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External Factors Influencing the Motion of Tectonic Plates

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Abstract

The investigation aims to understand how external forces influence tectonic plate movement, causing earthquakes and volcanic eruptions. Our emphasis was on calculating perigee forces at various moon-Earth distances. Our initial concern is the fluctuating perigee distance between the Moon and Earth. Later, we will cover Earth's mass fluctuations caused by crustal inhomogeneity. Gravitational force depends on distance and Earth's mass variations. Wobbling's Earth and translation around Sun are additional factors. Tidal variations from the Moon trigger subduction zone earthquakes. Volcanoes in the Ring of Fire are influenced by plate movement on fractures and faults.

Keywords

Sun, Moon-Earth Forces, Tectonic Plate Motion, Seismic Activity, Volcanoes

1. Introduction

Tidal movements have localized effects on coastal ecosystems and are strongly connected with the seismicity in those locations. [1]

This paper developed an update on the Moon rotating around the Earth and the distance variations in the Perigee. The result gave a cyclic variation, sometimes coinciding with the New or Full Moon. Once we obtained the plots with the Moon cycles, we tried to search for the possible effects of several events on Earth [2].

The Earth has precession or wobbles; its tilt axis on its rotation gyrates in a circular motion, sweeping out a cone-shaped area. The Moon exerts a gravitational force on the Earth; the Moon is 400 times closer to Earth than the Sun (**Figure 1**). However, part of the elliptical trajectory of the Moon on the day side is out of the magnetosphere. [3]

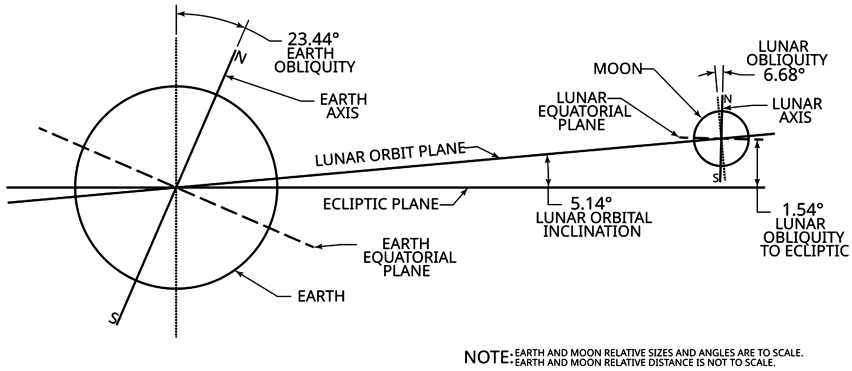

Figure 1. The distance and masses for the two bodies, Moon, and Earth, the distances are average in the picture. This paper considers the gravitational effect of the moon-Earth and the distance variation when the Moon is at Perigee.

The Moon stays in the Earth's magnetosphere for 3 - 4 days every month. The hot plasma-sheet plasmas in the Earth's magnetosphere can directly impact the lunar surface since the Moon has neither a global intrinsic magnetic field nor a thick atmosphere.

Therefore, most of the research on the Sun-Moon-Earth and ground interactions would be better studied by understanding the Moon influences.

As we have investigated before, the Earth's ground is enormously disturbed by solar events, and we have discussed it in several papers [4]-[7]. The former studies found the moon affects most of the subduction zones connected with the tidal frequencies. The disturbance is clear for deep and ultra-deep earthquakes. The Sun is important in those perturbations most when the three bodies are aligned. The Moon's position alignment has two possibilities one at the dayside (the moon is outside of the magnetic Earth's field) and the nightside when the moon will be into to magnetotail it reaches until 200 Earth's ratio. In a second study, we showed the variability of earthquakes by seasons when some anomalies were observed in Nazca-South America subduction zone. Those papers strictly connect with Moon-Earth interactions, the other studies although important to the development of this theory are not going to be described here since they most show Sun-Earth interactions.

Among many different facts is the gravitational force between the Sun- and Earth weakening between the two elements by $1/r^2$.

In the elliptical trajectory of the Moon revolving around the Earth, the force is more pronounced during Perigee and less during apogee. Our investigation involves ongoing updates to the gravitational force for the Moon during the Perigee.

The Moon's gravitational pull affecting Earth's tides is a well-established and extensively studied phenomenon in the scientific community. The bulging of the oceans and tidal movements result from the Moon's gravitational force on Earth.

The relationship between the Moon and Earth's surface events is intricate, encompassing gravitational forces, tectonic displacements, and magnetized rocks. The Moon's gravitational pull significantly influences Earth's tides, affecting coastal ecosystems and seismic activity.

The investigation explores how the Moon's tidal effects impact Earth, focusing on the oceans and land and highlighting the connection between the Moon's gravitational force and phenomena like earthquakes and volcanoes, especially in subduction zones like the Pacific's Ring of Fire. Hence, extensive research on the lunar cycles and the resulting tidal impacts originating from the gravitational disparities between the Moon and Earth is crucial. The Moon's elliptical orbit, mainly during Perigee, generates gravitational forces that drive the shifting of Earth's tectonic plates. Multiple factors, such as Earth's axis wobbling and its alignment with Polaris, drive the movement of tectonic plates. Earth's tectonic plates and poles both shift northwestward.

Within the contents of this paper, we aim to explore and present a theory that presents an alternative perspective to the widely accepted notion that the mantle is actively involved in the drifting of tectonic plates. The main issue with considering the Earth's interior as a kettle with boiling water is that it is an impossible model to adopt. The lack of uniform boiling characteristics in the mantle can be attributed to its high-density nature. As a matter of fact, there exist specific regions that can have a lower temperature compared to their immediate surroundings. Additionally, the viscosity of this substance must be considered, making it even more difficult to comprehend how it would react to heat in a manner similar to that of water. Consequently, the viewpoint offered is a simplified understanding of the elaborate conditions that are likely taking place beneath the Earth's surface.

In our theory proposal, we argue that the tectonic plates can be set in motion simply by applying external forces among the Sun, Moon, and Earth. Alongside the exploration of plate movements, there will be a thorough examination of how these movements affect both earthquakes and volcanoes.

2. An Update on the Variation in the Moon-Earth Force at Perigee

In prior articles [2] [3], we determined that the gravitational force fluctuates between the Moon and Earth during the Moon's Perigee, as shown in **Figure 2**. We considered the period 1996-2016; the result showed the change of the Perigee force, whose maxima values corresponded to the New or Full Moon (spring tides) and the minima for the 1st or 3rd Quarter (neap tides). Perigee is the Moon's nearest position in its elliptical orbit around the Earth. The force between the Moon and Earth is

$$F = GmM/r^2 , \tag{1}$$

Here, m = moon mass = 7.34×10^{22} kg, M = earth mass= 5.97×10^{24} kg, G = constant gravitational = 6.67×10^{-11} $m^3 \cdot kg^{-1} \cdot s^{-2}$.

