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*Corresponding author

Flavio Barbier, Engineer and researcher, Livorno, Italy

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Mini Review

# Earth an Unstable Planet Why and How the Poles can Shift

**Flavio Barbiero***

*Engineer and researcher, Livorno, Italy*

## Abstract

There is compelling evidence that the poles have shifted in the past, but this idea is dismissed as impossible by the scientific community on the assumption that the stabilizing effect of the equatorial bulge is so great that no conceivable force could make the Earth shifting on its axis, except for the collision with a planet-size body. In theory, however, a wide shift of the poles could be obtained simply by reshaping the equatorial bulge, a ring of matter that from about 15km at the equator decreases down to zero at the poles. At least 20% of this matter is made by water, which covers 2/3d of the whole Earth. A well-known physical law assures that free liquid surfaces create instability, thus Earth is an inherently unstable planet. Every displacement of water provokes a wobbling of the axis of rotation. An ocean wide tide or tsunami of hundreds of meters would displace the axis of some degrees, therefore the polar icecaps would rotate off-center developing a toppling torque. The shift would increasingly grow to the point of provoking the sudden rebound of the Earth's mantle and in the end a reshaping of the equatorial bulge around a different axis of rotation. We can imagine more than one reason that in theory could provoke a tide of the required magnitude, but the most probable culprit should be the impact of a large asteroid. The analysis of the behaviour of a gyroscope subject to a disturbing torque provides a clear explanation of why and how the impulsive torque produced by the impact of an asteroid could trigger a process which in the end results in a shift of the poles.

## Evidence that the Poles have Shifted

It is well known that the poles have changed their position on the Earth's surface during the past geological eras. The marks left by thick ice sheets in Africa and India, the residual magnetism in ancient rocks, the old coral reefs' and coal deposits' distribution and so on, all together are compelling evidence that the poles have wandered from what is today's equator to the actual poles [1-5].

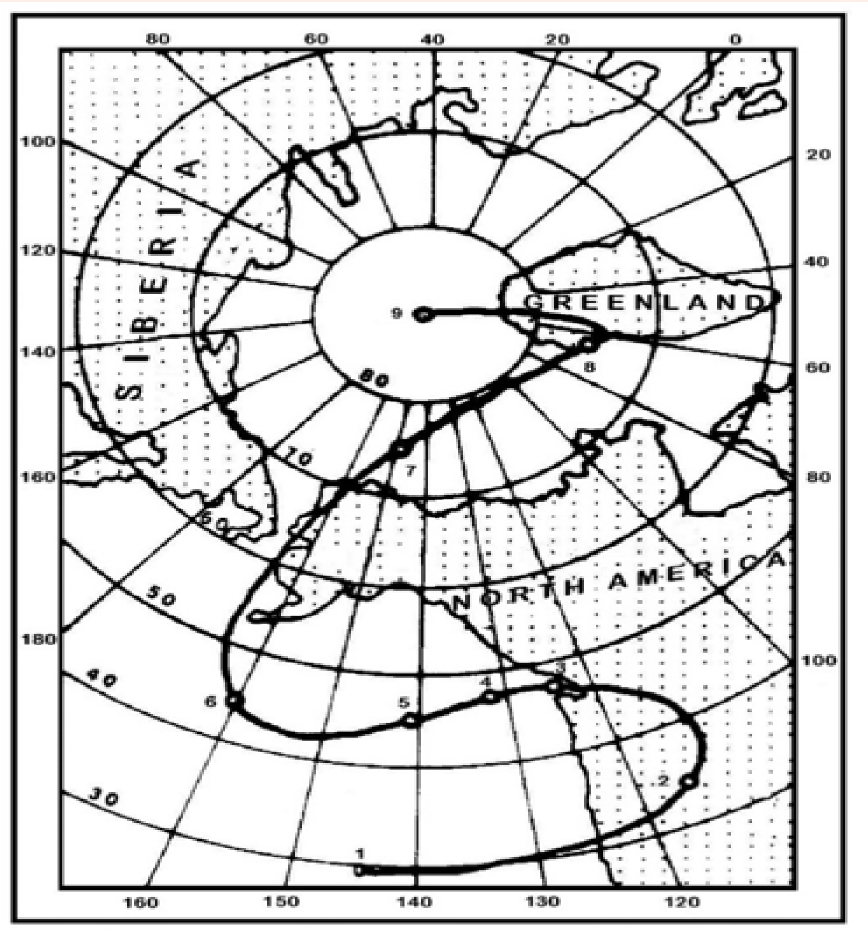


**Figure 1:** The wandering of the North Pole during the last 300 million years.

Scientists account this wandering to the drift of continents and to the displacement of large quantities of materials, due to erosion and sedimentation processes, which in theory could provoke a very slow shift of the poles, a few centimeters per year at the most, which in hundreds of millions of years can result in shifts of thousands of kilometers.

