically active layer compositions from evidence of large storms. While Jupiter has a mean distance from the Sun of approximately 4.95 AU it also has a mass of about 300 times that of Earth\textsuperscript{5} which means the changing Tidal Force Deformation from the Sun is
greater than what is experienced by Earth. Another large contribution to changing Tidal Force Deformation is that Jupiter has 4 Galilean moons; these moons greatly contribute to the changing Tidal Force Deformations acting on Jupiter. The first three moons lie on an interacting toroidal orbit (orbit above and below Jupiter’s equatorial line in a toroidal region) around the planet. This effect increases the changing Tidal Force Deformations acting on Jupiter. Changing Tidal Force Deformation from the Galilean moons is amplified even further due to Jupiter’s large size. Jupiter is also on a 10° axial tilt as compared to the 22° tilt that the Earth has. It also has a 9.9 hour period of rotation (1 day). The changing Tidal Force Deformations acting on Jupiter would be amplified by each of these characteristics and thus a much larger magnetic field response would be noticed which is confirmed by observation.

Figure 10: Theorized layer compositions of Jupiter
Note: Figure shows some of the theorized layer compositions for Jupiter.²⁸

Figure 11: Ionization of Gas due to Magnetic Field of Jupiter
Note: In this figure the gas being vented from Io’s volcanos is entering a Flux Tube due to the strong magnetic field of Jupiter.²¹

Error Analysis:

Northwestern Coastal Accretion: Along the northwest coast of the North American continent there is the San Andreas Fault line. The plates have shifted from a convergent plate boundary to a transform plate boundary. Which means that the stress concentrations have been reduced and lighting occurrence correspondingly decreases. The Juan De Fuca plate converges north of the San Andreas Fault line. The Convergent boundary is completely submersed in the Pacific Ocean, this means that the cycle of charge separation of the land is completely submersed and there is relatively no occurrence of lightning. There is an amorphous accretion prism that doesn’t hold constrained crystalline properties, therefore it doesn’t create a piezoelectric response in the crust.

Figure 12: Juan De Fuca North American Plate Boundary
Note: In this figure the Juan De Fuca plate is under the Pacific Ocean and there is an Accretion Prism that corresponds to a large section of amorphous land mass above.\textsuperscript{32}

**Arabian and Sahara Desert:** The Arabian Desert and Sahara Desert have similar properties to the Accretion Prism in Figure 12. The desert sand is under a non-constrained boundary condition and therefore does not experience any states of stress. Desert sand is be unsuitable to create a piezoelectric response and would therefore have a lower occurrence of lightning in regions of crust that are composed mainly of sand.

**Figure 13:** Map of Sahara and Arabian Desert with Lightning Occurrence
**Saturn:** Saturn has one of the largest magnetic fields detected in the solar system, with a magnitude 580 times Earth’s magnetic field. The mass of Saturn is 95.159 Earth masses. The side reel rotation of the planet is 10.656 hours. Its orbit is 9.682 AU from the Sun. The presence of metallic hydrogen is also theorized on the planet. While there are multiple large satellites orbiting Saturn, the largest is Titan. The closest in size Rhea which is about 1.5% the mass of Titan. This means that the dominant body that exerts tidal forces on Saturn is Titan. With a mass of $1.3455 \times 10^{23}$ kg it is 1.83 times the mass of the Earth’s moon and orbits at a distance of 2575 km from the Saturn which is 1.482 times the distance of the Moon’s orbit around Earth. The radius of the Saturn is 9.449 times larger at the equator and 8.552 times larger at the poles compared to the Earth. The theoretical difference of the tidal force effects of Titan on Saturn would then be 505.5 times larger than the Moon on Earth. The tidal force from the Sun on Saturn would be about the same as the Earth.

**Jupiter’s Moons:** Each Galilean moon of Jupiter holds different information about the production of magnetic field in response to changing Tidal Force
Deformation, but because there is not enough evidence or precise measurements for the observations, thus the subjective hypothesis for the Galilean moons will remain in the Error Analysis section.

**Figure 14:** Hypothesized Composition of the Galilean moons of Jupiter.

![Diagram of Galilean moons composition](image)

**Note:** This figure presents the hypothesized internal structure of each Galilean moon.¹¹

Io¹⁸: Io is the closest and of the Galilean moons. Io is tidally locked, but there are changing Tidal Force Deformations from both Europa and Ganymede. These changing Tidal Force Deformations contribute to the nearly completely molten state of Io. Since Io has a very thin crust²¹ there is a very small magnetic response to the small piezoelectric polarization.
**Europa**\(^\text{18}\): Europa has shown no sign of a magnetic field.\(^\text{18}\) Europa has a mean distance of approximately 671 km from Jupiter whereas Io and Ganymede have approximately 422 km and 1070 km mean distance, respectively (Europa’s orbit is in-between Io and Ganymede). Europa’s hypothesized composition is not sufficient to create the proper system for the piezoelectric effect due to a lack of a tenable crust and would not result in any significant magnetic field.\(^\text{21}\)

**Ganymede**\(^\text{18}\): Ganymede is the only Galilean moon to have a significant magnetic field. With magnetic field strengths on the order of 750 nT,\(^\text{34}\) it has about one fortieth of the strength of Earth. Ganymede is tidally locked with Jupiter\(^\text{18}\) and has layer compositions that should allow for an active piezoelectric system;\(^\text{21}\) the main contribution to changing Tidal Force Deformations would be the interaction with other Galilean moons. This might be a possible explanation for the small strength and size of the magnetic field on Ganymede.

**Callisto**\(^\text{18}\): Callisto is the furthest Galilean moon of Jupiter. Its internal structure does not have an iron rich core.\(^\text{21}\) This homogeneous consistency means that there are incorrect layer compositions for a piezoelectric polarization. Callisto does not experience the same changing Tidal Force Deformation given that it is approximately 800 km away from the next nearest Galilean moon.\(^\text{22}\)

As a note: This paper is support to support additional information to dynamo theory, and create another mechanism to have the voltage potential due to lightning fully explained. There were fundamental missing pieces of information before this as to how certain mechanisms worked. This paper solves many of those questions.

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