The only variable is r—the distance between the Moon and Earth at Perigee, which varies by about 3.5% yearly. The oscillatory force is small, with a period of 6 - 7 months.

Between 1996 and 2008, this specific period was repeated 11 times. Given that this variation remains relatively constant over a solar cycle, we could forecast the next solar cycle. The interval for a solar cycle is 11 times the moon cycles. There is a chance that a new cycle could start at the close of 2019. We established this date since the solar cycle did not change the Moon-Earth force; therefore, it was a steady relationship.

Our latest research examined the relationship between moon phases and megathrust earthquakes, starting from the one in Japan on July 9, 869. This earthquake mainly happened in a moon phase 4 days after the Third Quarter and four days before the New Moon. The historical earthquakes demonstrated a higher frequency during the New Moon phase than the other three phases. It was shown that most Mega quakes happened at the New Moon, and the possibility of happening in other phases was almost the same, as 1st Quarter, 23%, 3rd Quarter, 21%, and the Full Moon, 20%.

The exact search for large quakes ($M \geq 8.0$) during the period 1900-2015 indicated equivalent results to the New Moon, 35%,1st Quarter, 23%, 3rd Quarter, 20%, and Full Moon with, 22%. The locations with the most significant probabilities are most of the Pacific or the Indian Ocean, where 92% of the events occurred. More remarkable events happened in the intraplate, with only 8% observing that all happened in the North, with 7% in the intraplate in the Northern and 1% in the Northern Atlantic. Nevertheless, the Southern Hemisphere experienced 62% of significant earthquakes, with the Northern Hemisphere accounting for the remainder. When the New Moon occurs, the Sun, Moon, and Earth align, with the Moon facing the Earth's dayside. During the New or Full moon phases, the oceans experience the highest tides, known as Spring Tides. The regions are not affected by the tides in the same way; the tectonics of each area have different geometry and structures, and they play a vital role in the tides. Significant earthquakes occur in subduction zones when the marine influence reaches the inner levels and lower boundaries beneath the platform, as observed in the East Pacific.

During the highest tides, the water spreads more rapidly in subduction zones beneath the continent's land. Those locations accumulate a lot of energy stress, the water adding strain and pushing the older platform to the Earth's gravity center.

Subterranean water facilitates various processes, such as rock serpentinization and the generation of convection currents that propel hot water to the surface. Consequently, oceanic currents, altered by tides, play a significant role in strain accumulation in these regions, indicating a temporal correlation between tides and earthquakes. The water in these areas, driven by ocean waves and the dynamics of tides, can reach temperatures that cause liquefaction, releasing additional water. This process is extensive and complex, yet it falls outside the scope of this paper.

Large earthquakes result from prolonged processes and depend on a region's capacity to withstand stress before failure. A megathrust earthquake may take years to develop. Although syzygy tides occur during the New or Full Moon, our analyses show that such events are more likely to happen closer to or during the New Moon. This raises the question: Is there a connection between tides and earthquakes? Moreover, why don't all regions with high tides experience major earthquakes if so?

In the Bay of Fundy, Canada detected the highest tides in the world, and there are no outsized earthquakes. The Bay of Fundy inlet of the Atlantic Ocean between the Canadian provinces of New Brunswick (North and west) and Nova Scotia (South and east). It extends 94 miles (151 km) inland, is 32 miles (52 km) wide at its entrance, and is noted for its fast-running tides, which may produce rises as significant as 70 feet (21 meters), the highest in the world. The explanation for why there are no significant earthquakes in the region relies on the fact that the geological and tectonics of this region are entirely different from the Pacific coast.

The subduction zones make it possible to trigger massive earthquakes instead of other seafloor formations as allied to Canada. Comprehending the Pacific floor structure, formation, faults, and other geological structures is vital.

Moon-Earth's Gravitational Forces and Earth's Surface Events

We obtained a gravitational force variant created when the Moon reaches Perigee. The maximum value is F_{max}—2.32×10^{20} N, and the minimum is F_{min}—2.14×10^{20} N. The maximum value occurred several times during the Full or New Moon, and the minimum during the First of the Third Quarter. We divided the results into two parts to carefully examine the Moon's periodicity when considering the Perigee location. The Moon's speed around the Earth is 3.7 km/h; in one hour, it travels 2.3×10^6 km. However, the elliptical movement around the Earth has placed the Moon in an apogee or perigee location. Our calculations indicated that the apogee position does not draw periodicity like the Perigee. Apogee offers a slight gravitational force on the Earth and does not make a sinusoidal variation. Therefore, the only location to be considered in this paper is the Perigee, which has maxima and minima developing a sinusoidal repetition as described in **Figure 2** and **Figure 3**.

The following picture shows the updated data and the moon cycles between 2015 and 2024, as seen in **Figure 3**. Both confirmed that the maximum perigee values often coincided with the New or Full moon. This would explain the higher occurrence of earthquakes during those two phases despite the other phases (1st or 3rd Quarter).

We found the periodical movements around the Earth indicating maximum and minimum values that we called moon cycles. **Figure 2** shows that the Moon's periodical system is steady and cyclical around the Earth, and the sinusoidal movement is kept steady during the three Solar Cycles computed. Those intense variations on the gravitational force of the Moon-Earth, particularly during the Perigee locations, will contribute to a bunch of changes not only in the hazard events but in the Earth's surface, as we will explain in the following paragraphs.

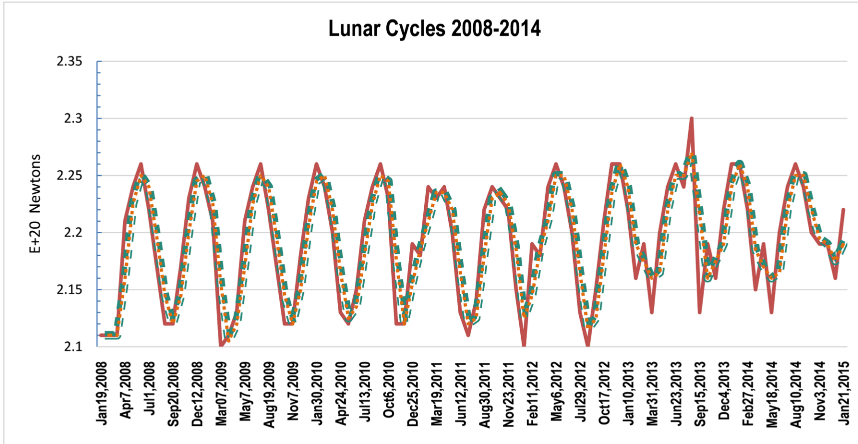

Figure 2. It shows the moon perigee force period 2008-2015.

