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THE PLANET MARS IN COMPARISON TO EARTH, ESPECIALLY TECTONICALLY

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Abstract: There is considerable similarity between the planet Mars and planet Earth. Both were formed about 4 billion years ago out of the solar nebula that gave rise to the sun and planets. Mars, however, is much smaller than Earth, its magnetic protection has been degraded, and accordingly also its atmosphere. The water on Mars, which once even accumulated sufficiently to form oceans, has largely evaporated and disappeared. The crust and lithosphere of Mars are of a unique configuration called a hemispheric dichotomy, which means that the crust is significantly thicker in the southern hemisphere than in the northern hemisphere.

Keywords: *Mars, Earth, Gravity of the Sun, Change in the location of the Equator of Earth and Mars, Hemispheric Dichotomy of Mars*

I. GENERAL DESCRIPTION OF MARS IN COMPARISON TO EARTH, FROM A GEOLOGICAL/TECTONIC ASPECT

Study of the planet Mars (Figure 1) began centuries ago, by means of telescope from Earth. In recent decades Mars has also been studied by sending spacecraft, some of which have orbited Mars and studied it by means of instruments on the spacecraft, while others have landed on the Martian surface and studied it using various rover vehicles. The most significant studies have been carried out by the United States, by NASA and by Elon Musk; also by the Russians, the Chinese, some European countries and India.

In my present article I have used the map and globe of planet Mars by National Geographic (2012). General data regarding Mars, as gathered by these abovementioned researchers, can be found on Wikipedia and Google. For the purpose of general orientation:

Mars' diameter is 6,720 kilometers, about half of Earth's, which is 12,740 kilometers. Mars completes a daily rotation around its axis every 24 hours and 37 minutes, as opposed to Earth's 23 hours and 56 minutes. Mars completes an orbit of the Sun every 686.98 days (a Martian year), as opposed to Earth's 365.25 days (a terrestrial year). Mars' average specific gravity is 3.95 g/cm3, as opposed to Earth's 5.51 g/cm3. Gravity on Mars' surface is about 38% of gravity on Earth's surface. Mars' axis of rotation is tilted at an angle of 24.9 degrees to its plane of rotation around the sun, the ecliptic plane, as opposed to Earth's tilt of 23.44 degrees to the ecliptic plane.

Mars' surface is full of craters. Ice is found on Mars in various places, especially the poles. The ice there is dry ice, frozen carbon dioxide (CO2). The atmosphere on Mars is very thin, and there is little water. Mars once supported oceans and lakes, especially in the planet's northern hemisphere. There are two very interesting unique phenomena on Mars; one is the aforementioned hemispheric dichotomy, and the other is called the Tharsis Rise. As regards the dichotomy, the thickness of the southern hemisphere's crust is 58 kilometers, while that of the northern hemisphere is only 32 kilometers. The Tharsis Rise is an elevated region in which there are numerous volcanos, including the tallest volcano in the solar system, called Olympus Mons, 21 kilometers high (225 E, 20 N., Fig. 1).

. Also found on Mars is a huge canyon, Valles Marineris—4,000 kilometers long, 200-300 kilometers wide, and 10 kilometers deep. It was formed in a tectonic manner of tension in the equatorial region (Fig. 1) and constitutes a very long graben.

In the past there was water on Mars, which formed oceans and lakes. Flowing water formed valleys and areas of alluvial deposits. Additionally, some of the water penetrated the various strata, especially the sandy layers, forming ground water. The various strata on Mars include various deposits, including large quantities of the mineral hematite. The oxygenation of hematite is what gives the planet its red color.

