THE ROTATING EARTH AND PLATE TECTONICS

The shaping of Planet Earth by its Rotational Velocity

ROBERT MAURER

MSc CEng F. InstMC

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Author
ROBERT MAURER
MSc. CEng. FInstMC

31A The Avenue, Cowley, Uxbridge,
Middlesex. UB8 3AD United Kingdom

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ABSTRACT

This article postulates that the unrelenting upwards and outwards movement of Pangea from the latter part of the Permian period (300 to 250 Ma ago) to the present day can be explained as a function of the estimated circumferential and centripetal forces associated with the rotating unbalanced planet Earth.

To date, the magnitude of these often incorrectly termed 'inertial forces' have been generally considered to be negligible in the context of tectonic movements on the basis that the Earth is a freely rotating body about its centre of mass (COM).

The analysis given in this paper shows that the Earth alongside the other planets require an 'offset centre of mass' to allow the mutually gravitational pull between the Sun and the planets to establish a N-S axis of rotation around which the planets are caused to rotate.

The circumferential forces developed within the lithosphere due to the rotating 'unbalanced' or 'wobbly' planet are considered primarily responsible for the perpetual movement of the tectonic plates around the surface of the Earth thus allowing the continuous recycling of the lithosphere.

By implication, it is considered that the complex circulatory system of heated convection currents within the mantle have a passive rather than an active role in tectonic plate movements.

Acknowledgements

The sight of undisturbed sedimentary rocks on the top of the Bolivian Andes in 2001 prompted this research into the magnitude of the unrelenting forces associated with plate tectonics.

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1. INTRODUCTION

The observation of the uplifted but almost totally undisturbed Silurian to Carboniferous meta-basalt and turbiditic melange[39] beds to the top of the Andes near Potosi in Bolivia (Fig 1a & 1b) prompted the investigation into both the origin and the magnitude of the forces capable of lifting the western side of the South American continent from below sea level to c. 6km above sea level. This paper will attempt to demonstrate that forces needed over geological time, to sustain tectonic movements and the associated orogenic and metamorphic processes are generated as a function of the rotation of the 'wobbly' Earth in which its 'Centre of Mass' (COM) is not coincident with its axis of rotation. In doing so this paper will also demonstrate that sea floor spreading, magma intrusion into the oceanic crust, the creation of the transform faults traversing the ridges in the oceanic crust are an inevitable consequence of the generated tectonic movements. As such the convection currents in the upper mantle have a predominantly passive rather than an active role in tectonic plate movements.

A study of the tectonic movements[9, 49-51] of the major continental plates away from Pangea beginning in the early Jurassic[43] to their present day positions (Fig 2) clearly demonstrates that the movements have been continuously sustained over a time period of c. 275 Ma albeit in different directions. At present these movements have been mainly attributed to the 'ridge push' and the 'slab pull' forces proposed by Hess[1,18,53] that are created by heated convection currents within the Earth's asthenosphere. The same study has also shown that centripetal and circumferential stress forces have not been seriously considered and even discounted[34,38] as a mechanism for tectonic movements. The general use of the term 'inertial forces' in the literature appears to encapsulate the forces associated with the rotation of the Earth. The sustained unrelenting unidirectional movements both east and west, of the various plates away from the predominately central or 'fixed' African plate suggests that the forces responsible for driving tectonic activity could well be a function of the Earth's rotational velocity.

Fig 1a

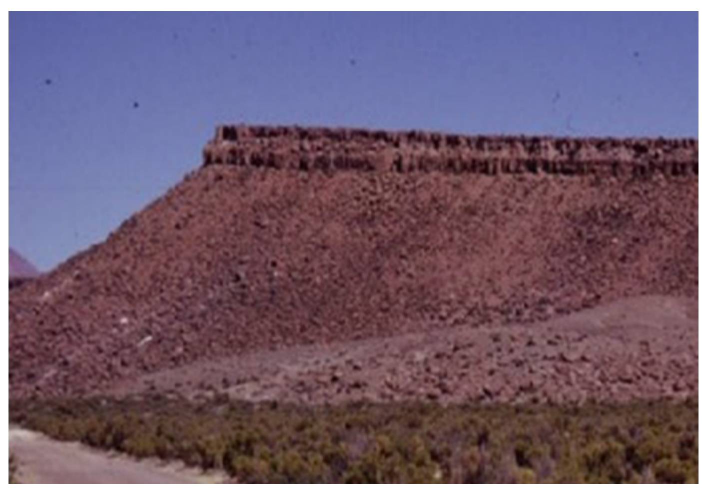

Fig 1b

It was noted that the 'wobbling' Earth with its associated Milankovitch cycles, closely mimics the vibrational processional movements of an unbalanced rotating body in which circumferential stresses are induced into the outer rim. This approach is thus used to estimate the circumferential stresses induced into the lithosphere using the well-understood mathematical approach relating to unbalanced rotating bodies[2,7, 26, 29]. Furthermore, this approach allows for viable explanations to be given to describe:

a) The northwards movement of Pangea in the Permian

b) The start of its break-up at c.200Ma by the unidirectional plate movements from the essentially central and stationary African Plate in the earliest Jurassic eastwards and westwards

c) The creation of the transform faults and

d) The probable reason for the 'crumpled' Pacific Basin oceanic crust west of the Hawaiian-Emperor volcanic seamount chain.

This approach also allows for a rational explanation regarding the creation of the N-S axis of rotation, the tilt and precession cycles by the mutual gravitational pull of the Sun on the 'offset' COM of the Earth as well as its sister planets. This in turn gave rise to a rational explanation describing the reason for the planets (except Venus) rotating in the same anti-clockwise movement as does the Sun itself. As Kepler's laws (Appendix 6) clearly demonstrate the Sun's direct gravitational control over the orbital and rotational velocities of the planets, the mathematical model relating the circumferential force F acting on the crust to the radius of eccentricity E i.e. $F = MR\omega^2E\pi/4$ (where M=mass, R=radius and ω=rotational velocity) on

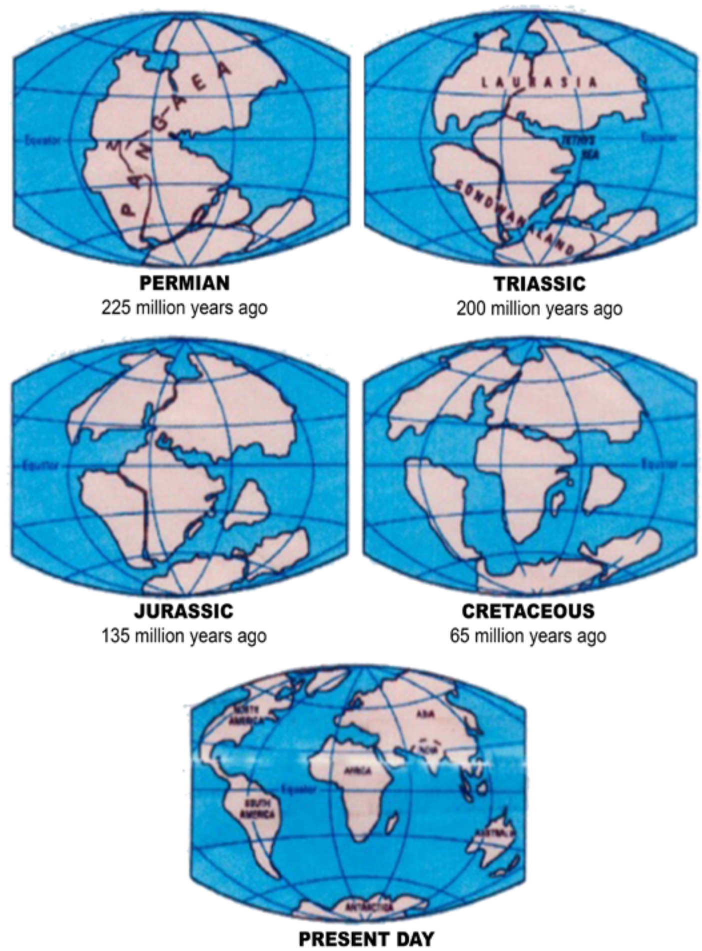

Fig 2 Break up of Pangea. Permian to Present day

the unbalanced rotating Planet Earth is given credence.

2. THE HESS MODEL

This hypothesis by A. Hess[1, 19,53]shown diagrammatically in Fig 3 suggests that the downward movement (subduction) of the colder and denser oceanic crust into the mantle by 'slab pull' forces resulting from the heated circulatory currents in the upper mantle, is the major force responsible for tectonic plate movements. This 'slab-pull 'force is also credited with the creation of the trenches in addition to the orogenic and volcanic activity on the uplifted plate. Other credits include the recycling of the oceanic crust at convergent boundaries, and magma intrusion from the split mantle onto the ocean floor being responsible for forcing the continents apart at divergent boundaries. The Hess model is extensively described in the literature. Park[38], Hamblin[17] and Davies[8] are given as typical references which are continually cited in later publications.

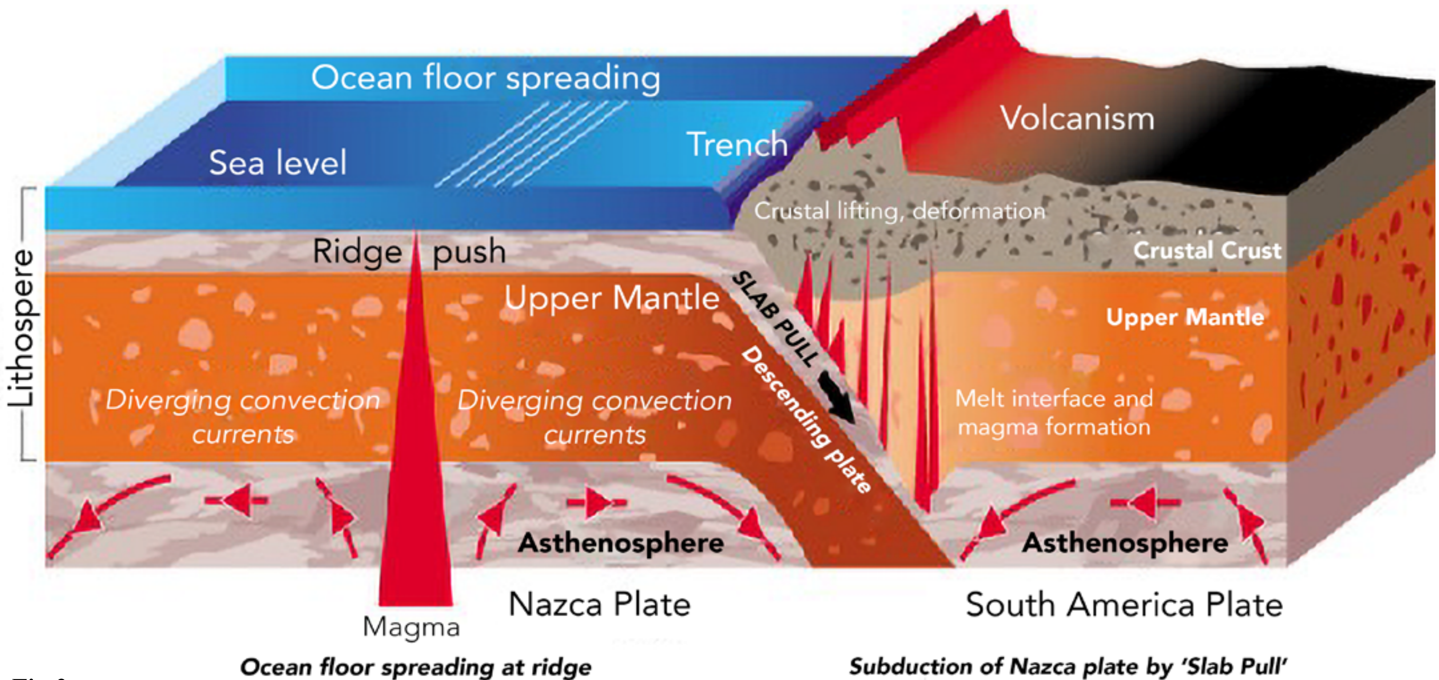

Fig 3

2.1 Anomalies associated with the Hess Model

While there is wide acceptance of the Hess model of convection currents, a number of research engineers, typically[13,16,27,38,47,49,] find it difficult to accept that the out-flowing magma along the mid-ocean ridges can contribute to the forces needed to drive continents apart. The lack of distortion (other than at the transform faults) of the disconnected strips either side of the mid-ocean ridge of intruded magma which show reversals in the Earth's magnetism (Fig 4) demonstrates the absence of a lateral push force. It is surprising therefore that with this high level of agreement[12,14,25,34,40,] regarding convection currents as being the major driving force for plate movement and subduction, the absence of a magnitude 'action-reaction' mechanical force diagram allowing the 'slab pull' force vector to be unambiguously represented, is puzzling. It is also surprising that there is still no consensus regarding the origin and direction of the heated currents in the mantle. Experimental data obtained from igneous petrology studies[5], seismic wave propagation5,[52,54], mathematical[1] and thermal modelling[13,20,21] as well as consideration of mantle plumes (hot spots)[3,14] has resulted in several different heat convection current systems being proposed[23,28]. Two of these proposed circulation systems including plumes[4,14] are summarised in Fig 5.