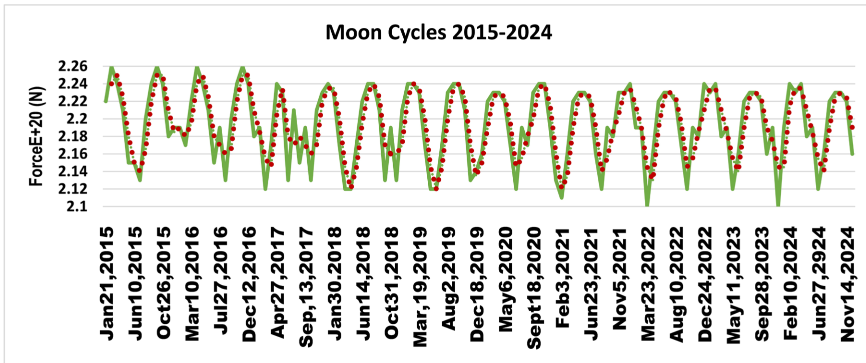

Figure 3. It shows the sinusoidal variations from 2015-2024 when the Moon is in the Perigee.

To be more accurate, we re-started our investigation in a solar minimum in 2008 and compared it with the moon cycles. Figure 2 and Figure 3 show the developments of these moon cycles between 2008 and 2024. The forces obtained had a maximum of 2.3×10^{20} N and a minimum of 2.14×10^{20} N. It determines how those variations fit with the worldwide volcano data. However, most eruption data happen around the Ring of Fire. In our previous paper, we considered the three solar cycles 22, 23, and 24; now, it is calculated ahead in cycle 25 (2024).

3. Lunar Cycle Variations and Influences on Volcano Eruptions

The Moon influences the Earth in multiple ways, through gravitational forces, positions during Perigee and apogee, and its connection to tides. These characteristics have various effects on our planet.

The following plots highlight the differences in volcanic eruptions across the Hemispheres. Figure 4 shows worldwide eruptions during the period 1990-2022; the picture shows the number of active volcanoes versus the eruptions for each year. There was a minimum number of events between 1997 and 2019. A maximum occurrence has been between 2004-2008, with 49, 46, 45, and 44 events during a corresponding solar minimum period. Those results are like the ones found for earthquakes. [6]

Volcanoes in the Northern Hemisphere exhibited seasonal patterns, peaking during the Summer. On the other hand, irregularities have occurred in the Winter and Spring for a few years.The peak occurrences in this Hemisphere occurred during the solar minima in 2008 and 2010 and in 2015 during the Spring or Summer. (Figure 5) Spring or Winter in the Southern Hemisphere corresponds to the opposite season in the Northern Hemisphere. The maximum reach of eruptions seems lower in the Southern region than in the Northern region, and 2002 and 2003 had the highest occurrences in the Southern region, coinciding with the solar minimum.

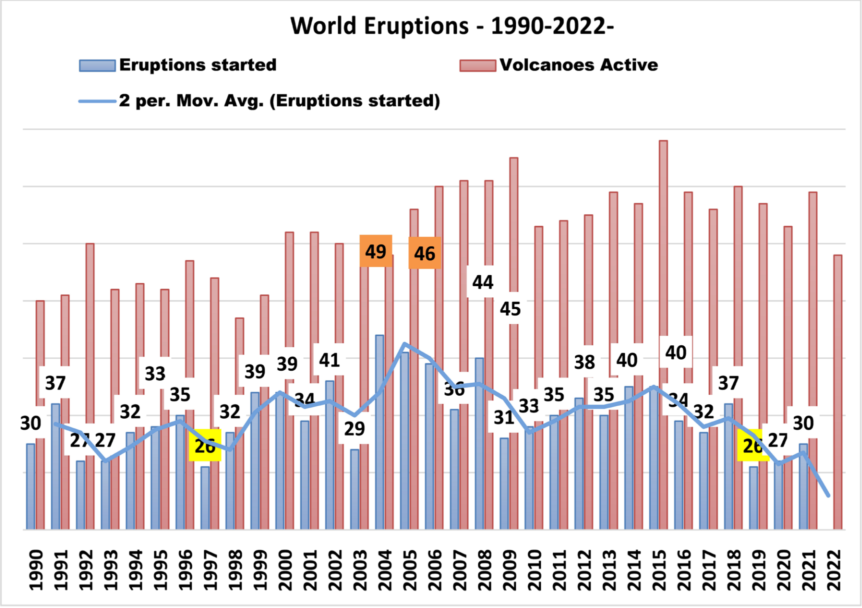

Figure 4. It displays the world eruptions compared with the active volcanoes 1990-2022.

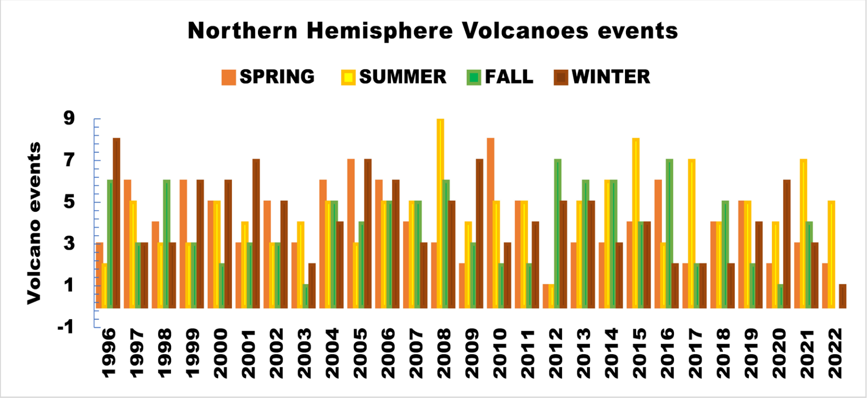

Figure 5. It shows that the Northern Hemisphere events and seasons from 1996-2022 did not have enough data in the records. The Northern Hemisphere, which calculates volcanoes by season, pointed out a maximum number of events.