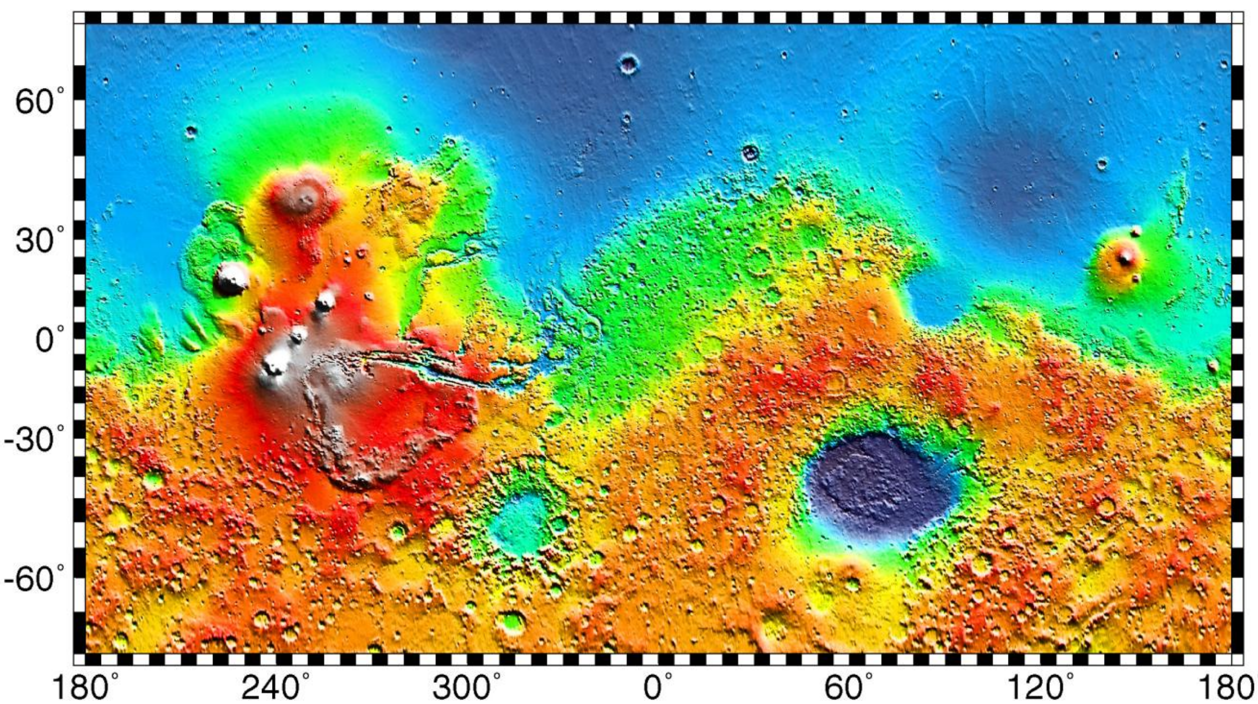

Figure 1: Map of Mars ' global topography data was produced by the Mars Global Surveyors MOLA instrument Produced ID P50409 MRPS 95009 Author NASA/JPLI/GSFC. Taken from Wikipedia

The customary method for geologically dating the planet Mars differs from geological dating methods of the Earth. The geological planetary periods of Mars are derived by counting craters, on the assumption that the surface areas more exposed to space over time have sustained more hits by asteroids and meteorites and therefore have more craters. Using this method, 3 different time periods have been identified:

The Noachian period began 3.5-4 billion years ago, in effect immediately after Mars was formed. It is characterized by a huge number of asteroid strikes upon Mars, which left many craters.

The Hesperian period began when the rate of asteroid strikes dropped, from around 3.5 to 2.9 billion years ago.

The Amazonian period began at the end of the Hesperian period 2.9 billion years ago and continues to this day.

II. DISCUSSION

a. How was Mars formed?

The planet Mars was formed as part of the process whereby the solar nebula, containing vast amounts of gas and dust, gave rise to the sun and planets of our solar system. Some of the nebular material went toward the formation of the four continental planets (Mercury, Venus, Earth and Mars). A large part of the material was shared by three bodies that were formed simultaneously, namely Earth, Earth's Moon, and the planet Mars. In my view, the bulk of the material, with much of the heavy elements such as iron and nickel, went to Earth, while the Moon and Mars were left with more of the lighter material, such as silica.

I draw this conclusion mainly from the specific gravity of these three celestial objects. The Earth's average specific gravity is 5.51 g/cm3, that of the Moon is 3.346 g/cm3, and that of Mars about 3.95 g/cm3.

Earth's diameter is 12,740 kilometers, the Moon's is 3,470 kilometers (one quarter of Earth's diameter), and that of Mars is 6,730 kilometers (half of Earth's diameter).

The heavier material, such as iron and nickel, became concentrated and formed the cores of the two planets, Earth and Mars.

The phenomenon of Earth's magnetic mantle was formed in Earth's core. Something similar probably happened on Mars. It may be assumed that immediately after the two planets, Earth and Mars, were formed, the dynamo phenomenon arose, forming a magnetic field around the two planets. The magnetic field protected both planets, although its protection of Earth was much stronger and more efficacious than that of Mars. Nonetheless, Mars' magnetic field does exist.

Of note is a very interesting and wondrous phenomenon, regarding the tilts of both Earth's and Mars' axes of rotation to the ecliptic plane, at similar angles—Earth at an angle of 23.5 degrees, Mars at an angle of 24.9 degrees. Also note that Earth's speed of rotation is similar to Mars' speed of rotation. A full day on Earth is 23 hours and 56 minutes, on Mars—24 hours and 37 minutes. (Some researchers believe that Mars' angle of rotation, over the course of Mars' existence, has been different than the extant angle to the ecliptic plane.) It follows that both planets were formed from the same nebular material and assumed similar characteristics as regards their motion around the sun, and as regards the angle of their tilt to the ecliptic plane. There is a difference, however, regarding the shape of their orbit around the sun. Mars' orbit is more elliptic than Earth's orbit (the ellipticity of Earth's orbit is calculated at 0.017, as opposed to Mars' 0.093, with zero representing absolute circularity).