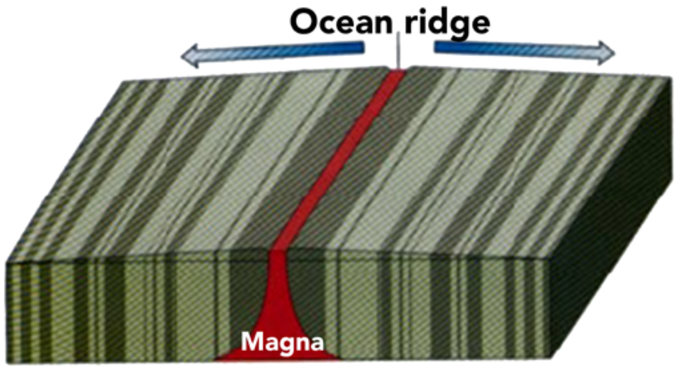

Fig 4

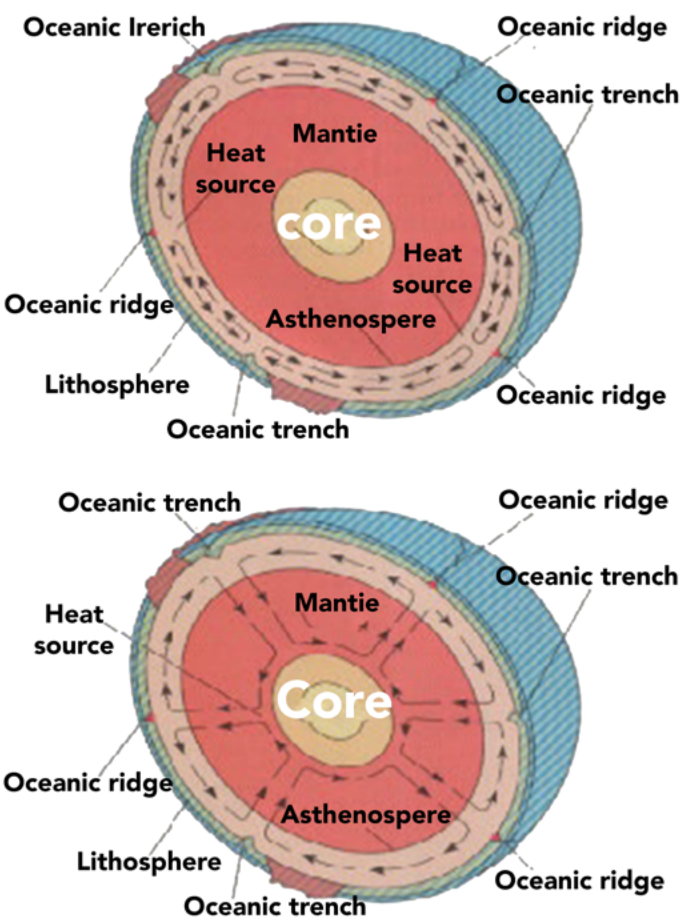

Fig 5

2.2 Convection currents and plate movements

Although this paper investigates the rotational velocity derived circumferential stress forces as the primary cause of tectonic and orogenic activity, a brief discussion on some aspects of convection current driven plate movements is considered relevant. Dewey[10,11], van Andel[46], and Davies[8] discuss the geometrical aspects of tectonic movement using Euler's Theorem, which states that the displacement of a plate over a spherical surface from one position to another can be regarded as a simple rotation about a suitable axis through the centre of the sphere. This basically implies that in the case of the South American plate, the angular velocity will vary along its length. It is extremely difficult to understand how a convection current will match this rotational mode from the equatorial to the much smaller diameter polar latitudes. If the west-east convection currents were or are localised along a south-north axis within the upper mantle then, taken in isolation, a case for the movement of the South American plate may be made. However, as the African plate has been relatively stationary, the north-south convection currents must have moved the present Indian plate in a north-north-east direction into the Eurasian plate. This implies that the opposing heated convection currents must have been, and still are, stable over the 140Ma period since the end of the Jurassic (Fig 6).

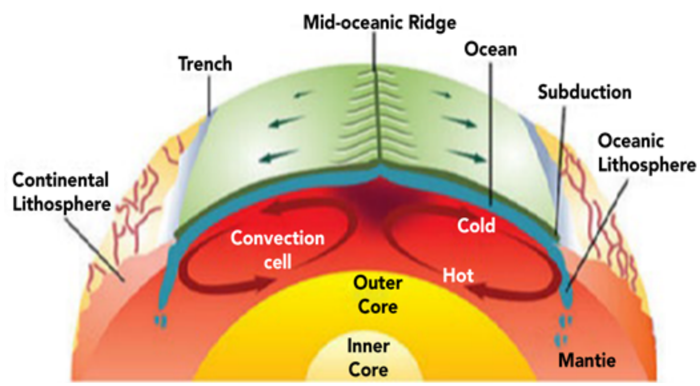

Fig 6: Stable Convection for 140Ma.

It is interesting to note that Davies[8] states that as the plate near the pole of rotation may be rotating about a vertical axis relative to the mantle, it would be inaccurate to think of the mantle motions in terms of simple roll cells of convection. In a spherical shell, the flow may need to connect globally in a complex manner. Davies[8] also summarises other contemporary work which suggests that the 'return flow' from subduction under the north-west Pacific back to the East Pacific Rise may pass under North America. This would approximate to a great circle path, with the flow under North America probably having a southerly component that would not be inferred from the local part of the plate system. A further difficulty arises when trying to understand how the convection-based 'slab–pull' forces, which moved the components of Pangea northward from their original position in the Permian, changed direction in the Jurassic to cause the break-up of Pangea in mainly east and west directions alongside the simultaneously north- and north-eastward clockwise rotation of the Indian and Australian plates (often referred to as the Indo-Australian Plate). Nor can the existing current convection hypothesis reconcile the variation in the velocity of the different plates as illustrated by Park[38] and Hamblin[17]. Overall, it is difficult to reconcile the sustained unidirectional movements of the various continental plates from their positions as part of Pangea over 275Ma ago to their present positions, with the clearly omni-directional convection current flow patterns.

2.3 The Andean and Himalayan orogeny's

It is obvious that the forces involved in pushing up the Andes Mountains to as high as 6,000 m above sea level has been, and still is, continuously sustained in one direction. The direction of the forces will be perpendicular to the alignment of the mountain chain. In this case, where the collision is between continental and oceanic crust, the uplift of the Andes is attributed to the noted subduction of Nazca oceanic crust by the 'slab pull' mechanism[18,19].

In contrast, the continuing uplift of the Himalayas (8,000m above sea level) along an east-west axis is attributed to the collision between two continental blocks. It is interesting to note that the subduction forces that were credited with moving India into central Asia are now totally credited with the continuing formation of the Himalayas. The continuously compressive and possibly isostatic forces now associated with the formation of the Himalayas appear to be far more complex than it would be if an obvious subduction zone were present at the India/Asia interface. Van Andel[48] and Davies[8] discuss this matter in some detail. From the purposes of this article point of view, the major significant similarity between the different orogenic processes (Andean, Himalayan, and Alpine) is the sustained manner of the unidirectional movements and the forces involved.

3. ROTATIONAL BEHAVIOUR OF THE EARTH

Despite the apparent paucity of published research work on the influence of the rotation of the Earth on tectonic activity, there have been notable contributions on the rotational behavioural of the rotating planet. Waller & Home[51] considered the rotating Earth as a non-homogenous shell that comprises an inner mantle which in turn surrounds a semi molten outer core, and a solid inner core. They further considered the core as being subject to dynamic heated convection currents as well as having a different rotational velocity to the upper layers. Sager & Koppers[42] described the movement of the Earth's spin-axis from as far back as the late Cretaceous. The movement of the Earth's spin-axis referred to by the authors as an 'apparent polar wander path' (APWP), is of the order of 3°-10° per million years. Sager & Koppers[42], Kearney and Vine[22] as well as Courtillot and Besse[6] suggested that this phenomenon might be the result of changes in the Earth's principal axis of inertia caused by the redistribution of mass in the mantle. The literature survey did not uncover viable agreed explanations regarding both the origin of the variable tilt angle of the Earth's axis (22.1°-24.5°) as well as the reasons for the Milankovitch precession movement cycles (Figs 7 & 8).

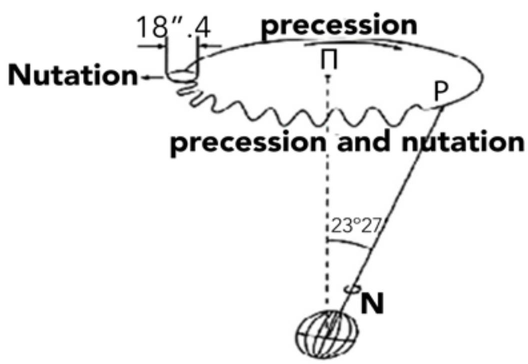

Fig 7

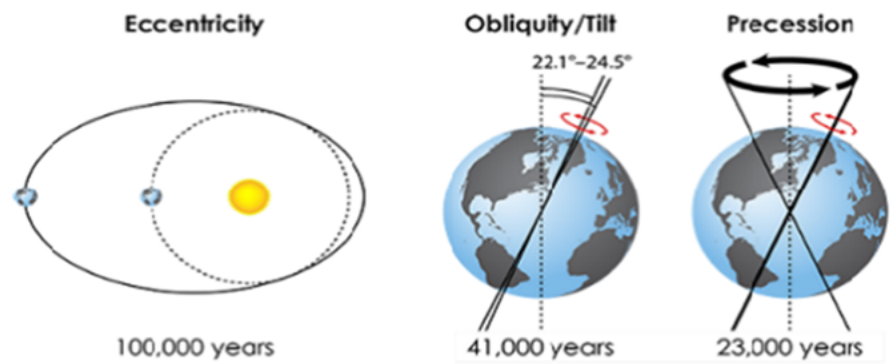

Fig 8

Laskar et al.[24] suggested that:

a) The gravitational pull of the moon on the Earth has stabilised the tilt deviation to the order of 1.3° and

b) The absence in the case of Mars of a stabilising gravitational force by a relatively large moon has allowed its axial tilt to vary from 10° to 60° in a manner over tens of millions of years.

Following the observations of the uplifted sedimentary sequences (Fig 1a & 1b) in the Andes it became apparent that the forces associated with the continuous unidirectional northward movement of Pangea from the Permian to the Jurassic, followed by the westward movement of the American plates and the north-east movement of the Indian and Australian plates (over 275 Ma, would have to be constant over this large geological time span.