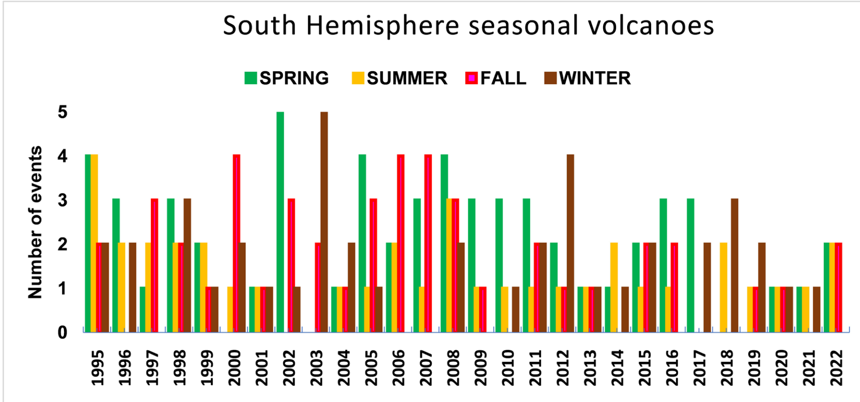

Figure 6. It shows the distribution of volcanoes in the Southern Hemisphere by season. Watch 2002, 2003.

The volcanoes' seasonality is tricky if we consider the influence of the moon perigee. The Moon, as we mentioned in the first part of this article, has a sinusoidal variation for example, there was a maximum of the sinusoidal force on May 29, 1997, in the same month the Full and New moon occurred in the following days May 22 (Full), May 6 (New) it also corresponds the Fall for the Southern and coincided with the maximum number of eruptions. In the Northern Hemisphere and Fall in the Southern, as seen in **Figure 6**. Let us take the next anomalous year, 2019. Southern Spring had no eruption occurrences, and the activity is concentrated in the winter. In the North, there was a minimum of eruptions during the Fall; however, this season corresponds to the Spring in the South.

Various natural factors make it hard to determine the correlation between Moon perigee force and volcano activity. Pinpointing the cause or predicting volcanic eruptions is a challenge. Regrettably, there was no way to identify a particular cause or likelihood connected to these procedures. Establishing a definitive link between volcanic occurrences and Sun or Moon influences requires additional evidence.

The complex structure of the Earth's lithosphere and asthenosphere makes it challenging to establish a direct link between the Sun's or Moon's impacts and its effects on our planet. External contacts between the Earth's lithosphere are established through gravitational three-body forces or magnetic connections.

Studying the gravitational forces and other Earth movements, including precession and translation, is essential. Earthquakes and volcanoes are more than just surface-level occurrences. In subduction zones, earthquakes can occur at depths greater than 500 km. Additionally, volcanoes exist beneath the Earth's surface. Therefore, the system is complex and dependent on what lies beneath the Earth's crust.

4. The Moon's Tidal Effects on Oceans and Land

Tidal effects from the Moon on Earth are known from the literature as high tides or low tides in the oceans. However, what is less known is the Earth's tide. Earth tide deformation of the solid Earth rotates within the gravitational fields related to Sun and Moon. Earth tides are like ocean tides. The Earth deforms because it has a certain degree of elasticity; was it perfectly rigid, there would be no Earth tides. The Moon influences the Earth's tides, but the Sun also generates considerable tidal forces. Solar tides are about half as large as lunar tides and are expressed as a variation of lunar tidal patterns, not as a separate set of tides. The tidal system can potentially impact earthquakes and volcanoes in particular zones, such as the Ring of Fire in the Pacific. We previously examined [8] the correlation between ocean tides and earthquakes in specific areas like subduction zones. Our focus in this paper does not involve studying the tidal effects on volcanic or other natural hazard events.

There are several distinct issues when examining the actions of Moon-Earth beyond the ones discussed in the first part of this paper. There are other minor movements, such as the Earth's wobble. Those activities will affect both bodies. Look that the Earth has tectonic plates that quickly move in a plastic environment below the plates. The conjugation between the Moon's and Earth's movements concerning each other may be coupled; therefore, not all the plates will follow the Earth's rotation from west to east. It depends on other factors discussed now.

Observed in **Figure 7**, when the Plate is moving down to the South American continent as Nazca; the continent is pushed in the opposite direction; therefore, even though the area is moving with the Earth's rotation under the Plate being pushed for a supposed gravitational force to the Earth's center.

There is a primary factor for those opposite movements on the plates, and it relies on the geological structure as observed in Antarctic plate boundaries, part of it pushing up and the other part remaining steady, creating opposite movement directions.

We must understand the connections between the three bodies and those variations to study the tectonic plate movements. Some are easy to follow, such as the Earth's seasons or the Moon influencing tides.

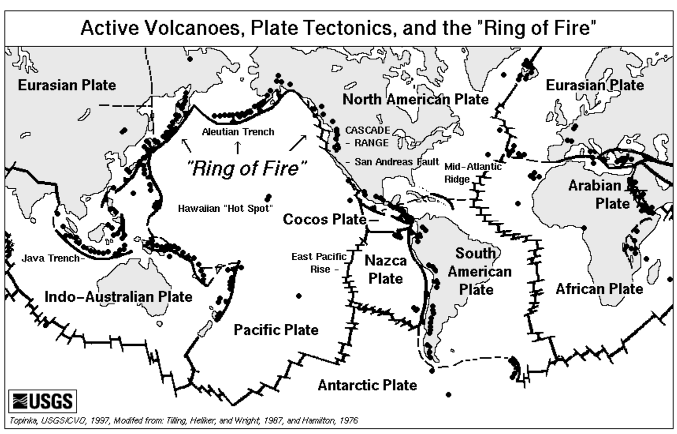

Figure 7. It shows the tectonic boundaries from each plate, depending on the geology of the location searched. It shows the direction each plate moves around the planet.

5. The Continental Plates under the Moon's Gravitational Forces

The crust of Earth is of two distinct types: Continental: 30 - 50 km (20 - 30 mi) thick and mainly composed of less dense, more felsic rocks, such as granite. The continental crust is thicker in a few places, such as the Tibetan Plateau, the Altiplano, and the eastern Baltic Shield (50 - 80 km (30 - 50 mi)). Oceanic: 5 - 10 km (3 - 6 mi) thick and composed primarily of denser, more mafic rocks, such as basalt, diabase, and gabbro. (**Figure 8**)

Because the continental and oceanic crust is less dense than the mantle below, both crust "float" on the mantle. The surface of the continental crust is significantly higher than the surface of the oceanic crust due to the greater buoyancy of the thicker and less dense continental crust (an example of isostasy). As a result, the continents form high ground surrounded by deep ocean basins. The continental crust has an average composition like that of andesite. However, the composition is not uniform, with the upper crust averaging a more felsic composition like dacite while the lower crust averaging a more mafic composition resembling basalt. The most abundant minerals in Earth's continental crust are feldspars, which comprise about 41% of the crust by weight, quartz at 12%, and pyroxenes at 11%.