Geological evidence, however, seems to indicate that the wandering of the poles was not gradual and continuous, but it happened by "jumps". There is strong evidence that such a jump occurred in a very recent past. Between 50 and 12 thousand years ago an impressive ice cap spread from the Hudson area southward, down to the actual New York's latitude, and westward to join, at its maximum extent, glaciers flowing down from the Rocky Mountains in Alaska. During the same period North Europe was covered by ice caps, which at their maximum extent reached the latitude of London and Berlin. The quantity of water trapped in these ice sheets and in the glaciers scattered around the world was so large that the sea level was more than 100 meters lower than today.

The current scientific explanation for the existence of these ice caps is that they were due to a cooler climate all over the world. But this theory seems to be contradicted by the absence of ice sheets in Siberia, which was populated, up to its northernmost regions well inside the Arctic Sea, by one of the most impressive zoological communities of all times. Strong evidence that the climate around the Siberian Artic was much milder than today, at least during wintertime [6-11].

**Figure 2:** Position of the northern polar ice cap at the end of Pleistocene

The most natural explanation for this climatic situation is that the poles were on a different position than today. They would have moved to the actual position at the end of Pleistocene. This, in fact, was the hypothesis taken into consideration since the 19th century.

However, some of the greatest scientists of the time, including J C Maxwell and Sir George Darwin (son of the famous Charles Darwin), considered this problem and decided that the stabilizing effect of the equatorial bulge was so great that no conceivable force could make the Earth shifting on its axis, except for the collision with a planet-size body. They therefore dismissed the idea of any shift of the poles as impossible and, in fact, not worth discussing.

Yet the evidence is so compelling that attempts were made to demonstrate that possibility. The most renowned is due to Charles Hapgood, who proposed the theory that the whole Earth's crust was displaced due to the weight of the polar ice caps. It was dismissed because incompatible with the plate tectonics. Another often proposed theory, although not supported by calculations, is that the impact of a large asteroid, like the 10-km-wide that caused the extinction of the reptiles at the end of the Cretaceous, could provoke somehow a shift of the poles. Compared to Earth, a 10-km-wide asteroid is a tiny sphere of 25mm. in front of a 25 metres ball. A simple look at figure 3 should convince that this is a non-viable idea. How a mass so irrelevant could directly provoke a shift of the poles?

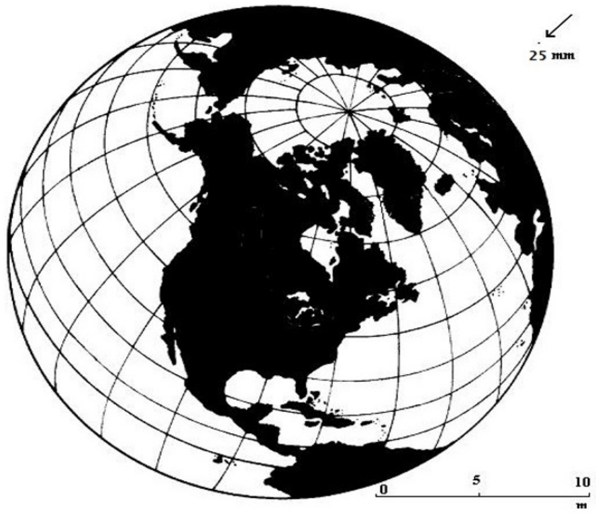


**Figure 3:** Compared to Earth, a 10-km-wide asteroid is a tiny sphere of 25mm in front of a ball of 25 metres.

Scientists assume that such an impact would have provoked a sudden drop of temperature and other world-wide climatic turmoil, because of the huge amount of matter injected in the atmosphere. But looking at figure 3 this theory too appears not fully convincing. Somehow that impact must have triggered a much more catastrophic phenomenon than a drop of temperature. A shift of the poles could better explain the geological phenomena and the mass extinctions, both inland and in the ocean, that followed the impact. But of course, geologists strongly deny this possibility because they cannot figure out a mechanism capable of explaining how and why this could happen.