In my view, the similarities between the two planets' angle of rotation and length of day are not accidental but rather indicate that the two planets were formed at the same time and under similar celestial conditions. This has led to their having certain similar characteristics over billions of years since they were formed, about 4 billion years ago. However, generally speaking Earth, including its magnetic field, is much more stable. Contrarily, Mars' magnetic field has almost or entirely disappeared. In my view, the dissipation of Mars' magnetic field was caused mainly due to bombardments of very large asteroids, such as the huge asteroid which created the large depression known as Hellas Planitia, located in Mars' southern hemisphere, at central coordinates S40 – E70. Its length is 2,300 kilometers (running east-west), its depth, 8,200 meters (Fig. 1).

b. General Tectonics of Earth, in comparison to Mars' Tectonics

Here we note the geological and tectonic characteristics of Earth and then compare them to those of Mars

The Main Cause Influencing the Movement of the Earth's Axis of Rotation is the Sun

The main factor influencing the movement of the Earth is the Sun. This factor determines the path of the Earth's rotation around the Sun, and it could have an effect on changing the Earth's axis of rotation and shape. The Earth completes a full rotation around the sun every year. The axis of the earth's rotation is at an angle towards the Sun of approximately 23.40 degrees (obliquity of the ecliptic).

Twice a year, in the spring and fall (21 March, 23 September), the gravity of the Sun operates mainly in the direction of Earth's Equator (the equinoxes), and twice a year, in the summer and winter (21 July, 22 December), the gravity of the

Sun operates to a great extent in the direction of the North and South Poles (the two edges of the axis of Earth's rotation) (Fig. 2). Because of this phenomenon, when the edges of Earth's rotation axis face the sun, there is relatively greater gravity of the Sun on the poles (edges) and this gravity causes a slight shift of Earth's mantle, thereby also causing a change in the direction of the rotational axis on the mantle and not a change towards Earth's orbital plane—the ecliptic plane. The shift of the axis of Earth's rotation on Earth's mantle is estimated to be on a scale of several millimeters a year, around 2 mm in summer and around 2 mm in winter, totaling around 4 mm a year.
In conclusion, the Sun is the main cause of the change in location of the axis of Earth's rotation on Earth's mantle, including the asthenosphere and the lithosphere, and accordingly, of the change in the Equator's location wherein the greatest centrifugal energy on Earth's surface is found. This change is the main cause activating the centrifugal energy on various parts of Earth and the movement of continents across its surface. These shifts are in directions that for the most part can be traced, at least during the last 200-250 million years, from the Mesozoic to the present, and can be foreseen in the future.
Greitzer, Y. (September 2020), Gravity of The Sun

The Theory on Which the Movement of the Continents is Based

The assumption is that over an extended geological period, the axis of the earth's rotation in a pseudo-circular orbit changes its location. A model presented with explanations (Greitzer, Jun. 2020) assesses the probability of a change in the axis of the earth's rotation in a peripheral manner by about 90 degrees and, accordingly, about a 90 degrees change in the Equator's location (Figs 3, 4) The actual movement of the continents depends also on many other geological factors. The movement of the continents was first discerned by Wagener (1922; 1966), who in his studies established the basis for the theory of plate tectonics.

In the present work, we assume that the location of the axis of Earth's rotation in circles of large circumference changes its position on the globe significantly relative to the mantle of the earth because of the Sun (Fig. 2, see details in Greitzer, Y., September 2020, Gravity of The Sun).