The continental crust is enriched in incompatible elements compared to the basaltic ocean crust and much enriched compared to the underlying mantle. The most incompatible elements are enriched by a factor of 50 to 100 in the continental crust relative to primitive mantle rock. In contrast, the oceanic crust is enriched with incompatible elements by a factor of about 10.

The estimated average density of the continental crust is 2.835 g/cm^3, with density increasing with depth from an average of 2.66 g/cm^3 in the uppermost crust to 3.1 g/cm^3 at the base of the crust. In contrast to the continental crust, the oceanic crust is composed predominantly of pillow lava and sheeted dikes, with a composition of mid-ocean ridge basalt, a thin upper layer of sediments, and a lower layer of gabbro. The brittle-ductile transition zone (hereafter the "transition zone") marks the Earth's crust's transition from the upper, more brittle crust to the lower, more ductile crust. For quartz and feldspar-rich rocks in continental crust, the transition zone occurs at an approximate depth of 20 km, at temperatures of 250˚C - 400˚C. At this depth, the rock becomes less likely to fracture and more likely to deform ductility by creep because the brittle strength of a material increases with confining pressure. [9]-[12]

In contrast, its ductile strength decreases with increasing temperature. **Figure 8** shows the distribution of thickness worldwide. Compare **Figure 9** and **Figure 10**, the first one shows boundaries in the plates, the direction of the plates moves, the locations of most active volcanoes, the second one displays the speed of those plates, and it is possible to see, for example, the speed in subduction zones as the ones placed in South America-Nazca subduction, located in the Pacific subduction zones are moving much faster than those situated in the Atlantic. Notice that the plates in the Atlantic are not subduction as in the Pacific; instead, they are divergent plate boundaries, see **Figure 9**.

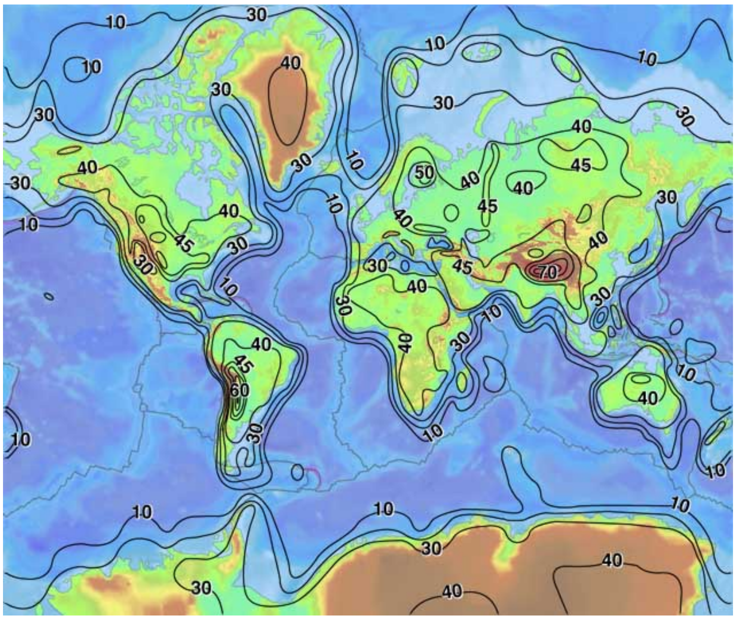

Figure 8. Observe the thickness of each Plate, particularly in the Nazca, the Plateau in Tibet; these are the thickest plates compared with the rest of the world.

Variation of thickness on the continents, the land masses move is not uniform under gravitational force or other external forces due to the crust's nature, as seen above.

For example, plates under the same average Fg will react faster or slower depending on their thickness. [12]

Figure 10 reveals a slight divergence from this account: the speed of the sea floor movement in the Pacific is consistently higher, regardless of the continent's density. Earth's rotation causes the land to be pushed by the lighter weight of the Pacific Sea floor. Under Newton's third law, the continental mass will react in opposite directions. We have encountered puzzling anomalies within the transform plates of the Northwest USA. The Plate is moving northeastward about North America along a convergent plate boundary. The Juan de Fuca plate is being subducted beneath the North American Plate at the Cascadia trench at a rate of approximately 9.8 to 13.8 feet per 100 years. In our investigation, there are some signs that the Moon-Earth gravitational pull is somehow influencing the movement of tectonic plates. However, it is not a lonely contribution for those movements since the entire South Pacific tends to rotate counterclockwise, although some plates will be dislocating clockwise. The only explanation is the contribution from other external forces, as we will follow later.

The subduction in this region continues to be counterclockwise within the subduction area. As a result, some subduction zones will rotate in a particular direction, while the continent will resist in the opposite direction.

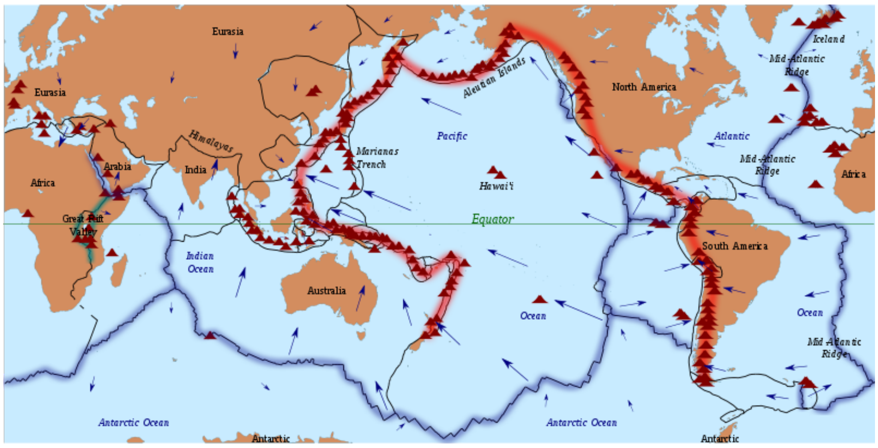

Figure 9. It shows the boundary of each Plate, ocean, or continental; it shows the plates the Ring of Fire, and the location of volcanoes.

The Moon's Perigee significantly impacts the Earth through the tides, whether full or new moon. Consequently, the gravitational pull of the Moon on Earth's surfaces could potentially play a role in inevitable earthquakes and volcanic eruptions that have not been documented or recognized as significant. The heterogeneity in Earth's crust and mantle layers contributes to the rise in earthquakes and volcanic eruptions. Figure 9 shows the boundary for each worldwide Plate. The Pacific's movement is influenced by interactions between continents and the ocean basin, resulting in differing rates of motion. The depth of the Pacific Ocean floor is typically deeper than the Atlantic Ocean floor, averaging around 4,280 meters (14,000 feet).