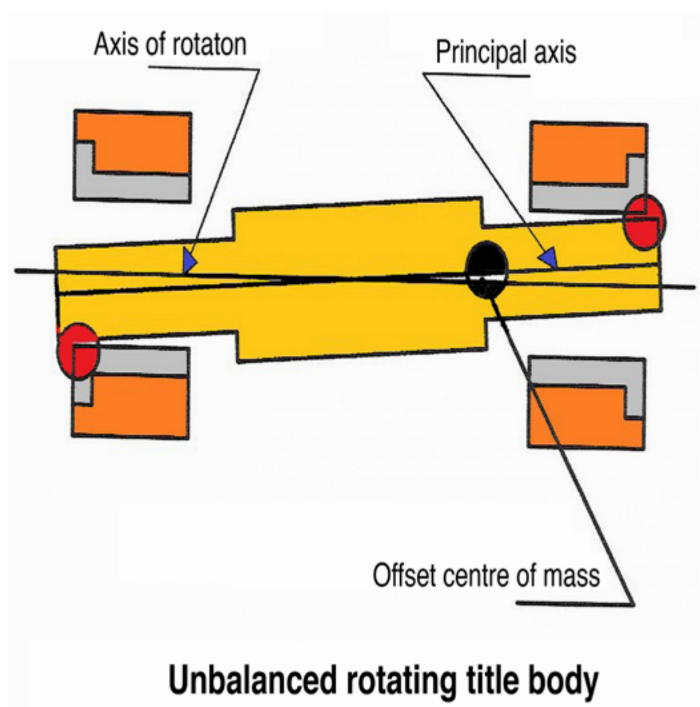

Fig 9

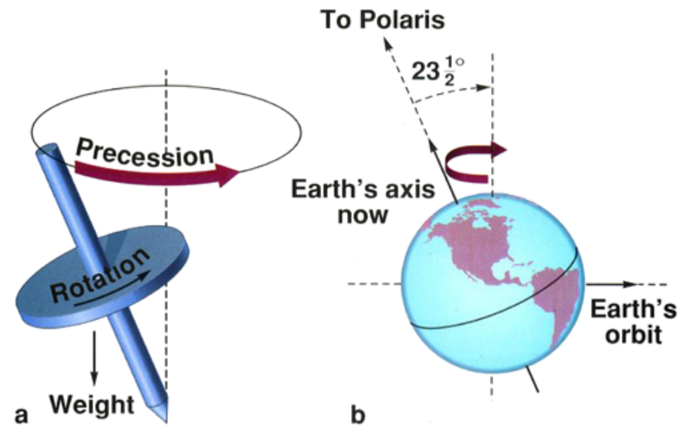

Fig 10a

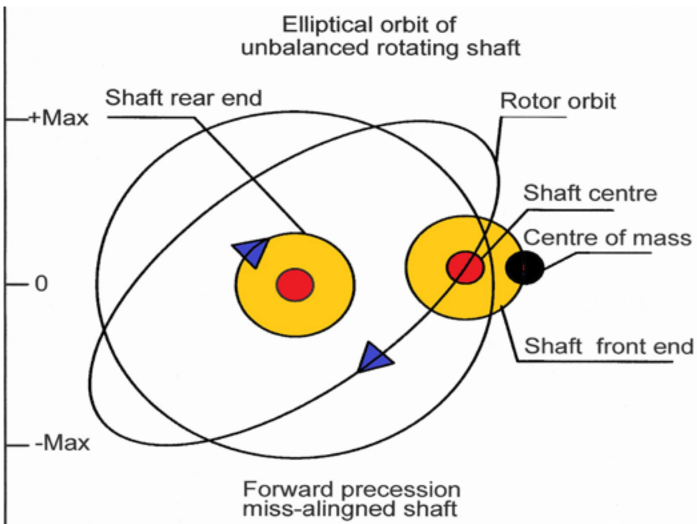

Fig 10b

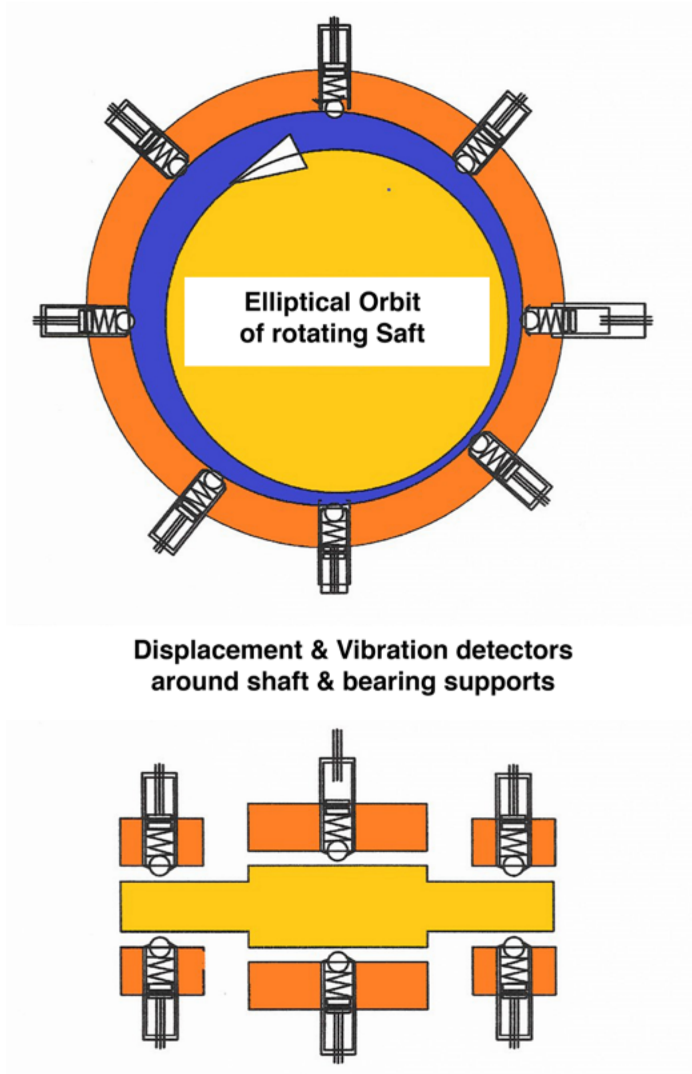

Fig 10c

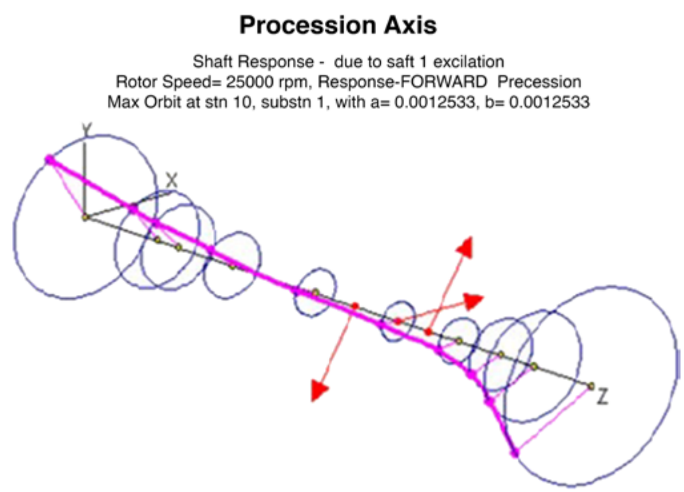

Fig 10d

It was this observation that prompted the investigation of the forces associated with the constant rotational velocity of the Earth. The most notable observations were the Milankovitch cycles[30,31] (Fig 7 & 8) which display cycles in:

a) The variation in the eccentricity of the Earth's orbit[30] (over 100,000 years)
b) Oscillations in its degree of axial tilt between 21.5° and 24.5° (over 41,000 years) and
c) The precession ('wobble') of its axis as it changes from pointing towards Polaris (the North Star) to Vega then back to Polaris (over 23,000 years).

Taken together with the Chandler and other minor cyclical 'wobbles' the rotating Earth displays very similar characteristics to the mechanical behaviour of a rotating shaft with an unbalanced load[2,24]. The 'Chandler Wobble' (3-15 metres at the North Pole) which is superimposed on the other wobbling motions has a rotation period of 433 days. The wobble is not unlike that of a spinning toy top. The following simplified diagrams are given to demonstrate the similarity between the end motions of the unbalanced shaft and the Milankovitch cycles. Fig 9 shows the damaging effect on journal bearings accommodating an unbalanced tilted shaft rotating around its mass centre rather than the designed geometrical centre line. Fig 10a shows the similarity the unbalanced rotating toy top and the unbalanced rotating earth accommodating an offset centre of gravity. Fig 10b shows the end view of the elliptical path taken by an unbalanced rotating circular body and Fig 10c the instrumentation surrounding it, to compute the position and magnitude of the counter-balance weight needed to affect balance and remove the inclined tilt. This motion plotted in Fig 10d shows a similarity to the Milankovitch precession cycles in depicting the elliptical movement of an unbalanced rotating shaft whose COM is offset from the centre of rotation. Fig 10d, also, shows a typical plot of the vibrational movement along the length of the unbalanced rotating shaft and Fig 10e will show the animated vibrational motions in PowerPoint[45]. An everyday example is the balancing of a motor vehicle wheel from the measurements taken at the test positions (Fig 10b) to ensure a smooth ride when a new tyre is fitted. There are International Standards such as ISO 1940-1:2003 Mechanical Vibration, relating to the equations and methods adopted to dynamically balance rotating machinery such as flywheels, ship's propellers, motor armatures, etc. the equations are also well documented in almost every textbook on applied mechanics[26,33,41].

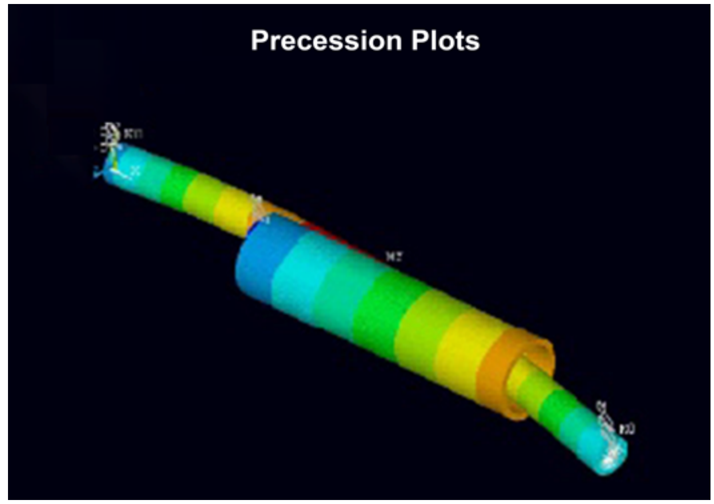

Fig 10e: This mimics the Milankovitch movements

4. POSITIONING THE CENTRE OF MASS AND THE AXIS OF ROTATION

In order to try and determine a possible source or cause responsible for the planet behaving like an unbalanced rotating body, some principal features of global tectonic activity need to be considered. As the ratio of the mass of the crust to the body mass of the Earth is small, the crust's surface position will have a negligible impact on the Earth's Moment of Inertia. It thus seemed sensible to try and determine the COM of the earth and use that value to estimate the 'differential circumferential stress forces' (DCSF) created in the Earth's lithosphere. With reference to Fig 11 the following observations are noted: (a) the geologically quiescent African Plate shows the characteristics of being in tension in that while there no evidence of subduction (except in the north), splitting of the plate is taking place at the Rift Valley. In contradiction, (b) the Pacific Basin with its deep peripheral trenches, crumpled topography (west of the Hawaiian chain) and subducted areas of the lithosphere (e.g. the Nazca plate under the South American plate) have all the appearances of being in compression.

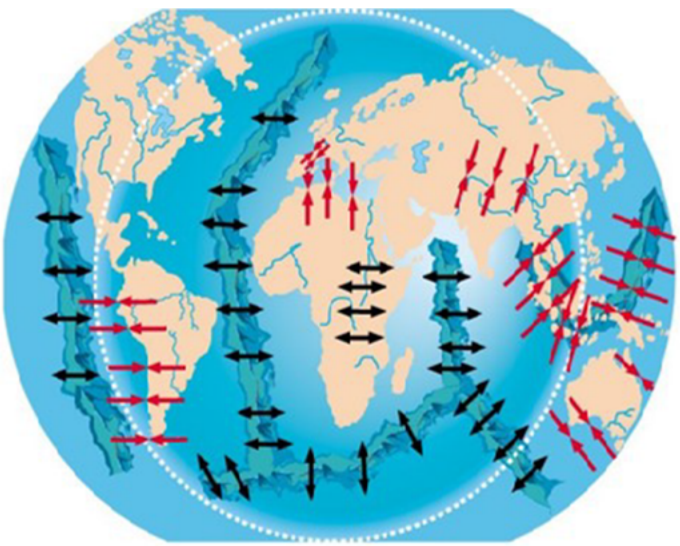

Fig 11: Convergent & Divergent boundaries

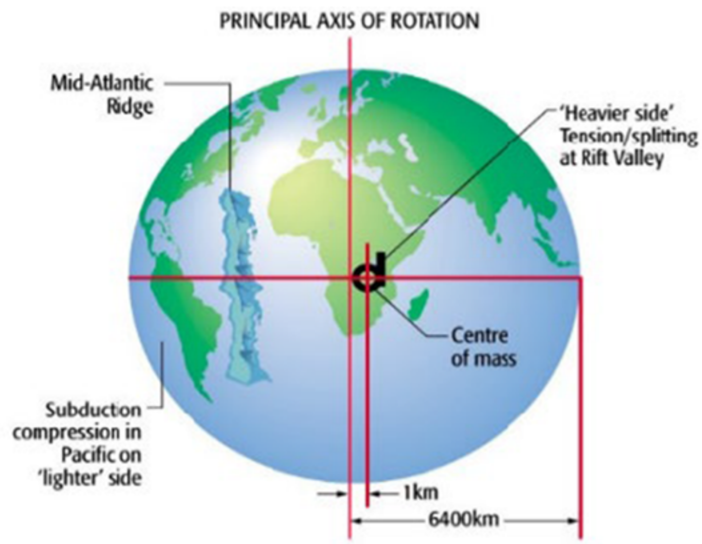

Fig 12

If as postulated above, the Pacific Basin is under compression whilst the African Plate is under tension, then an unbalanced rotating body model requires the COM to be positioned east of the spin axis (as we view Fig 12) but 'west' of the Rift Valley. This is in keeping with the mechanics of rotating unbalanced bodies (as described in Section 5 and annotated in Figs 18 & 20, in which the 'lower mass' side will be in compression, and the 'higher mass' side will be in tension. In attempting to determine the possible position of the COM, consideration was given to the physics relating to the phenomenon referred to as isostatic equilibrium. Essentially isostatic equilibrium calls for the balancing of forces (associated with different weights on different areas) acting against each other through a fluid column. A