## Earth is an Unstable Planet

Maxwell statement that "only" a planet-size-impact could make the poles shift was not fully correct, because there is a much less catastrophic event that could do it, that is the "reshaping" of the equatorial bulge. He himself, in fact, pointed out that the stabilizing torque of Earth is developed not by the entire mass of the planet, but only by the equatorial bulge, that is, by a ring of matter which at the equator has a medium thickness of about 15km, going down to zero at the poles, only the 0,2 % of the terrestrial radius. A small deformation of this 0,2 % can induce wide shifts of the poles, and this can happen without displacing masses from one side to the other of the surface. Centrifugal forces could easily do the job.

Apparently, Maxwell did not consider a well-known (at least by naval engineers) physical law according to which free liquid surfaces create instability in every system. Just a look at the extent of its oceans is enough to conclude that Earth is an inherently unstable planet. Let's see why.

Imagine that somehow Earth should be forced to rotate around an axis shifted of, let's say, 20 degrees. Inevitably after a while the equatorial bulge would be reshaped around this new axis, because the centrifugal forces would make rebound the surface along the circle normal to it and the old equator would be flattened. The amount of the deformation would not be relevant. The rebound of the new equator at its highest point would be of around 1km, going down to zero at 90°, were it crosses the old equator. Distributed over a semicircle of 20,000km this means a deformation of 5cm per km. Less for smaller shifts.

The problem is to know what could force Earth to rotate around a shifted axis. Here it is where the water comes to play. We know that tsunamis make the axis wobble; not too much, of course, because the mass of water displaced by a normal tsunami of a few meters is irrelevant. Imagine, instead, a tsunami hundreds of meters high and some thousands km wide moving from the equator towards the poles, or better a tide of that magnitude at medium-high latitudes.

It would make the axis of rotation shift of some degrees. The effect of the tide would be strongly amplified by the fact that the polar icecaps would become eccentric thus developing a toppling torque. Therefore, the axis of rotation would gradually shift until somewhere the Earth's surface would rebound under the action of centrifugal forces, probably at the bottom of the oceans where it is more plastic. We can discuss if the rebound of the crust would occur for a shift of the axis of 10 degrees or 5 or even less, but not to doubt that it would happen. In these conditions it certainly will. This initial rebound would trigger an ample reshaping of the bulge and a consequent permanent shift of the poles.

It now remains to understand what could provoke tsunamis or tides of the required magnitude. In principle nothing prevents that they could happen and there is evidence that in fact they did happen in the past. Earthquakes, underwater landslides, a sudden sliding in the ocean of large chunks of the Antarctic icecap, a close passage of a planet-size body, impacts of asteroids? The only plausible cause is the last one. We can demonstrate, in fact, that a large asteroid impacting Earth (not necessarily on the ocean) could trigger a process that in a very short time would produce precisely that result. Let's see how.

## How the Poles could Shift

Due to the large disproportion between Earth and a 10-km-wide asteroid (Figure 3) the possibility that such an impact could induce a shift of the poles seems to be out of the question: the mass of such an asteroid, and the associated energy, cannot directly provoke a shift higher than a few centimetres.

However, if mass and energy of the asteroid can be neglected, the same cannot be done for the torque developed by the impact. To understand why, we must consider that the stabilizing torque of Earth is developed not by the entire mass of the planet, but only by the equatorial bulge. Due to the very high speed of the asteroid (between 20 and 70km/sec), provided that the angle of the impact is large enough, the impulsive torque developed could reach a peak value so high as to overtake the reaction torque developed by the equatorial bulge. Just for a short instant, but enough to "trigger" the process which in the end results in a shift of the poles.

To understand how it works we must analyze the behaviour of a gyroscope when subject to a torque equalizing that developed by the gyro. A problem that was never analyzed from a mathematic point of view, because of no technical interest. We will analyze it with a graphical method.

## Rotational Components in a Disturbed Gyroscope

The rotational components in a disturbed gyroscope are connected to each other by the following equation, due to Laplace, which expresses the principle of conservation of energy:

$$J_o\Omega^2 = J_o\omega^2 + J_p\omega_p^2 = J_i\omega_i^2 \quad (1)$$

where:

$\Omega$ = speed of rotation of the undisturbed gyroscope
$\omega$ = speed of rotation of the gyroscope around its main axis
$\omega p$ = speed of precession
$\omega i$ = speed of instantaneous rotation
$Jo$ = main momentum of inertia
$Jp$ = momentum of inertia related to the precession axis
$Ji$ = momentum of inertia related to the axis of instantaneous rotation

The value of the torque developed by a disturbing force $F_p$, applied to the main axis of the gyroscope with an angle β, is given by:

$$C_p = RF_p Sen\beta \quad (2)$$

where R is the arm of the force.