Seamounts, ridges, and abyssal plains define the topography of the Atlantic Ocean floor. The Atlantic Ocean floor has thicker sediments compared to the Pacific. The Atlantic's sedimentation rates are elevated due to the abundance of rivers and continental runoff. The Pacific Ocean floor is encircled by the "Ring of Fire," notorious for its frequent earthquakes and volcanic eruptions. The first moves faster when comparing the plates around the Ring of Fire and the Atlantic. The counterclockwise movement of tectonic plates can be affected by multiple factors caused by the diverse composition of the crust and mantle. The thickness map displays variations in the crust, with higher heterogeneity in the Middle East and along the Pacific coast of South America. Many plates have an average thickness of 30 km, some even thicker at around 40 - 45 km. However, there are two points where the thickness is double that, measuring 60 and 70 km. It is said that tectonic plates are supposed to float above the stable mantle. By comparing Figure 9 and Figure 10, we can observe that the movement of thicker continental masses is slower than the heterogeneous ones. Earth's surface movements due to rotation and gravitational forces can trigger earthquakes and volcanic eruptions by moving magma. The surrounding material formation mainly influences the growth or shrinkage of faults, particularly in subduction zones like the Pacific. Africa, North America, and Russia are experiencing the opening of faults, as observed.

6. Gravitational Forces Triggering Earthquakes and Volcanic Eruptions Worldwide

The last part of our study is more complex and intriguing. A sudden slip on a fault causes an earthquake. The tectonic plates are always slowly moving but get stuck at their edges due to friction. When the stress on the edge overcomes the friction, an earthquake releases energy in waves that travel through the earth's crust and cause the shaking we feel. [13]

However, in this paper, we discovered that the process is far more complex; it is necessary to have internal and external forces working together to explain the movements of plates on the lithosphere. The external forces described here as the gravitational Moon and Earth are part of the problem; however, the Earth plates float over the asthenosphere under the influence of the gravitational force, but there is also some resistance from the asthenosphere, which can be almost steady concerning the plates floating above. However, the plates are not even, and the earth's topography makes the thickness of each plate variable.

The gravitational force we calculated in this paper considered the M_E a constant, though the mass varies and the thickness of each land mass then; there is also the oceanic crust that is dense in the Atlantic, making a slight difference to any calculation on the gravity. Since there is no knowledge of how it varies, we considered the Earth's mass an average and calculated the gravity just when the moon is at the perigee. Nevertheless, the movement of the plates is variable depending on each Plate we are considering, as we see in **Figure 10**.

One of the fastest-moving tectonic plate boundaries is between the Pacific and Australian Plate near New Zealand. This region is known for its prominent level of tectonic activity, including frequent earthquakes and volcanic eruptions. The Pacific Plate is moving westward relative to the Australian Plate at about 40 - 50 millimeters per year in this area.

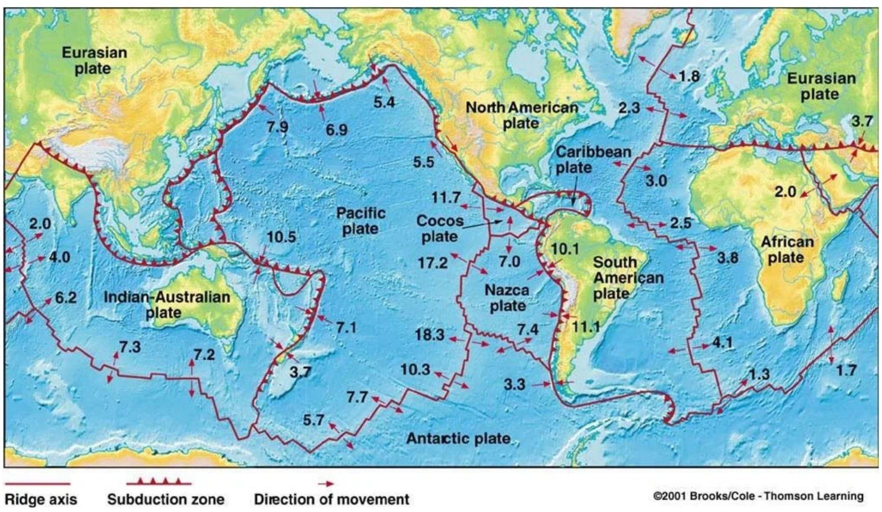

Figure 10. Plates tectonic speeds notice the plates in the Pacific are faster.

Another fast-moving plate boundary is the boundary between the Nazca Plate and the South American Plate off the coast of Chile and Peru. Here, the Nazca Plate is subducting beneath the South American Plate at about 80 - 90 millimeters per year, leading to frequent seismic activity in the region.

Overall, while these are some of the faster-moving regions on Earth due to plate tectonics, it is essential to note that the movement is still relatively slow on human timescales. Oceanic plates move faster than continental plates. Oceanic plates have ridges (pushing) and attached subducting slabs (pulling). At the base of oceanic plates in the LVZ (low-velocity zone), a region of partial melting provides "lubrication" at the base of the plates. [14]

The equation $F = G M_e m/r^2$ focuses only on the variable distance r as the factor between the two bodies. Our calculations focused solely on the perigee distance, which strongly correlates with the Earth. This led to a sinusoidal pattern with $F_{max} = 2.37 \times 10^{20}$ N and $F_{min} = 2.14 \times 10^{20}$ N. Consequently, we kept the other values unchanged. Gravitational anomalies can vary from −60 to +60 mgal. (**Figure 11**) In the Indian Ocean, data scientists have noticed a significant anomaly with extreme gravity fluctuations.

Another value, such as the Earth's mass, must be changeable to account for the variation in gravitational force. Therefore, it can occupy a position with $M_e = M_e/2$ and another with the mass being $M_e = 2M_e$. These updated values would modify the gravitational force by multiplying or dividing. Despite a slight variation in the initial average mass, the gravitational force between the two objects would significantly alter.

The updated equations incorporate the Earth's variable mass, leading to a new maximum force of $F_{2max} = 1.16 \times 10^{20}$ N.

Dividing the minimum by half of m will also result in,

$$F_{2min} = 1.07 \times 10^{20} \text{ N} \quad (3)$$

On the other hand, we should also consider locations where m = 2 m, resulting in a new force value.

$$F_{3max} = 4.64 \times 10^{20} \text{ N} \quad (4)$$

$$F_{3min} = 4.28 \times 10^{20} \text{ N} \quad (5)$$

The latest data suggests that the mass affecting gravity can have extreme maximum and minimum values but can also assume other non-extreme values.