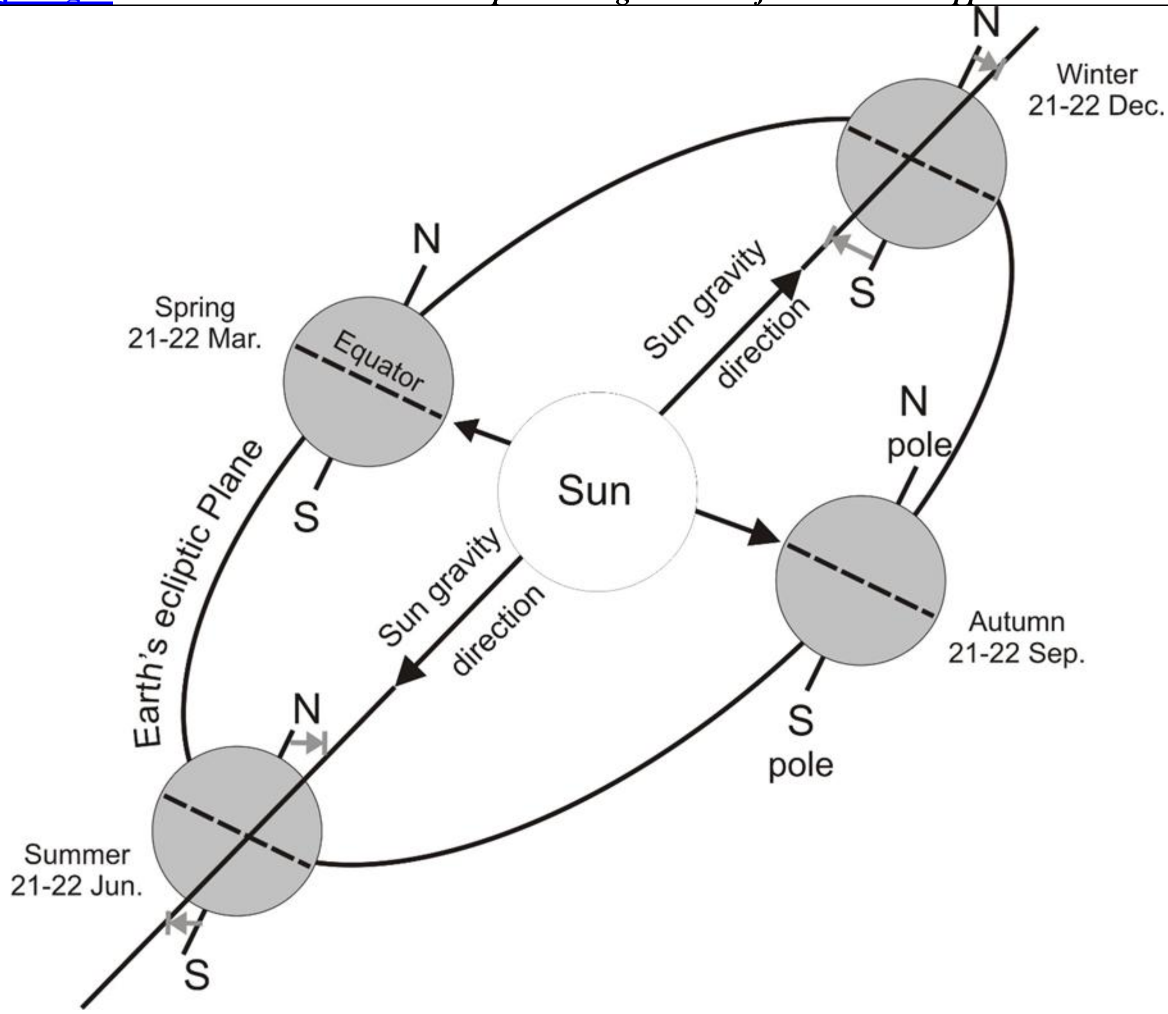

Figure 2: : The force of gravity of the Sun on the Earth. By Y. Greitzer, Sep. 2020

The speed of rotation of the mantle crust of the earth is highest at the Equator and gradually decreases towards the North and South Poles. Hence the change in location of the Equator will cause a significant change in the forces of movement—speed of rotation—the centrifugal forces that act on the continents and move them. Accordingly, the movements of the continents will be related to the intensity and directions of the new centrifugal forces.

We assume that since the creation of Earth and its initial rotations, in the course of the geological eras the change in location of the axis of Earth's rotation has had a trend and direction (Figs. 3, 4). I try to reconstruct the possibility of a change of location of the axis of Earth's rotation, and accordingly, of a change in the location of the Equator that relates to the last geological era, approximately the Mesozoic to Recent (around 200-250 million years). Likewise, we assume that in earlier periods, Earth's rotational axis changed its location to the extent of several rotations on the globe (see details, Greitzer, Feb. 2022). This did not necessarily take the form of full circumference circles, but assumedly large circles.

The Sun's Influence on the Movement of Mars' Axis of Rotation, and accordingly on the Movement of its Equator

Like Earth, Mars is influenced by the Sun's gravity, in that the Sun moves Mars' axis of rotation, and accordingly also guides the movement of its equator across the mantle. How the Sun's gravity influences the change in Earth's axis of rotation is presented and explained in detail above and in a previous article of mine (Greitzer, Y., September 2020, Gravity of the Sun), and similarly applies to Mars. On Mars, however, it's on a much smaller scale. One reason for this lesser influence is the fact that Mars' orbit around the sun is more elliptical than that of Earth, and the section in which the Sun moves the axis of rotation across the mantle, in winter and in summer, is much smaller than the corresponding section on Earth. For Earth to complete a full rotation around the Sun in its elliptical orbit takes 365.25 days, whereas for Mars it takes 686.98 days. This difference also diminishes the intensity of the movement of Mars' axis of rotation. Additionally, Mars' greater distance from the Sun relative to Earth, in summer and in winter, diminishes the influence of the Sun's gravity on the movement of Mars' axis of rotation. Furthermore, additional changes may diminish the influence of the Sun's gravity on moving Mars' axis of rotation, due to the much smaller size of Mars' mantle.