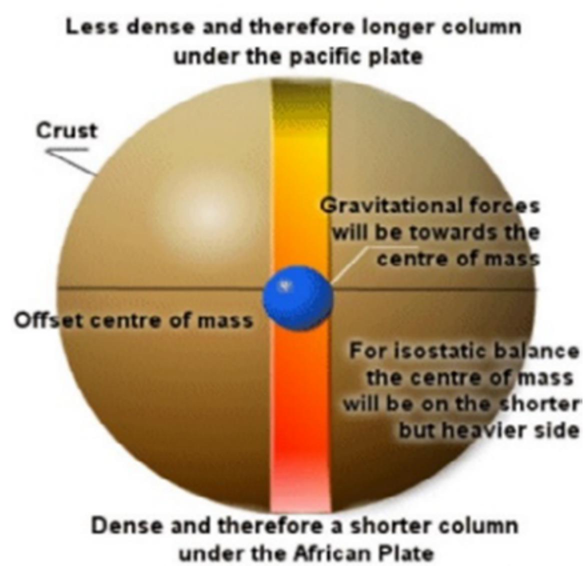

Fig 13

hydraulic jack is a common everyday example. In the case of Earth movement, isostatic equilibrium is associated with the balancing of forces due to different weights of landmasses in proximity. An example is the post ice age net uplift (rebound) in Fennoscandinavia which is still rising by up to 8-10 $mmyr^{1}$ following the disappearance of the Northern European ice sheet[44]. This reached its maximum volume c.23,000 years ago, depressing the crust/mantle under its weight. If this principle can be invoked on a global basis (Fig 13), then the 'column' supporting the lighter Pacific Plate will need to be longer than the opposing 'column' supporting the heavier African Plate with its larger mass of continental crust. In doing so, the following equation can be derived to give a simple approximation of the position of the COM by considering the difference in average elevation between the oceanic crust of the Pacific Basin and the continental crust of the African continent to be 8 km. For ease of explanation the densities of the mantle and outer core is assumed to be constant.

Taking rounded values, we have:

Average elevation difference between the

Pacific Basin and African continent= 8 km

R= radius of Earth= 6400km

ρ crust = density of crust= 2.8 kgm^{-3}

ρ core =density of the core = 10.7 kgm^{-3}

X-sectional area of columns= 1km^2

E= distance (km) from the core centre to the balance point

Thus, the weight of the 1km^2 Pacific Column to the balance point

= (6400-8)x1x 2.8+Ex1x10.7= 17897.6+10.7xE

Similarly, the weight of the 1km^2 African Column to the balance point

= (6400)x1x2.8= 17920.

Solving for E, at the balance point we get 17897.6+10.7x E= 17920

This resolves to give the E= (17920-17897.6)/10.7= 2.09 km

For ease of calculating the circumferential forces at the Earth's surface, the COM E is placed 1.0 km off-centre from the axis on the African plate side. Although this extremely small but feasible displacement of the COM from the centre of rotation is of the order of 0.5 to 1.0 Km, or 0.015% of the Earth's radius, the actual magnitude of the subtended surface forces as shown by the analysis are substantial.

5. ANALYSIS OF AN UNBALANCED ROTATING PLANETARY BODY

The proposed mathematical models relate the magnitude of the circumferential forces in the outer rim to the unbalanced Earth rotating about its COM which is offset from the axis of rotation. This assumption has met with resistance on the basis that the generally held consensus is that the Earth and other planets are considered as freely rotating bodies about their COMs which is co-incident with their axis of rotation. Using these assumptions, the moment of inertia would be zero as would be any subtended forces at the surface of the planet. There is thus a notable absence of serious published study on this subject. Consideration of Kepler's second law regarding the variable gravitational pull of the sun on the Earth (Fig 14) as it moves through a full elliptical orbit clearly demonstrates the cyclical speeding up and slowing down of the orbital velocity. This occurs both on the movement towards and away from the perihelion. Planetary movements are thus directly controlled by the mutual gravitational pull between the planets and the Sun and as such cannot be considered as freely rotating bodies. In Appendix 1 'Consideration of the Rotational Behaviour of the Sun and Planets' this argument is extrapolated to suggest that a common mechanism exists which causes the planets (except Venus) to rotate in the same anti-clockwise direction as the Sun's rotation (Fig 16). The term 'Gravitational Connecting Crank' (GCC) is now introduced as a possible explanation.

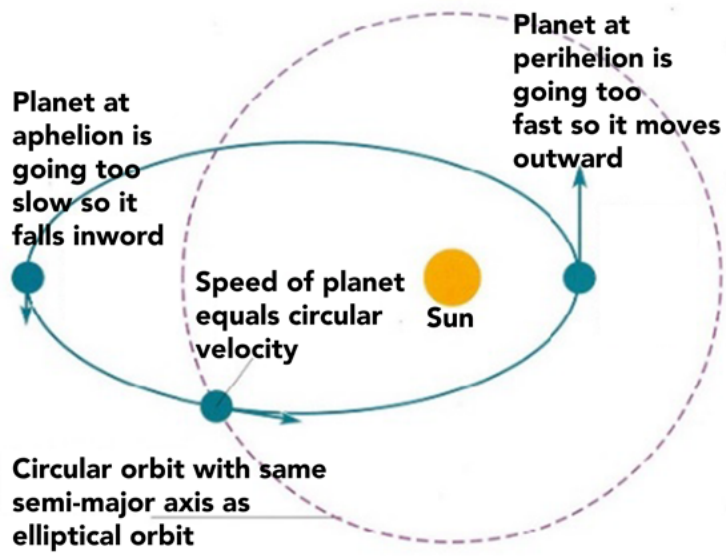

Fig 14

Fig 15

As it is not possible to cause rotation by any force acting solely on the dimensionless centre line of any object, rotation can only be initiated by the application of an offset torque force. This concept is illustrated in Fig 15 showing the movement of a circular object on a spindle via an offset torque force.

This concept also brings with it the exciting and unexpected conclusion that the COMs must be 'off centre' in order that the gravitational pull from the Sun acting on the offset COM, will in fact provide a torque moment to affect rotation and in doing so, the axis of an unbalanced rotating planet is established. This approach may also explain that the extremely low rotational velocity (58.646 Earth days = 1407.5 hours) of the planet Mercury compared to <25 hours for the other six plants except Venus is due to the possibility that the COM and the axis of rotation are almost co-incident. This is noted by its low tilt angle of 0.034° and thus a noticeable absence of an offset COM for the Sun's gravitational pull to act on.

The gravitationally driven unbalanced rotating planets with their offset COM's will also tilt towards the heavier side and vibrate or 'wobble'. An everyday example is the need to re-balance a vehicle wheel after fitting a new tyre. This 'wobbling' action of the planet Earth will manifest itself by the precessional behaviour of its axis of rotation and is noted as one of the Milankovitch cycles. From Fig 16 shows that all the planets have a similar inclined axis of rotation to a greater or lesser degree. As their rotational velocity is driven by the Sun's gravitational pull on their 'offset COM's', they should all exhibit Milankovitch type precessional cycles.

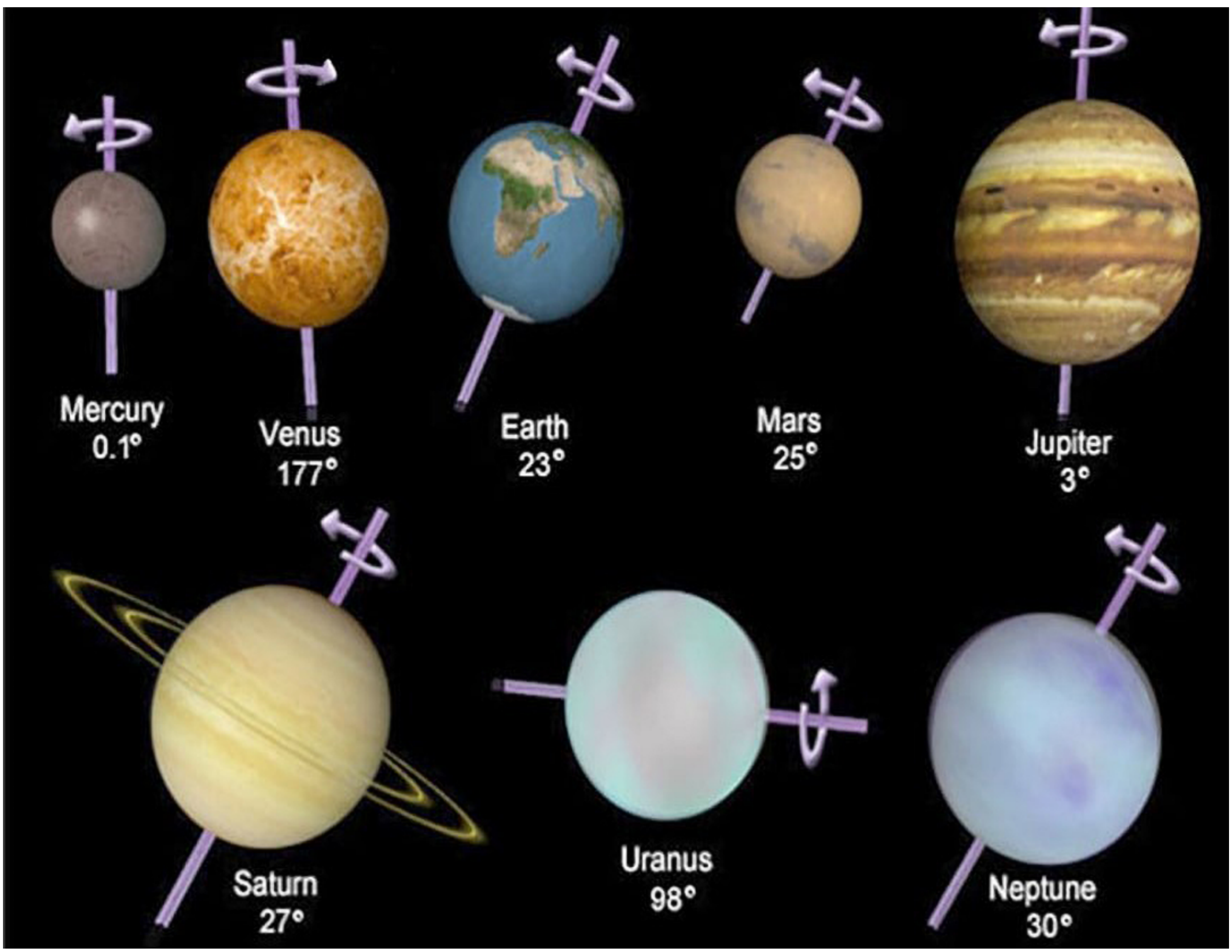

Fig 16

6. EQUATIONS RELATING CIRCUMFERENTIAL STRESS FORCES TO THE OFFSET CENTRE OF MASS

Based on Kepler's laws of rotation(Appendix 6) and the arguments as set out in Section 5 let us assume as a working hypothesis, that the Earth can be modelled as a rotating body where its COM is offset from the principal axis of rotation. For the purposes of this paper, two approaches are considered to determine the principal forces associated with an unbalanced rotating body.