Depending on the region, these four values would alter the gravitational pull, resulting in a lighter or heavier crust. Therefore, the tectonic plates will move with an average mass, but some points oppose the movement, and some will dislocate without resistance. Analyzing in terms of crust, we discover that the subduction zones are suffering sufficient push from gravitational forces external and internal pushing to below the other plates, for example, the Nazca below South America; those interactions trigger earthquakes. In other cases, as the Tibetan Plateau has the highest average elevation and thickest crust on Earth at present, with the central regions of the plateau having crust thicker than 70 km, the external forces and internal gravity to the Earth's center are opposite to the movement pushing the Asian plate. In the classic model of the Tibetan Plateau formation, a fast-moving Indian continental plate it means that the Indian plate was lighter and collided head-on with the relatively stationary Asian plate about 50 million years ago.

Nevertheless, a few are being pushed in a clockwise direction because of the Earth's wobbling motion from east to west. Using GRACE satellite observations, JPL scientists examined this idea and its impact on Earth's mass. The new gravitational map satellites from Nasa correspond to Figure 11.

Let us discuss the tectonic movement from the extremes of Earth's point, the North and South poles. The North American plate extends all the way over the North Pole and even contains Siberia and Japan's northern island. It also includes Greenland, Cuba, and the Bahamas.

The 2nd largest plate on Earth is the North American Plate. Each plate moves deceptively slowly. For example, the North American plate shifts just centimeters every year. The mid-ocean ridges in the Arctic Ocean that continue from the North Atlantic Ocean are the boundary between Eurasia and the North American plates. The mid-Arctic ridges connect eastward to the Laptev Sea, Far East Asia, after passing through the eastern Siberian continent.

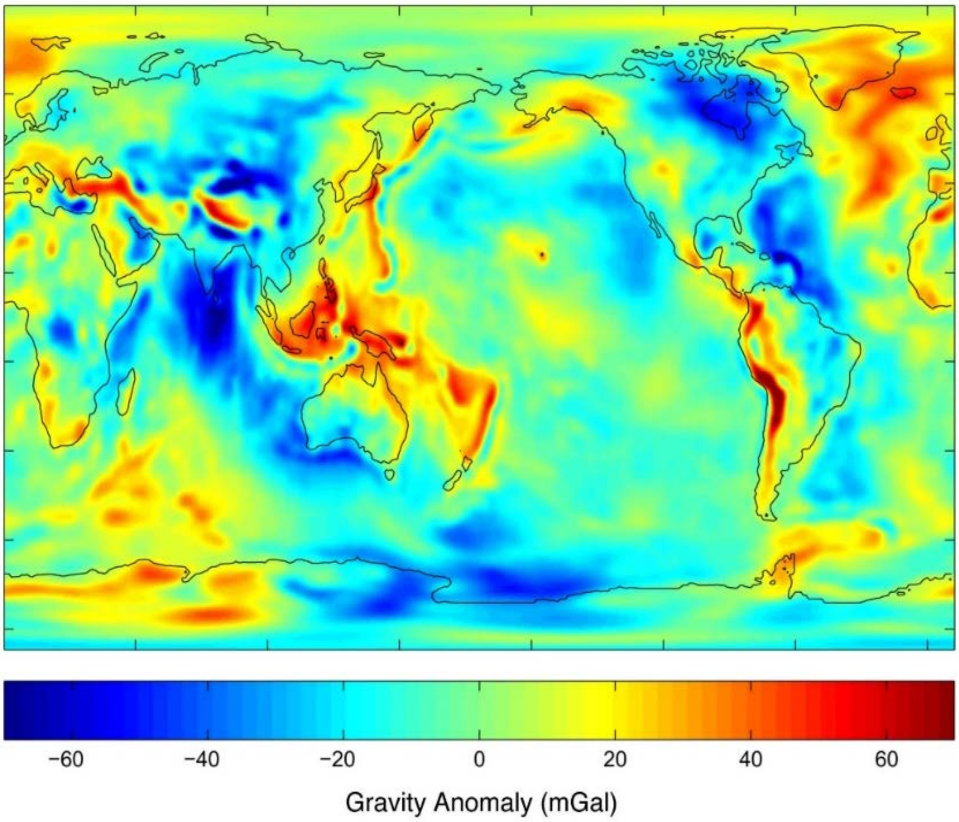

Figure 11. Data from NASA's GRACE mission shows how gravity varies across Earth. Red areas have stronger gravitational forces, while blue areas are weaker. (NASA GRACE/University of Texas at Austin)

The North American plate is—generally—mainly moving west, to slightly northwest overall. The spreading center is in the mid-Atlantic, with subduction zones along the western coast of South and Central America. Today, the continent of Antarctica is part of the larger Antarctic Plate, one of the Earth's seven major tectonic plates. The Antarctic Plate includes continental crust, which makes up Antarctica and its continental shelf, and oceanic crust beneath the seas surrounding Antarctica. Over the next 50 million years Antarctica will move north, shedding its icecap. The Antarctic Plate starts at the western edge of South America and stretches east into the southwestern part of the Atlantic Ocean. This Plate moves north and slightly west towards the Caribbean and North American plates. The Antarctic Plate generally moves northeast towards the Atlantic Ocean at about 1 cm per year.

Most of the data in this paper could not perfectly display the thickness or the plate boundaries for the Earth's extreme points as around Arctic or Antarctic. Our research somehow is inconclusive then we supposed both moving in the North direction as they were driven or attracted to an invisible center mass. Those two extreme locations of Earth are considered in this study, lightly; there is a lack of documentation in those locations, such as fractures and other geological features, such as subduction or other kinds of interactions, which would allow further analysis.

Scientists have yet to comprehend the gravitational pull between the Moon and Earth fully. The gravitational force, the Earth's rotation, the celestial bodies' wobbles, and the Earth's seasonal positions concerning the Sun will all add to the Plate's movement different responses as we described.

These locations indicate weaker points in the crust that can break under stress. It can happen suddenly or for a period when it accumulates energy until it can activate an event. Most quakes present foreshocks warning the next shake, and some have aftershocks as well, but seldom in history have they happened two times in the same regions, similar in magnitude to Türkiye (2023).

The highest magnitude events occur in convergent configurations, surpassing other locations. Earthquakes caused by continental normal faults usually have a maximum magnitude of 7.5 M, compared to 8.0 M for mid-ocean normal faults. M8.0 - M8.5 is the maximum magnitude for intraplate events, while subduction zones can reach M9.5. The "stickiness" of a fault segment should be considered when assessing faults. The northwest movement of the Pacific is caused by the seafloor spreading from the East Pacific Rise in the Gulf of California.