To summarize, then, in principle the Sun's influence on the change of location of Mars' axis of rotation is similar to the workings of this mechanism on Earth, but on a much smaller scale. In my view, as on Earth, the Sun's influence on the change of location of Mars' axis of rotation began when Mars was formed in a spherical shape, about four billion years ago. The Sun's significant impact on Earth's axis of rotation since Earth's formation, also about four billion years ago, led to Earth's performing several 360-degree turns until the present day, and that influence continues.

As regards Mars, however, as noted above, the influence was much smaller: Mars' axis of rotation has changed by only 180 degrees over some four billion years. Accordingly, the location of the equator has changed by only 180 degrees, moving from south to north throughout the planet's existence. Having given rise to Mars' hemispheric dichotomy, that impact of the Sun now continues.

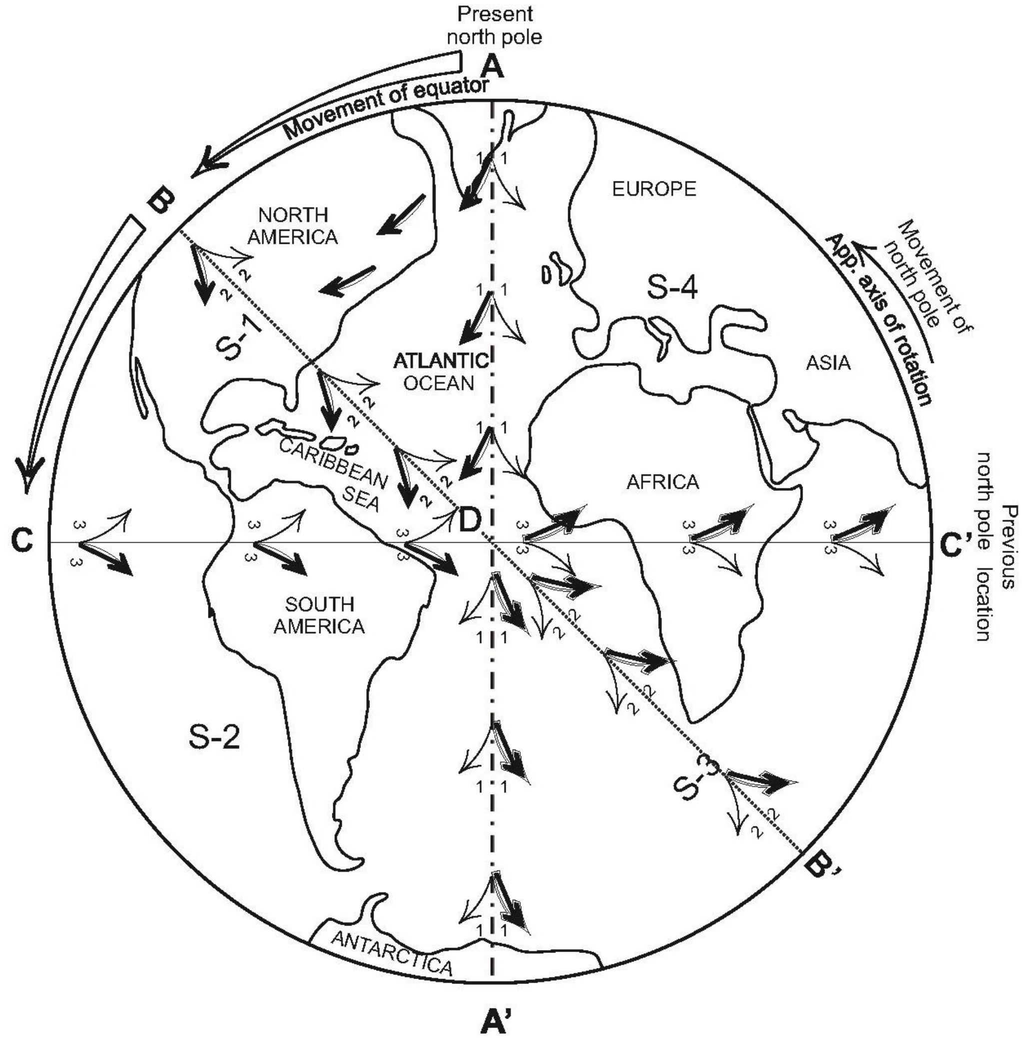

Figure 3: : Movement of equator 90 degrees from point A to C (movement of pole also 90 degrees from point C' to A). View from Atlantic Ocean – Caribbean Sea. By Y. Greitzer, July. 2020