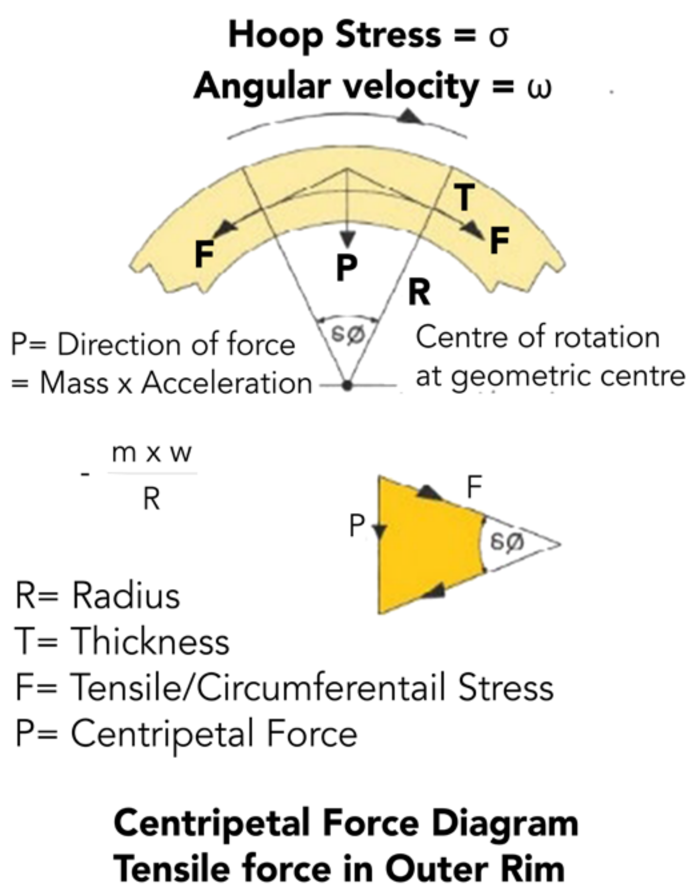

Fig 17A

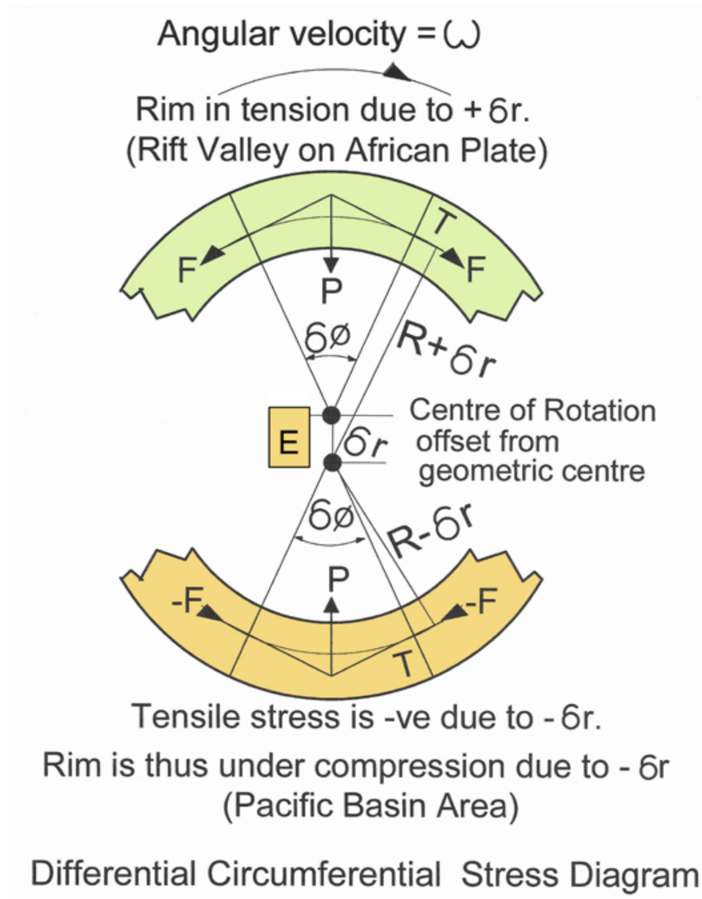

Fig 17B

6.1 Model 1: Rigid Body Dynamics

As discussed in Section 4, the Pacific plate has all the appearances of being in compression while the almost diametrically opposed African plate appears to be in tension. The simplest model is to consider the Earth as an eccentrically rotating solid body such as unbalanced flywheel. Although this model (Fig 17A) and enumerated in Appendix 4 accounts for the compressive and tensile stresses developed in the outer rim it does not describe the circumferential forces which are thought to be linked to the tectonic forces resulting in plate movement. This model which describes the circumferential stress forces also describes the situation that would occur if the lithosphere were treated as a thin shell sphere subjected to an internal pressure with a developed 'vertical force P'. Fig C within Fig 19 is shown as an aid to understand the terms involved. In this case the area of maximum stress would be along the diameter of the shell at right angles to the force. The area resisting this developed force is described by the thickness of the thin shell multiplied by the mean diameter. The propagation of the crack that is now the Mid-Atlantic Ridge is in this area of maximum stress and would have occurred after separation had begun.

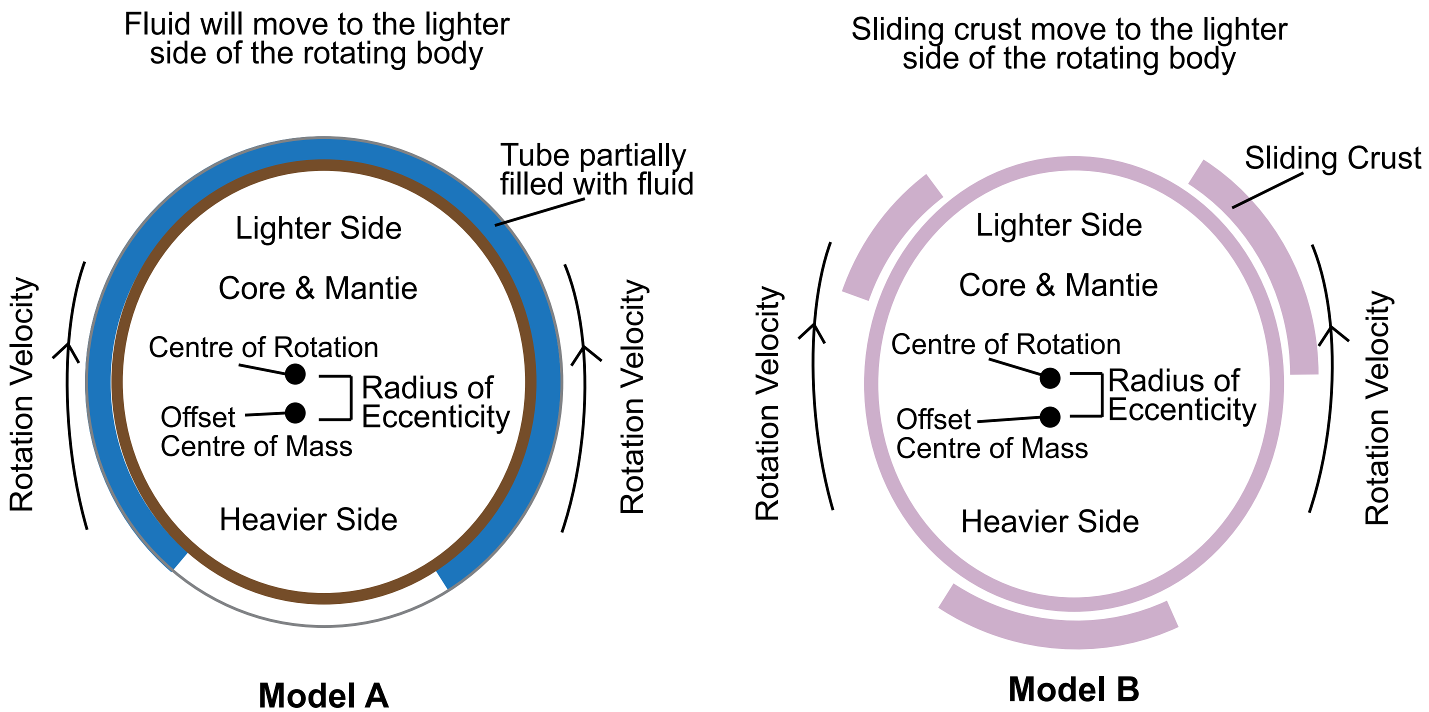

Fig 18A & 18B
Models used for the calculation of the differential circumferential stress forces required to move the crust to the mantie. The movement to the lighter side is independent of the hard rotation

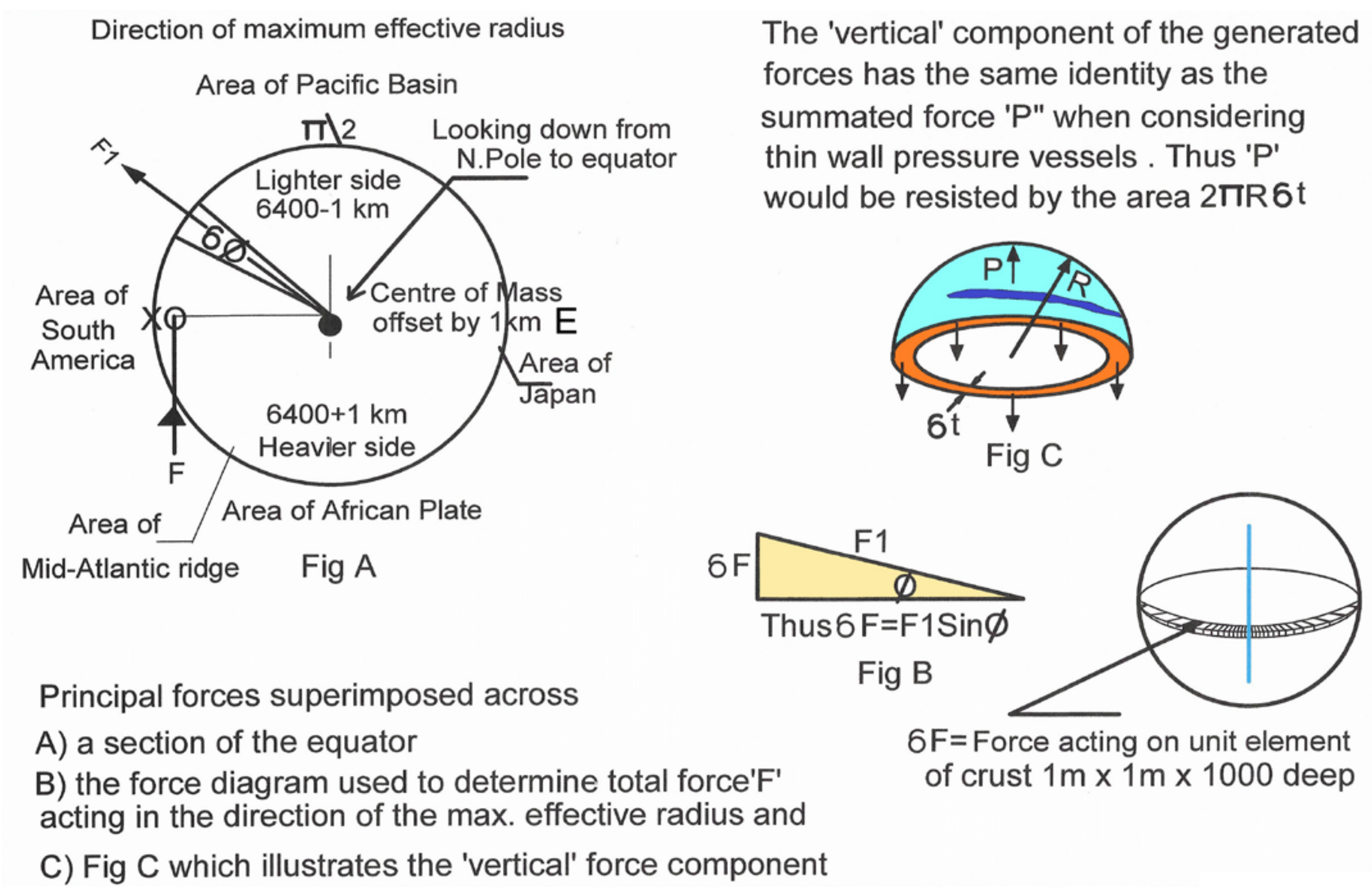

Fig 19

6.2 Model 2: Outer rim able to slide relative to the main body

In order to determine the forces postulated as being responsible for tectonic movement, the model used is one in which the thin crust can slide relative to the solid body at the crust/mantle interface. By way of illustration, Fig 18A shows that if an unbalanced disc with an outer annular ring containing fluid is rotated about its principal axis, the liquid will move to the 'lighter' side. This action would also give a plausible explanation to account for the sea level in Pacific Ocean being permanently higher[37] than that of the Atlantic and Indian Oceans. This situation is noted by the difference in tidal heights either side of Panama. The mean level of the tidal heights is also affected by weather patterns, salinity and possibly Coriolis forces. Fig. 18B shows an analogous situation with the sliding continental plates.