Due to seafloor spreading at the mid-Atlantic Ridge, the North American Plate is pushed towards the west and northwest. Subsequently, the asthenosphere's internal forces counteract the Earth's rotational movement from west to east. Those forces together also contribute to volcano eruptions surrounding the Ring of Fire. Gravitational forces and the opposition to them from the asthenosphere more stable and steadier layer add constant stress on the crust, creating new fractures and expanding the old ones. It is of paramount importance to map the worldwide crust with accurate data. The thickness of each

Plate plays a crucial role in triggering earthquakes and forming new cracks in the crust. Volcanoes play with the same rules and accumulate more magma, increasing the pace of eruption with high dependence on external factors. The Arctic exhibits diverse tectonic settings, including collision zones along plate boundaries, deformed regions within continents, mantle plumes, and rift systems.

The gravitational force and the movement of the tectonic plates are responsible for earthquakes and volcanoes. They were, altogether, triggering more earthquakes and volcanoes.

7. Earth's Translation, Precession, and Rotation

Rotation, translation, and precession are the primary movements of the Earth. The Earth-Moon gravitational connection will consider only the moon's rotation movement around the Earth. These movements will have crucial roles in the overall movement of the tectonic plate and must be analyzed and discussed in the last part of this paper, as in Figure 12.

As shown in the figure, the Earth's rotation and precession are in a counterclockwise direction, and the precession is in a clockwise direction. The set moving around the Sun makes a translation that takes one year to be completed.

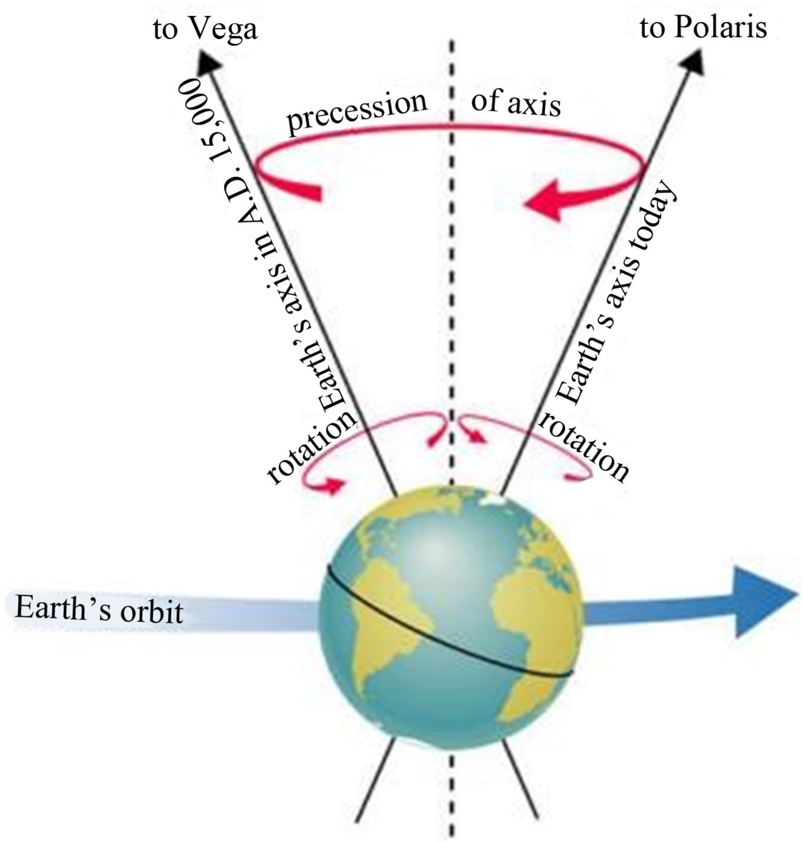

Figure 12. There are two Earth movements, precession and rotation on Earth's axis. Their movements are in opposite directions.

The significance of these Earth movements lies in their potential to drag the plates, seemingly at random but influenced by the rotation from west to east or the northwest push. The North American Plate's variable movement rates may seem surprising, considering plates move as rigid bodies. The plates move rotationally; that is the explanation. For instance, the North American Plate rotates in a counterclockwise direction. Therefore, the North American Plates synchronized their movement with the Earth's rotation, whereas the Eurasian Plates followed the wobble motion (clockwise direction). Both plates are in the Northern Hemisphere. The direction of movement for most plates studied is influenced by crust thickness, occurring in both counterclockwise and clockwise directions.

8. Conclusions

Concluding the investigation, here are the results obtained for the Moon-Earth interactions from 2008 to 2024. The study was conducted during the Moon's closest proximity to Earth.

a) The plates move from west to east due to gravitational forces.

b) Plate movement can be faster or slower due to the complexity of Earth's crust, which is influenced by gravitational force and Earth's rotation.

Plate displacement leads to energy accumulation, which triggers earthquakes of different magnitudes depending on the specific boundaries involved.

The highest magnitude earthquakes are triggered by subduction zones in convergent areas. The Ring of Fire in the Pacific is known for its seismic activities and the release of volcanic energy. Moreover, all observed phenomena on Earth's surface will gather energy before manifestation. The gravitational forces are connected to other types of external movements, such as those induced by the Moon, the Earth's rotation and translation around the Sun, and the wobble that causes the Earth to tilt on its axis. They collectively shift the tectonic plates, moving towards the Northwest. According to scientific observation, earthquakes and moonquakes are triggered by the multiple forces on Earth and the Moon. Moonquakes are an interesting phenomenon that can be attributed to the diverse forces acting on the moon's surface. The moon encounters different forces depending on where it is in its rotation around the Earth, such as the dayside, bow shock, and nightside. The moon faces the Sun at the dayside, there will be a transitional phase known as the bowshock, which marks the shift from the dayside to the nightside.

The moon will undergo heightened geomagnetic storms and suffer rapid changes under solar winds storms, as it is into the magnetotail, or nightside. And in this special location, the perturbance will be stronger. When the Moon is in perfect alignment with two other bodies, whether it's during the day or night, the chances of experiencing moonquakes significantly increase. All those transitions will induce earthquakes on the Moon's surface.

It plays a crucial role in forming volcanoes, affecting magma's movement beneath the Earth's crust. Overall, the Earth's external forces and the Moon's and

Sun's interactions are more critical, and we must look at them with a new vision to better understand the Earth's tectonic movements, the enhancement of earthquakes, and active volcano eruptions.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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