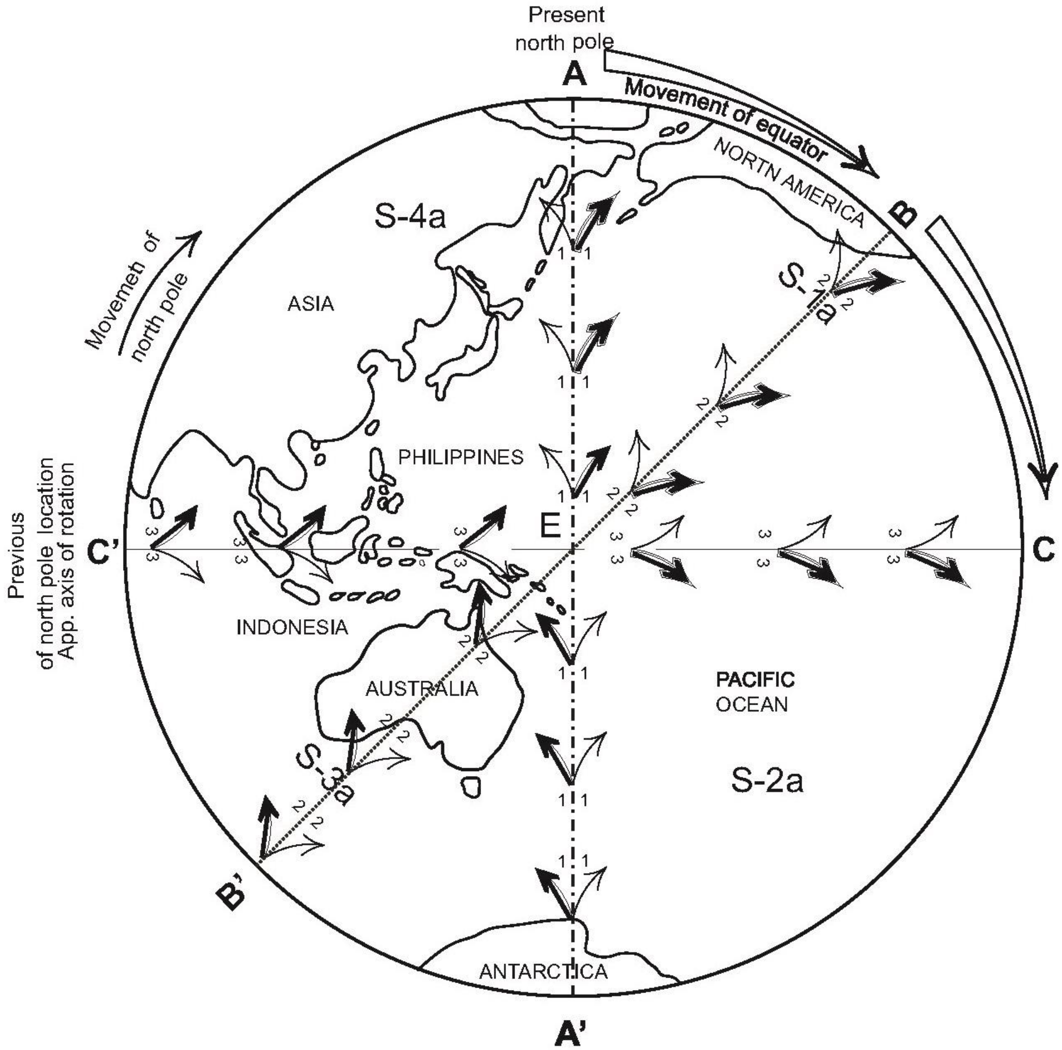

Figure 4: : . Movement of equator 90 degrees from point A to C (movement of pole also 90 degrees from point C' to A). View from Pacific Ocean, Philippines – Caribbean Sea. By Y. Greitzer, July 2020

Hemispheric Dichotomy of Mars

Mars' dichotomy stems from the discrepancy in the thickness of the crust between the planet's northern and southern hemispheres, with the change occurring at the Equator—in the southern hemisphere the crust's thickness is 58 kilometers, while in the northern hemisphere it is only 32 kilometers.

On Mars as on Earth, the rotational speed of the continents located at the Equator is the greatest. On Earth, when the Equator's location changed, in its advance it caused an increase in the rotational speed of the continents towards which it advanced, which in turn led to their fragmentation and the movement of their parts, what we call plate tectonics (Greitzer, Y., July 2020; Wegener, A., 1966; Wolpert, Stuart, August 9, 2012).