Instant by instant the disturbed gyroscope rotates around a different axis while its main axis moves along a cone with angular speed $\omega_{pa}$ around an axis parallel to the disturbing force (see fig. 1), called "axis of apparent precession" (for Earth is called simply "axis of precession").

The value of $\omega_{pa}$ is given by:

$$\omega_{pa} = \frac{\omega_p}{sen\beta} \quad (3)$$

Equations 1), 2) and 3) allow to study the behaviour of a disturbed gyroscope by means of an essentially graphic method.

Given a gyroscope let's draw, on the basis of its inertia ellipse, another ellipse whose semi-axis are respectively:

$$a = \sqrt{\frac{J_o}{J_p}}; \qquad b = \sqrt{\frac{J_o}{J_o}} = 1$$

Every radius of the ellipse, r(θ) , where: θ = 0 ÷ 2π, would have the value:

$$r_\theta = \sqrt{J_0 / J_\theta}$$

where J is the momentum of inertia of an axis forming an angle θ with the main axis.

If we put $\Omega^2 = 1$, for equation 1) every radius r(θ) is proportional to the speed of rotation that the gyroscope must have around axis θ to keep its initial energy unchanged. The end of the arrows representing $\Omega$ and $\omega i$, therefore, always fall on the ellipse, while all the other rotational components are inside. Therefore, this ellipse allows to analyse the behaviour of the rotational components of the gyroscope (Figure 4).

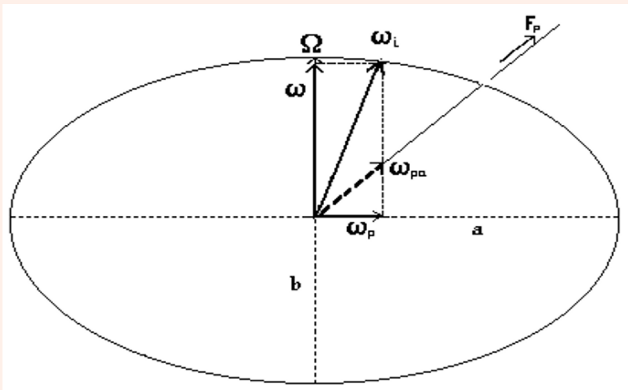


**Figure 4:** Ellipse allows to analyse the behaviour of the rotational components of the gyroscope.

A gyroscope subjected to a disturbing torque reacts generating an equal and opposed torque, by means of a precession movement, $\omega_p$, around an equatorial axis which makes the gyroscope rotate "unbalanced", i.e. rotate instant by instant with angular velocity $\omega_i$ around an axis forming with the main axis an angle proportional to the disturbing torque. The axis of the four rotational components of figure 4 always lay on the same plane, which is not fixed in space, but revolves around the direction of $\omega_{pa}$.

When a gyroscope is subjected to a disturbing force $F_p$, of increasing value, $\omega_p$ grows and therefore $\omega_i$ moves towards $\omega_{pa}$, (parallel to $F_p$.). When Fp reaches a value $F_{pa}$ equivalent to the reaction force developed by the gyro rotating around the axis of $\omega_{pa}$, we will have:

$$\omega_i = \omega_{pa}$$

At that moment the axis of instantaneous rotation coincides with the axis of apparent precession and becomes fixed with respect to the gyroscope (Figure 5).

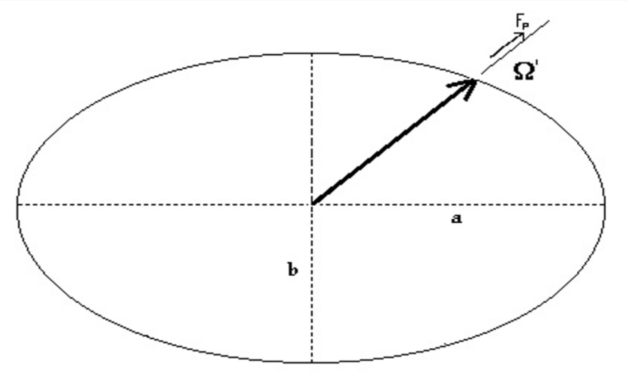


**Figure 5:** Axis of instantaneous rotation coincides with the axis of apparent precession and becomes fixed with respect to the gyroscope.

This is a special condition in which the system composed by the gyroscope and the disturbing torque, $C_{pa}$, behaves like a non-disturbed gyroscope, with a rotational speed *Ω*'. This means that the axis of *Ω*' has become the main axis of the system and it is permanent with respect to the gyroscope.