If we consider the crust as being able to move relative to the mantle, albeit it over a long geological time span, then force vector diagrams (Figs 17B & 19) can be constructed by making the following assumptions:

a) The crust is a thin shell that is able to slide relative to the mantle

b) The forces due to eccentricity are superimposed on the stress caused by the general rotation and gravity and

c) The stress, which is of interest for the purposes of tectonic movement, is the differential stress owing to this eccentricity.

By approaching the problem in terms of a thin shell moving relative to the mantle, it is possible to consider which increments of the tensile force are responsible for putting the Pacific Basin under compression (crumpled profile, Ring of Fire) and the African Plate under tension (Rift Valley). The calculations to derive the expression of the circumferential stress at the surface of the Earth are based on the consideration of the eccentrically induced loads on the thin crust as detailed in Appendix 3. The term 'radius of eccentricity' was introduced to denote the distance between the centre of mass and the major axis of rotation. From Appendix 3 the following relationship was derived:

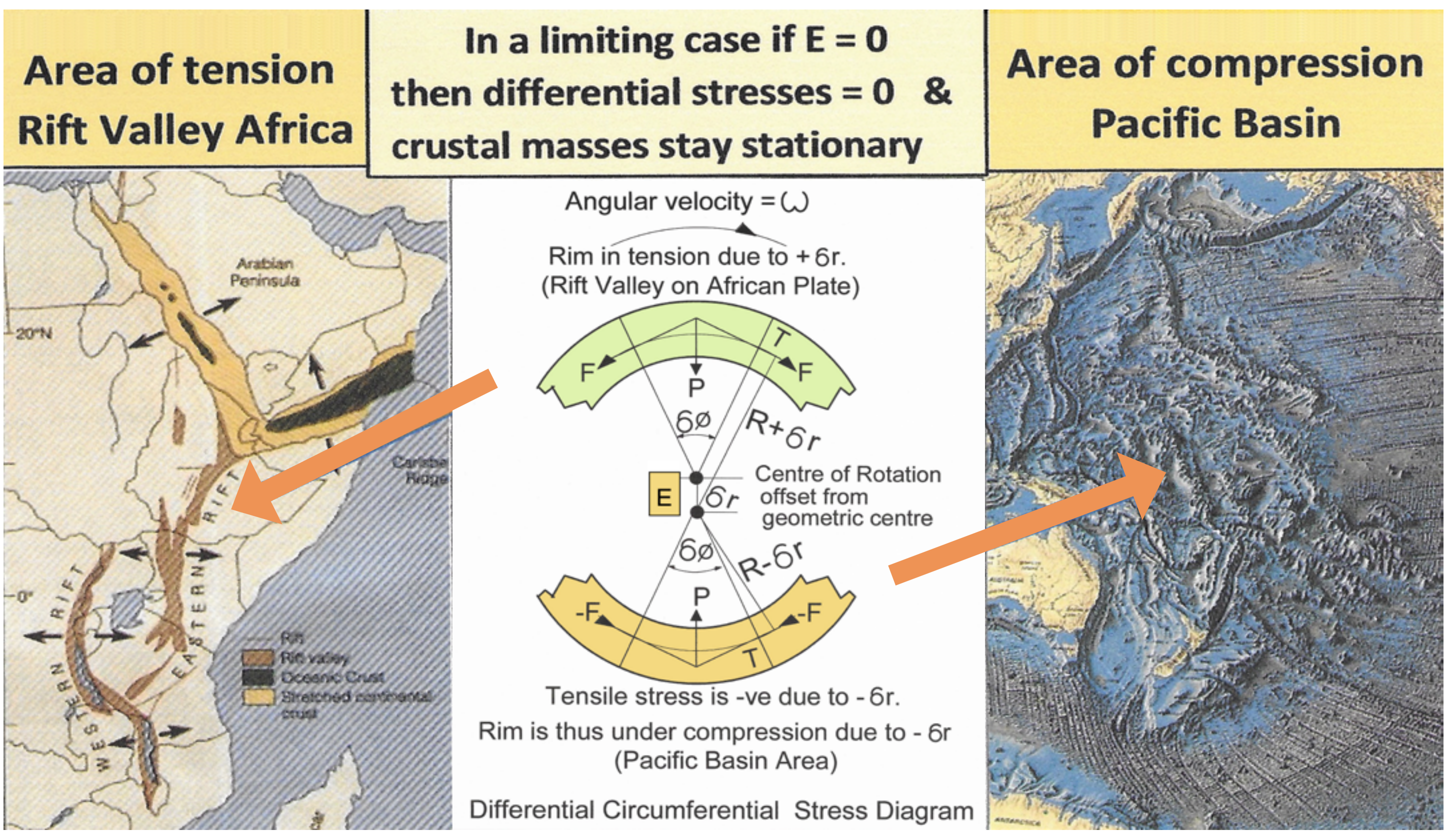

Fig 20

Total circumferential force (F) acting on the crust = $MR\omega^2E\pi/4$ **Equation (2)**

If we take into equation 2, an element of crust to be 1000 metres thick with an average density of 2.8×10^3 kgm-^{3}, then for a 1000m column of cross-section 1m x 1 m, the mass per unit area of crust (m^2) is 1000 x 1 x1 x $2.8 \times 10^3 = 2.8 \times 10^6$ kg.

If the radius of the Earth (r) = 6400 km (6.4×10^6 m), the rotational velocity of the Earth at the equator (ω) = 7.27×10^{-5} radians sec^{-1} and the Radius of Eccentricity at the Core (E) = 1 km. we get:

$F = 2.8 \times 10^6 \times 6.4 \times 10^6 \times (7.27 \times 10^{-5})^2 \times 10^3 \times \pi /4 = 6.64 \times 10^7$ N.

Since the magnitude of the circumferential stress is Force/Area, this becomes $6.64 \times 10^7 / 1 \times 10^3 = 6.64 \times 10^{-2}$ Nmm^{-2}.

Hence the circumferential tensile stress is = 6.64×10^{-2} Nmm^{-2}, 0.644 Bar or c. 9.8 $lbs.in^{-2}$

In order to determine the mean forces to a 95% confidence level, uncertainty calculations (Howarth) have been applied to the consideration of:

(a) The density of the continental crust varying between 2.3×10^3 kgm^{-3} and 2.9×10^3 kgm^{-3}

(b) The density of the oceanic crust varying between 2.83×10^3 kgm^{-3} and 2.89×10^3 kgm^{-3}

(c) The Earth's radius varying between 6.3567×10^3 km and 6.3781×10^3 km and

(d) The equatorial rotational velocity varying between 7.27×10^{-5} rad. sec^{-1} and 7.292×10^{-5} rad. sec^{-1}.

By assuming these values can be taken as endpoints of several uniform distributions, then by generating a random sample of 999 values (see Appendix 5) the following values are obtained

Mean Circumferential Stress (Continental Crust) = F_c = 72.97 (68.14, 76.74) $\times 10^6$N

Mean Circumferential Stress (Oceanic Crust) = F_o = 75.87 (74.97, 76.69) $\times 10^6$N

Thus, the differential circumferential forces created by placing the centre of mass of the Earth 1.0 km off-centre are large and cannot be ignored. The calculated circumferential forces if applied to the cross-sectional area of the South American plate are more than enough to push it over the Nazca plate.

Whereas Figs 18 & 19 shows the logic train used to develop Equation 2, Fig 21 displays its application. The graphical relationship between F and E is shown in Appendix 3. In a limiting case, if the 'radius of eccentricity' is zero, the rotating body will be balanced, and the differential circumferential forces (DCF) will be zero.

7. EXAMPLE RELATING TO THE MAGNITUDE OF THE STRESS FORCES

In order to better understand the magnitude of the calculated circumferential stress in the continental crust, it is helpful to relate the model to more familiar applications. This is shown pictorially in Fig 22.

The stress value of 7.29×10^{-2} Nmm^{-2} if applied to a 1 tonne braked motor vehicle with a rear surface area of 1000 mm x 1300 mm=1.3×10^{6} mm^2 will yield a push force of 94,770 N.

In Imperial units this equates to a push of 21,305 lbf (pounds force) or 9.5 tonf (tons force).

Rounded up and put more simply, this equates to the vehicle being pushed by 118 people each of whom weighs 180 pounds (81.8 kg) (see Fig 22). If the altitude of the Andes is taken as 5 km and the distance between the Peru-Chile trench and the Cordillera–Real is taken as c.1000 km, the incline is approx. 1:200. Therefore, the vehicle can be considered to be on a level surface for scaling purposes. Normally a 3 tonne hoist will easily pull the vehicle up a 1:3 incline onto a pick-up truck It is also worth noting that an upward acting net force of 2.37×10^{-2} N/mm^2 (3.5 psig) on a 60 metre wing span of an aircraft is sufficient to keep a large 350 tonne aircraft flying. A puff of wind with dynamic pressure as low as 0.135×10^{-2} N/mm^2 (0.2 psig) acting on the large surface area of a ship's sail will cause a boat to move across water.

Fig 21: Actual Incline is 1:200

8. THE EFFECTS CENTRIPETAL FORCES ON PLATE MOVEMENTS

Consideration of the calculations in Appendix 4 shows that the Centripetal or Radial Outward Force **$F= M\omega^2R$** (in Newtons) is responsible for the equatorial bulge that causes a 0.34% reduction in the gravitational force from that experienced at the poles where the rotational velocity is zero. This difference is considered enough to cause the plates to move around the Earth on a frictionless surface.

At this junction it is pertinent to note that due to the low rotational velocity of Venus at the equator (one rotation in 243 Earth days = 6.5 kmh^{-1}) compared with 1674.5 kmh^{-1} on Earth, the centripetal forces available compared to the similar-sized planet Earth will be in the ratio of $(6.5)^2 / (1674.5)^2$ = 42.25/2,803,950.25 = 0.000015:1. This would give a stress value of $3.9\text{x}10^{-3}$ Nmm^{-2} (0.059 psig). The circumferential forces thus available for tectonic activity on Venus are extremely small.

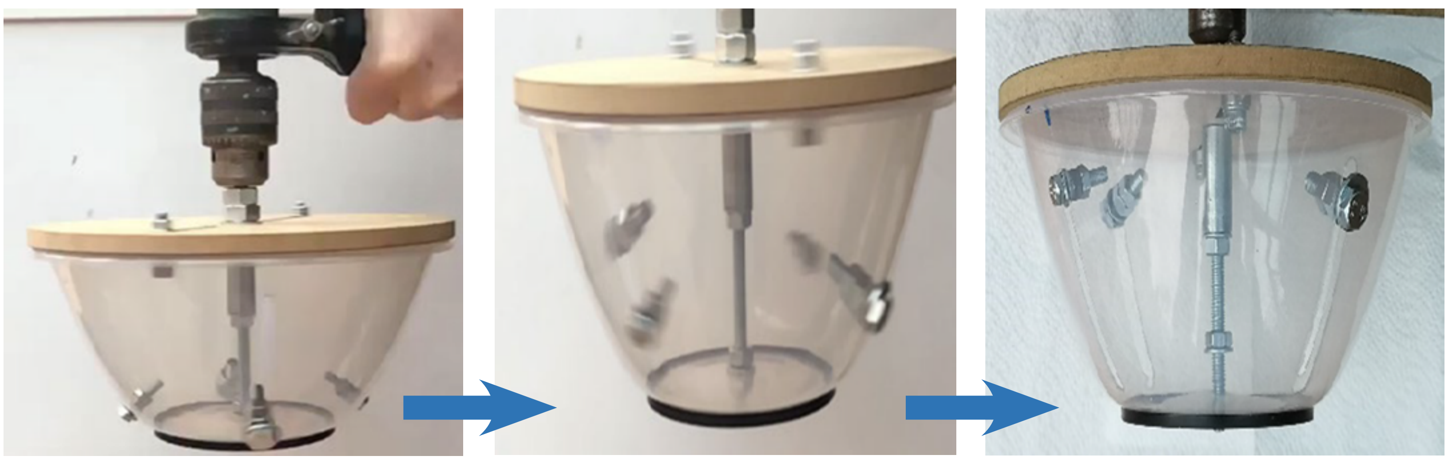

Fig 22

The calculations derived in Appendix 4 are mainly applicable to the longitudinal East and West movements of the plates away from the African Plate and at first sight do not really help explain the northwards movement and breakup of Pangea from the Permian to the present. A demonstration rig (Fig 22) was made using a hemispherical bowl with 4 vertical slots in which different sized metal bolts are free to move along and within the slots.