On Mars, the Sun's action on moving the planet's axis of rotation, accordingly moving its Equator as well, as explained above, was much smaller than on Earth. In my view, the axis of rotation moved 180 degrees, the north pole of today being located where the south pole once was. Accordingly, the Equator moved also by

180 degrees. In the equatorial region the movement caused tension and the rise of magma, which led to a thickening of the crust. Since the Equator advanced continuously—albeit gradually, for only a short distance each time—the magma rose again as it advanced, causing a thickening of the crust in the equatorial region. As Mars' axis of rotation advanced from south to north, and accordingly, its Equator too advanced from south to north, there was a continuous thickening of the crust as the Equator advanced, to a greater thickness in the southern hemisphere than in the northern hemisphere—giving rise to the hemispheric dichotomy. In my view, this process began when Mars took on spherical form some 4 billion years ago and continues to this day. However, there are various opinions among scholars as to how the dichotomy was formed (Andrews-Hanna, J.C. et al., 2008; Ke, Y. & Solomonov et al., 2006; Keller, T. & Tackley, P.J., 2009; Nimmo, F., Hart et al., 2008; Watters, Thomas R. et al., 2007; Zhong, S. & Zuber, M.T., 2001).

The tension in the equatorial region of Mars' crust, which was created in the course of the Equator's advance, can be seen today in tectonic tension and geological faulting, and in the creation of the deep graben known as Valles Marineris, which is 4,000 kilometers long and 200 kilometers wide (Fig.1). In other proximate regions, pressure arose due to the movement of lava through the crust, giving rise to a volcanic region known as the Tharsis Rise (Center 245E 5N., Fig. 1) .The creation of the dichotomy and the advance of the Tharsis Rise can be compared to the movement of the continents—plate tectonics—on Earth.

Tharsis Rise of Mars

The Tharsis Rise region is located at approximately 245 degrees East and 5 degrees North (Fig.1). The region is home to several volcanoes, including Olympus Mons, which is 21 kilometers high (255E 20 N, Fig.1) and another three large volcanoes: Arsia Mones, Ascraeus Mones, and Pavonis Mones,

In the south, the region is located near the Equator, but it mainly lies north of the Equator, in the northern hemisphere. It may be assumed that the rise of the magma and the creation of the Tharsis Rise region took place as the Equator advanced from south to north and the crust of Mars' southern hemisphere thickened. The Tharsis Rise region began to form at a very early period. There are various opinions as to how it was formed (Hynek Brian et al., 2011; Wenzel, M.J. et al., 2004). According to one opinion, the advance of the Tharsis Rise region occurred by means of convection currents, similarly to what happens on Earth. In my view, the advance of the Equator and the Tharsis Rise region was caused by the Sun's gravitation acting on Mars's axis of rotation, and accordingly also on the advance of the Equator (see the explanations above). However, it is also possible that both of the above forces are acting on the Tharsis Rise region and its advance. According to researchers (Simon Morden, July 2022, p. 167), Mars' axis of rotation moved to a distance of 1,100 kilometers, and as a result the Tharsis Rise region also moved northward, at an estimated yearly rate of approximately 2 millimeters.

Possibly the Tharsis Rise region also helped the balancing function and stabilization of Mars' axis of rotation. And possibly also Mars' core was able to move to help the balancing function of Mars' axis of rotation

Magnetic Protection (Dynamo Action) of the Planet Mars and its Atmosphere

Mars' magnetic protection arose from when Mars began to form, some 4 billion years ago, similarly to the magnetic protection of planet Earth. However, right from the start there were large differences in the strength of their magnetic fields. The magnetic fields emanate from the cores of the two planets, made up mainly of heavy metals like iron and nickel. Earth's core is probably much larger than Mars', both absolutely and apparently also in relative terms, with reference to Mars' mantle and crust. This can be inferred from Mars' specific gravity, which is much lower than Earth's. Mars' specific gravity is 3.85 g/cm3, as opposed to Earth's 5.51 g/cm3.

Earth's core is mobile and moves mainly to the north and south (Earth turns on its axis from west to east), performing the function of maintaining Earth's equilibrium and stability (Greitzer, Y., October 2020).

Mars' core possibly performed a similar function of maintaining equilibrium, especially due to the formation of Mars' hemispheric dichotomy, so the crust of its southern hemisphere was in a process of deformation.

In the early stages of Mars' formation, the magnetic field protected Mars and preserved its atmosphere, which mainly protected against meteorite strikes as well. It bears mention that between Mars and Jupiter there is a belt of asteroids, made up of rocks of various sizes, up to several kilometers in length and width. Mars' relative proximity to this asteroid belt resulted in several episodes of asteroidal bombardment over time. In my view, this has led to a degradation of Mars' magnetic protection and its atmosphere. The degrading impact on Mars' magnetic protection and atmosphere was caused by the strikes of large asteroids; notable among them was the huge asteroid which formed the largest crater on Mars, which is located in the southern hemisphere and is called Hellas Planitia, with a diameter of 2,300 kilometers and a depth of 8.2 kilometers. Its center is located at 70 degrees east and 40 degrees south (Fig. 1).

To a certain extent, it is comparable to the large asteroid that struck Earth in Mexico some 60 million years ago, leading to the extinction of the dinosaurs. However, because Mars is so much smaller than Earth, the effect of an asteroid strike of such a scale was that much more destructive, causing huge damage upon Mars.