If at this point the force $F_p$ diminishes again, the system behaves like a gyroscope to which is applied a torque of value:

$$C'p = C_{pa} - C_p$$

Therefore, the axis of *Ω*' begins to precede around the main axis of the gyro, and $\omega_{i'}$ moves back along the ellipse following the same path represented in Figure 4, but the rotational components of the gyro will be reversed, as represented in figure 6. $\omega'_{pa}$ will coincide with the main axis of the gyro, while ω' will coincide with the previous axis of $\omega_{pa}$.

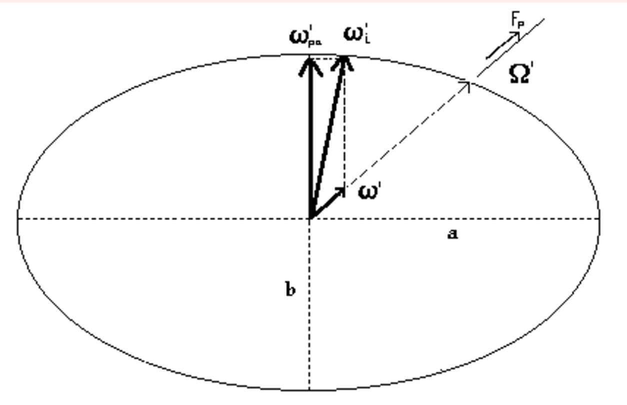


**Figure 6:** Rotational components of the gyro.

The most important thing is that the rotational component along the axis of ω' is fixed with respect to the gyroscope because it coincides with the main axis of the system gyro-perturbing-torque. This means that the gyroscope keeps "memory" of the position of this axis. That rotational component is cancelled only if and when $F_p$ is completely spent down. If $F_p$ should not be zeroed, the gyroscope would keep this rotational component, and therefore the "memory", indefinitely.

## Behaviour of the Gyroscope Earth

In principle, the behaviour of Earth when subject to a disturbing torque is the same of a gyroscope: it precedes, which means that instant by instant it rotates around an axis shifted with the respect to the main one. If the torque is increasing this axis moves away from the main (Figure 4) until it becomes permanent if and when the disturbing torque equalises the reaction torque developed by the equatorial bulge (Figure 5).

## What can Develop a Torque of that Size?

Simple calculations show that a 1-km-wide asteroid, although with a mass irrelevant with respect to Earth, impacting at high speed and with a wide angle produces an impulsive torque that can be largely higher than the highest reaction torque possibly developed by the equatorial bulge. (see by the author: "Changes in the rotational axis of Earth after asteroid/cometary impacts and their geological effects").

We must assume that the very short duration of the torque does not change the behaviour of a gyroscope as described before. In this case, as soon as the value of the torque developed by the impact equalises that developed by the equatorial bulge, the Earth's axis of rotation would be shifted in a direction parallel to the direction of the impact, becoming permanent. As soon as the shock terminates, an instant later, Earth should immediately recover its previous axis of rotation and everything would end there. The only consequences would be the local destructions resulting from the impact.

However, we have seen that to cancel the "memory" of the new axis the torque must be completely spent. There are good probabilities, instead, that this may not happen. Earth is subject to a torque generated by the gravitational forces of the sun and the moon on the equatorial bulge. This torque is by far smaller than that developed by the impact, but its role in this case is critical. If it has the same direction of the torque produced by the impact, it is added to this and it contributes in its small way to the instantaneous change of the position of the poles. A few instants later the shock terminates while the Sun-Moon gravitational attraction continues and it develops a torque higher than zero, which means that the "memory" of the axis acquired for a short instant during the shock is not completely cancelled.

Apparently, in this case, the motion of Earth soon after the shock is exactly as before, but there is a crucial difference: at this point the only rotational component fixed with respect to Earth is that tiny "memory". The speed of its rotation is extremely small, but nonetheless it develops a centrifugal force strong enough to induce a tide (of a few meters at first) on a circumference normal to it, a miniature "equatorial" bulge. While sea water moves to form this tiny "bulge" the speed of the fixed rotational component increases, therefore increasing the force which makes the water move towards the new bulge, and so on. This process gradually accelerates until a huge tide is formed across the oceans, thus forcing (together with the decisive contribute of the polar masses that become eccentric) the planet to rotate around a shifted axis for a time long enough to induce sudden deformations of its mantle.

From that moment the reshaping of the equatorial bulge would go on through catastrophic events and after a long period of turmoil Earth would be stable again, with a different axis and different poles.

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