On rotating the bowl, the bolts travelled vertically upwards and outwards. This centripetal force action mimicked the northwards movement of Pangea and the associated upwards separation of the South American plate as it went westwards and the Indian and Australian plates as they moved eastwards. The possibility that the above process is responsible for the creation of the divergent southern circumferential East Pacific and Antarctic ridges and the south-west and south-east Indian ridge boundaries is a matter

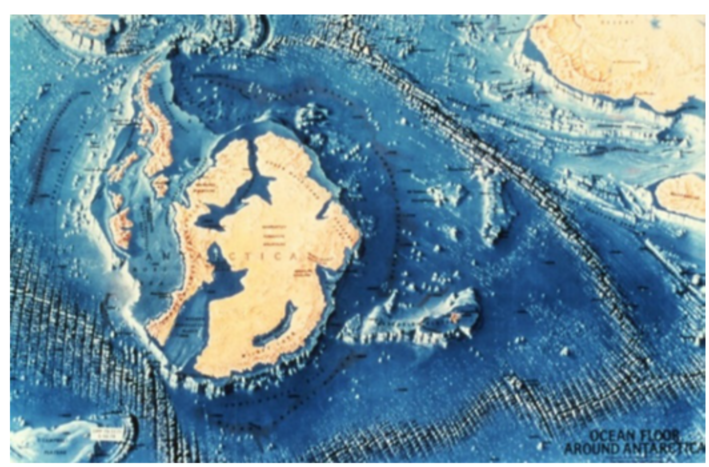

Fig 23

for consideration. Furthermore, it is also feasible that the same centripetal forces are simultaneously pushing the Antarctic plate southwards to move into a larger area around the south pole The outward centripetal forces creating the oblate shape of the Earth will also tend to move or pivot the northern land masses comprising the Eurasian and North American plates in a southerly direction into a larger diameter area. These processes will result in putting the Pacific Basin under compression.

Fig 23 displays the National Geographic[37A] Mid-Ocean east Pacific and Antarctic ridges including the south-west and east Indian ridge boundaries with perpendicular fracture zones.

The pictorial 'force' diagram shown in Fig 24 yields a viable explanation how west-east centripetal or radial forces can result in the south-north plate separation.

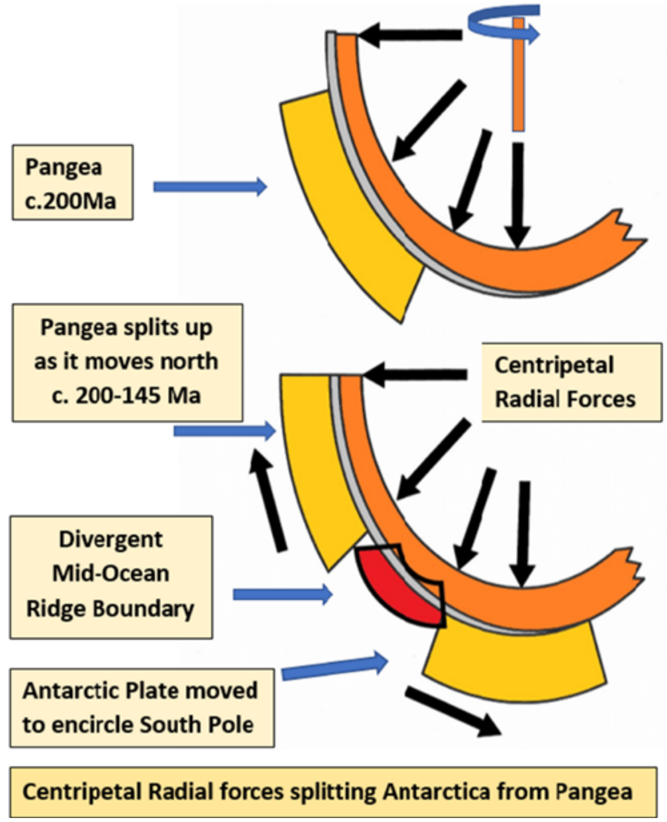

Fig 24

9. PLATE BOUNDARY FORMATION ANALYSIS

PLEASE NOTE. The Heezen-Tharp 1977 (H-Z 1977) oceanographic map is used as the basis for the following discussions. As the Mercator type projection distorts the land areas by displaying the spherical globe layout on an equal grid flat map (Fig 24) some misinterpretation regarding tectonic processes is very possible. Although care has been exercised in taking this into account some observations will be open to debate.

Fig 25

This Google downloaded map has been reproduced by the USGS & the National Geographic Society and is used as the major reference in the following sections. Examination of the 'Transform Faults' as noted on the H-Z 1977 map as being simply the displacement of parts of a ridge either side of the main ridge line by lateral movements of the plates after separation may not be completely true in every case. The initial northward pivoting split of Laurasia from Pangea and the subsequent break up into the North American and Eurasian Plates from the larger Laurasian plate would have initially only stretched and rifted the mantle between them and not necessarily the complete Mid-Atlantic ridge. This point is open to debate as is the question regarding the formation of the oceanic crust along the line of separation.

The following sequence of events is envisaged at this stage

1. The continental mass of Pangea would have been shifted northward by the combined circumferential and centripetal forces.
2. The ductile mantle would have stretched under the applied tensile stress forces.
3. The stretching would have thinned the mantle and the pulling action would be noted by the elongated stress lines some of which may have developed into the now referred

to 'Fracture Zones'. The length and width of these 'Fracture Lines or Zones' would have been subject to varied mantle composition and the latitude related rotational velocity-based stress forces.

4. Finally, fracturing at right angles to the stress forces would have occurred with the subsequent creation of separate plates. At this point magma would intrude into the ever - widening ridge giving rise to the mirror imaged parallel lines of paleo-magnetic reversal cycles either side of it. 'Fracture Zone' stretching would cease.

5. The displaced 'Transform Fault' along the Mid-Atlantic Ridge starting at Greenland and continuing through to a line drawn between North Africa (Morocco) and the top western point of Brazil in South America, may well have occurred during the initial breakaway stage of the North American plate prior to the later separation between the South American plate and the central and southern part of the African plate. If this is the case, the above-mentioned visually noted (H-Z map) misalignment of the ridge compared with the Mid-Atlantic ridge between South America and central and southern Africa may not be a Transform Fault.

6. Once further separation had taken place, between the northern part of the African plate and the Eurasian part of Laurasia, ingress of water from the Panthalassa and Tethys Oceans allowed the beginning of the formation of the new Atlantic, Indian and Pacific Ocean boundaries (at this stage, at c.150 Ma, the North Atlantic was yet to open).

7. An attempt has been made to display the above sequence in the illustration Fig 30.

The above argument does not preclude that the now separated plates with their different size characteristics would move relative to each other to re-align themselves with the stress loads and in so doing give rise to the transform faults that traverse the intruded magma flows (Fig 25). This separation will continue until the crustal plates are moved to the lighter (Pacific Basin) side of the Earth. The intrusion of magma onto the separating ocean floor boundaries which is generally credited with the force capable of moving continents apart causing 'sea floor spreading is now seen as being an inevitable passive consequence of the mantle having being been split by the circumferential stresses. This process is referred to as 'Sea Floor Stretching' in this paper.

Following on from the initial break-up of Pangea, the separated continental blocks, presently postulated as being driven by the differential circumferential stresses and centripetal forces, will be pushed over the oceanic crust towards the lighter side of the planet. If these movements away from the now central part of the African plate are approached from a convection current circulatory system, it would be difficult to reconcile all the following moving towards the Pacific Basin, i.e.: (1) Pangea moving north in the Permian, (2) what is now the Eurasian plate moving north-east and rotating, (3) the South and North American plates moving west and (4) the Indian and Australian plates moving north-east. The same difficulty would apply in reconciling these plate movements with (a) the apparent north-westward movement of the Pacific Plate over the Hawaiian hot spot in forming the Hawaiian-Emperor volcanic seamount chain (b) the convergent boundary along the Aleutian Trench (c) the divergent boundary of the east-west circumferential Pacific/Antarctic ocean ridge and those extending south-east and south-west from India. Fig 25 shows the present plate movements and their different type boundaries. It is extremely difficult to offer a rational explanation to cover the various circulatory convection motions particularly as they would have to consider the different Earth circumference measurements with latitude.

If, however the various movements within the Pacific Basin are considered using the centripetal

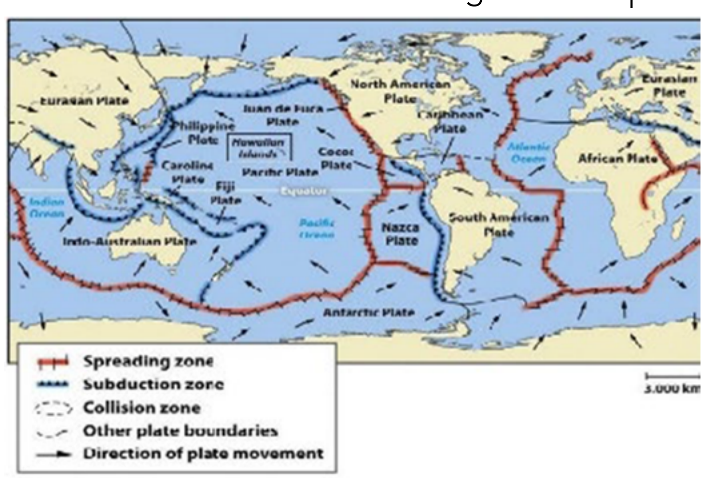

Fig 26

and differential circumferential stress forces associated with the rotation of the Earth, the following explanations may well be considered viable:

1. The Eurasian continental plate despite the impediment to its westward motion by its engagement with the Indo-Australian plate at the Himalayan interface, is being subjected to a Euler pivotal action over the Pacific oceanic crust in a westward direction.

2. The North American plate including the Transform fault area shows an overall trend for an eastward pivotal movement over the Pacific Basin as noted by the convergent boundary at the Juan de Fuca and the Cocos plate areas.

3. The inward and downward pivoting motion of both the Eurasian and North American plates, coupled with the centripetal force causing the total land mass to move southwards to occupy a larger area at a lower latitude, could well have contributed to an east-west compression trench split between them in the Aleutian area.

4. To the above, a S-N compression component is applied by the north-north-west movement of the Indo-Australia plate on the eastern side of the Pacific Basin. This additional compressive force may be responsible for the totally crumpled distorted Pacific Basin area between the Eurasian plate and the Emperor Seamount-Hawaiian mountain island chains extending south to the Kermadec trench.

5. This compressive force could also be the main reason for the propagation of the vertical S-N aligned Palau, Mariana and the Izu-Bonnin trenches, on the eastern side of the basin in the folded crust bordering the Eurasian plate. The ovoid shape of the Philippine Basin (Fig 27) may well be due to the S-N compressive force in association with the E-W elongation in the bulged equatorial belt by the centripetal forces. In this case the circumferential tensile forces will act in opposition to the centripetal forces at the Eurasian plate side and synergistically at the Pacific Basin side.

6. It is also possible that the East-West circumferentially aligned Pacific-Antarctic, south-east and south-west aligned divergent boundaries from India are a result of the centripetal forces pushing the major continents northward whilst at the same time centralising the southern Antarctic plate to find the largest area around the South Pole. This scenario would give a plausible explanation for the situation as shown in Fig 23 and detailed in Section 8 above. It is difficult to explain the disposition of the boundaries at the Polar region by convection current considerations.

7. The above scenarios are in keeping with the projected behaviour as outlined in Fig 17B in which the heavier side, split under tension, is opposite the lighter side in compression 180 degrees away on the other side of the planet.

8. The examination of the sea floor area around Southern Japan suggests that the splitting of the Nankai Trench under compression via the northern movement of Australia has produced compression type folds between Japan and the main Eurasian plate. This scenario may also be applied to the Philippine plate. However, the above points may be based on an incorrect interpretation of the enlarged portion of the H-Z 1977 map (Fig 25).