It may be assumed that there were additional massive strikes of asteroids and meteorites on the surface of Mars' northern hemisphere as well, in the region that is relatively low topographically, where apparently there used to be oceans, although the craters they formed are apparently covered by sands and other geological layers

Existence of Water on Mars, and How It Was Formed

In my view, the beginnings of water on Mars are similar to its beginnings on Earth (Greitzer, Y., July 2024). Water was formed during the formation of planet Mars and its various geological strata, due to the large quantities of hydrogen and oxygen in the stellar dust from which Earth and Mars were formed at about the same time.

On Mars, ice can be found today in various places, mainly at the poles; most of it is dry ice, formed from the freezing of carbon dioxide. There is ice also in other places on Mars' surface, like that found at the poles, and perhaps also ice formed from water. In my view, these various places were formed due to the movement of Mars' axis of rotation, and with that the movement of the planetary poles, leaving ice in those places where the poles had been located. I estimate that since its formation, Mars' axis of rotation has moved by about 180 degrees, from south to north (see the explanation in the section "Hemispheric Dichotomy of Mars").

On Mars there once were lakes and oceans, especially in the northern hemisphere. Due to the degradation of Mars' magnetic protection, most of Mars' atmosphere has disappeared. Only a thin and meager atmosphere has been preserved, which proved unable to protect the water from evaporating from Mars. Therefore, the lakes and oceans that used to be upon Mars disappeared by evaporation. Water was left only within the geological strata which did not lie exposed at the surface, giving rise to the ground water that exists to this day on Mars.

The Asteroid Belt

It bears emphasis that there is an asteroid belt located between the planets Mars and Jupiter. The belt contains millions of rocks of various sizes, from the size of a grain of sand to hundreds of kilometers in diameter. The asteroids are made up mainly of rock, and a certain percentage are made up of heavy metals (iron and nickel).

This asteroid belt separates the four planets made up of solid lithic material—Mercury, Venus, Earth and Mars—from the huge gaseous planets: Jupiter, Saturn, Uranus and Neptune. Since the asteroid belt is proximate to Mars, it has had a significant impact on Mars due to occasional bombardment by asteroids and meteorites, including large asteroids. On the more distant Earth it has had a much lesser impact

III CONCLUSION

There is considerable similarity between the planet Mars and planet Earth. Both were formed about 4 billion years ago out of the solar nebula that gave rise to the sun and planets. Mars' diameter is about 6,720 kilometers, about half of Earth's diameter of 12,740 kilometers. But in several aspects, there is wondrous similarity between the two planets. Mars completes a full rotation around its axis in 24 hours and 37 minutes, while Earth completes a full rotation around its axis in 23 hours and 56 minutes. Mars' axis of rotation is tilted at an angle of 24.9 degrees to the planet's ecliptic plane, while Earth's is tilted at an angle of 23.44 degrees to its ecliptic plane.

On Mars there is an interesting unique phenomenon known as the hemispheric dichotomy. The thickness of Mars' crust varies between the two hemispheres, the southern hemisphere being thicker than the northern hemisphere, with the change in thickness occurring approximately at the Equator. In the southern hemisphere the crust's thickness is 58 kilometers, as opposed to 32 kilometers in the northern hemisphere. This is a phenomenon unique to Mars, and there are various theories as to how it was formed. In my view, the action of the sun caused Mars' axis of rotation to move by 180 degrees, the north pole of today being where the south pole once was. Accordingly, the Equator too moved by 180 degrees.

This movement is slow and gradual, leading to intense tension and pressure at the Equator, as well as to a rise of magma, which led to a thickening of the crust in the equatorial region. Thus, the southern hemisphere has thickened in the course of the Equator's movement by 180 degrees throughout the planet's existence.

Mars' magnetic protection began to form as soon as Mars itself began to form about 4 billion years ago, like the magnetic protection that was formed on Earth. Right from the start, however, Mars' magnetic field was weaker than Earth's.

An asteroid belt is located between the planets Mars and Jupiter. The asteroids contain rocky material of various sizes, from a few millimeters to dozens of kilometers across. Due to the belt's relative proximity to Mars, the planet's surface has been bombarded by asteroids and meteorites in various periods of its history. In my view, very large asteroids—such as the one that created the depression known as Hellas Planitia in the planet's southern hemisphere—caused a degradation of Mars' magnetic protection. Due to the lack of magnetic protection, the planet's atmosphere became degraded too. Before the atmosphere's degradation, there were large amounts of water on Mars, which even accumulated to form oceans in the course of Mars' formation, just as on Earth. However, because all that was left of the atmosphere was thin and weak, the water evaporated and escaped from Mars, and only some ground water remained, mainly in the sandy geological layers.

VI ACKNOWLEDGEMENT

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