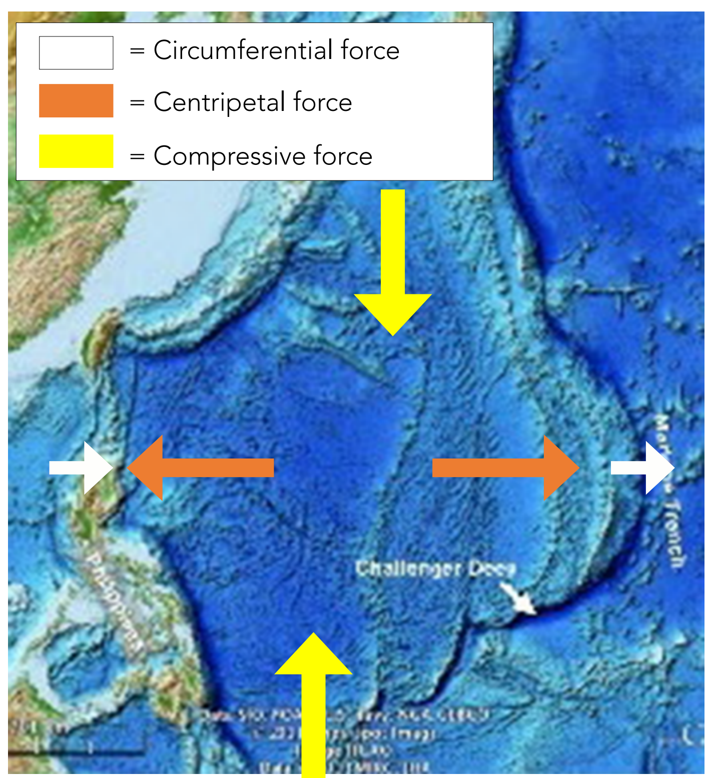

Fig 27

10. COEFFICIENT OF FRICTION: CRUST / MANTLE INTERFACE

The estimation of the magnitude of the circumferential forces acting on an element of crust (see section 6.2 and Appendix 3) allows for the calculation of the coefficient of friction (μ) at the crust / mantle interface. The force diagram required for this calculation is depicted in Fig 28. The determination of the coefficient of friction will thus yield an indication of the material and topography at the crust/mantle interface.

Fig 28

Let F be the 'moving force' on the 1m x 1m x 1000m crustal column and W= the 'vertical downward force' exerted by the weight of that column.

As the ratio of the height of the Andes to the distance between the western edge of the South American shelf to the Cordillera Real is c.1:200 the inclined plane presented by the Nazca plate can be considered as being essentially flat.

If we take the radius of eccentricity to be 1 Km, then from eq. (2) as above we have

F= 6.64 x 10^7 N and

W=2.8x10^6x 9.807 Kg

N= 2.745 x10^7 N.

Hence μ= F/W= 6.64x10^7 / 2.745 x10^7 = 2.419.

Alternatively, if the radius of eccentricity is taken to be 0.5km then μ =1.35

The graphical relationship between μ (coefficient of friction) and the calculated force (F) and the corresponding radius of eccentricity is shown in Appendix 3.

The research programme by Morrow and Lockner[32] on the cored rock samples from the Hayward Fault region in Northern California showed the coefficients of friction of these samples (sandstone, basalt, fine and coarse-grained gabbros, and keratophyre). These were calculated from the fracture angles which occurred under the applied axial loading and were shown to range between 0.5 and 0.9. At low applied loads of 32 and 64 MPa (to simulate depths of 2 and 4 km) the μ values for the coarse gabbro, basalt and keratophyre varied between 1.0 and 1.5. The calculated values of the coefficient of friction are not unrealistic and compare favourably with laboratory simulations.

11. REGIONAL METAMORPHIC REACTIONS & VARIATIONS

In order to maintain the sustained unidirectional movement of Pangea northwards followed by the east and westward movements of crustal plates either side of the central part of the African plate, the applied forces have to be both substantial and have a stable permanent origin. It is this requirement that will cause the relative movement of the continental crust, with its variable underside topography, to be forced over the almost mountainous terrains of the oceanic crust. The resistance to motion will result in a plethora of metamorphic processes varying from high and low pressure water rejection, to high pressure/high temperature regional metamorphism that would change the crystal structure of the rocks involved. This is in addition to the pushing, tilting, deformation and uplift of sedimentary sequences from their original horizontal position thus forming the mountain ranges we are now familiar with. The forces associated with the above-mentioned processes would need to be evaluated in conjunction with laboratory simulations and reported field observations to determine the realistic value of the Circumferential Force F and the applied pressure loads at the particular locations. These processes are illustrated in Fig 29.

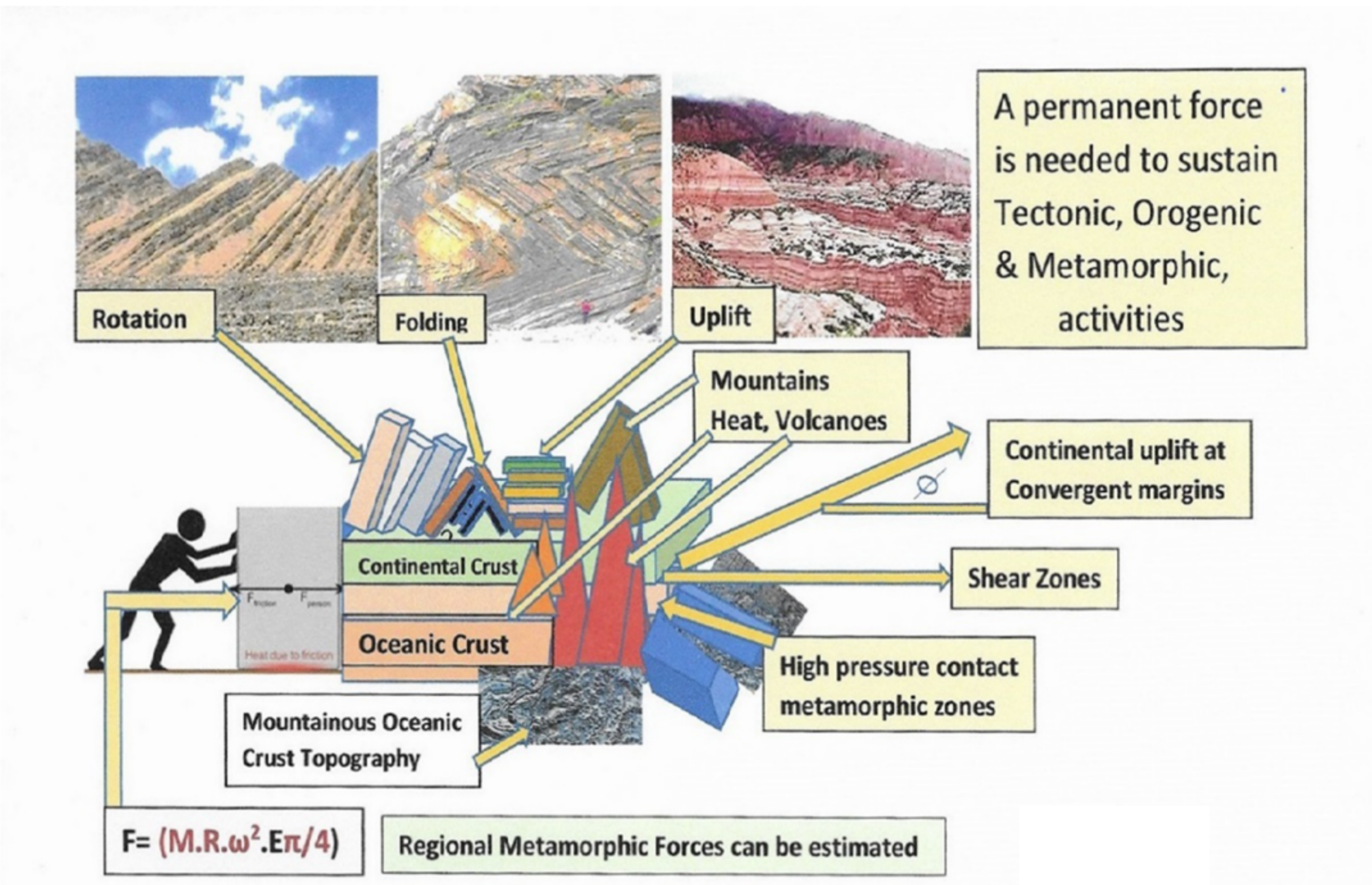

Fig 29 / ©2020 R. Maurer

12. TECTONIC FORCES DIAGRAM BASED ON THE CIRCUMFERENTIAL STRESS FORCES

Fig 30 reinterprets the original Hess model of subduction by circulatory convection currents with one that shows tectonic plate movements as being a function of the centripetal and differential tensile forces associated with the constant rotational velocity of the Earth. Thus 'Slab Pull' on the oceanic crust is replaced by 'Tensile Stress Pull' on the continental crust as being the major force for moving continents together or apart. In this respect the variable omnidirectional convection current driving force is replaced by a permanent constant force related to the rotational speed of the Earth. Furthermore, 'Seafloor Spreading' as described by Hess is replaced by 'Upper Mantle Stretching' and magma intrusion onto the sea floor is considered as an inevitable consequence of the propagation of the rifting of the mantle. As such, magma intrusion has no contribution to the forces moving tectonic plates. This interpretation does not invalidate research work at the convergent and divergent margins as the mineralogical and geological outcomes will be the same. As the stress calculations are based on the Earth's constant rotational velocity, the forces available for all tectonic processes are not subject to conjecture regarding both the source and direction of the omnidirectional convection currents. This approach allows for the mathematical analysis that is applicable to fixed rotating bodies to be modified and utilised for the study of tectonic, orogenic and metamorphic processes.

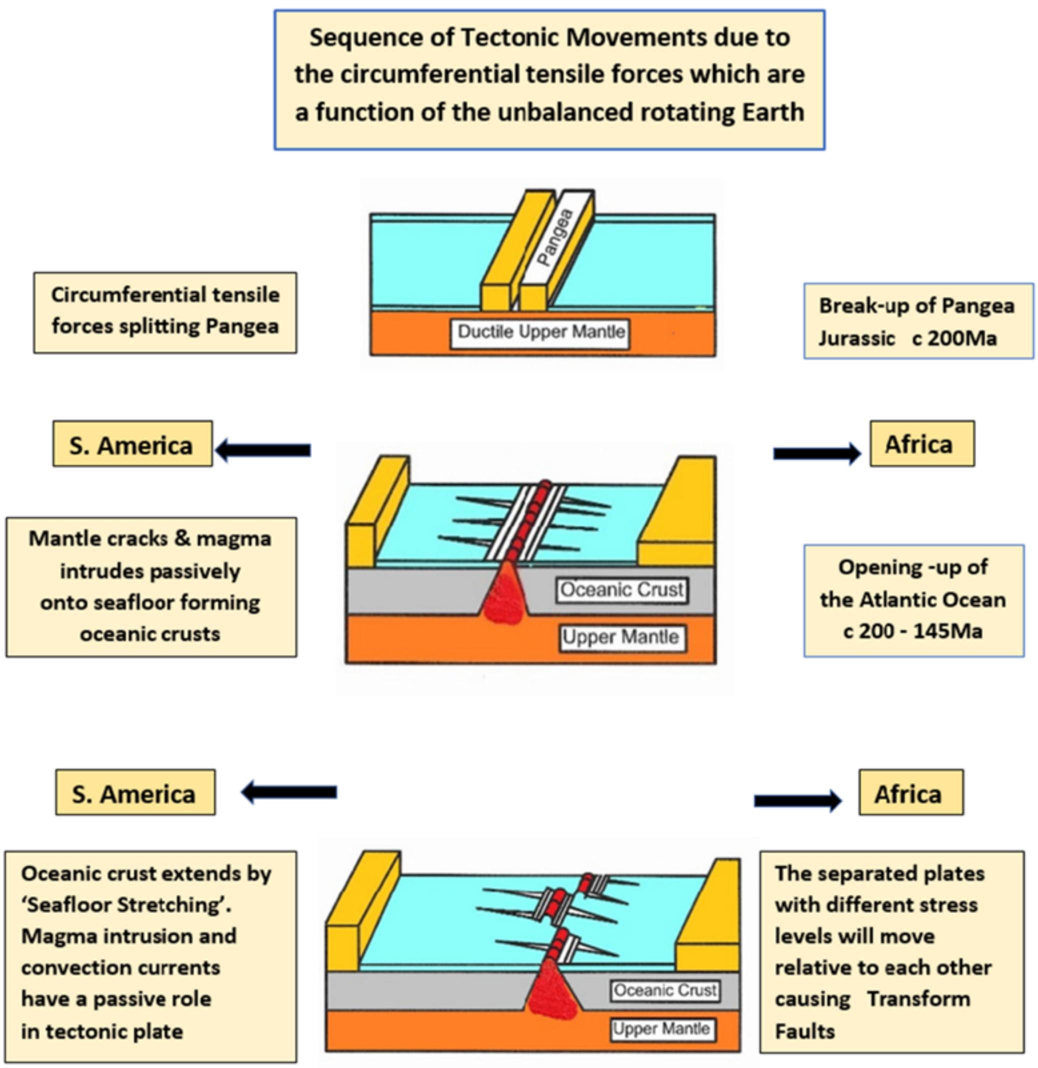

Fig 30

13. CYCLE OF PLANET REGENERATION

From the arguments put forward above it is possible to construct the regeneration cycle of the Earth's lithosphere. This is shown in Fig 31.

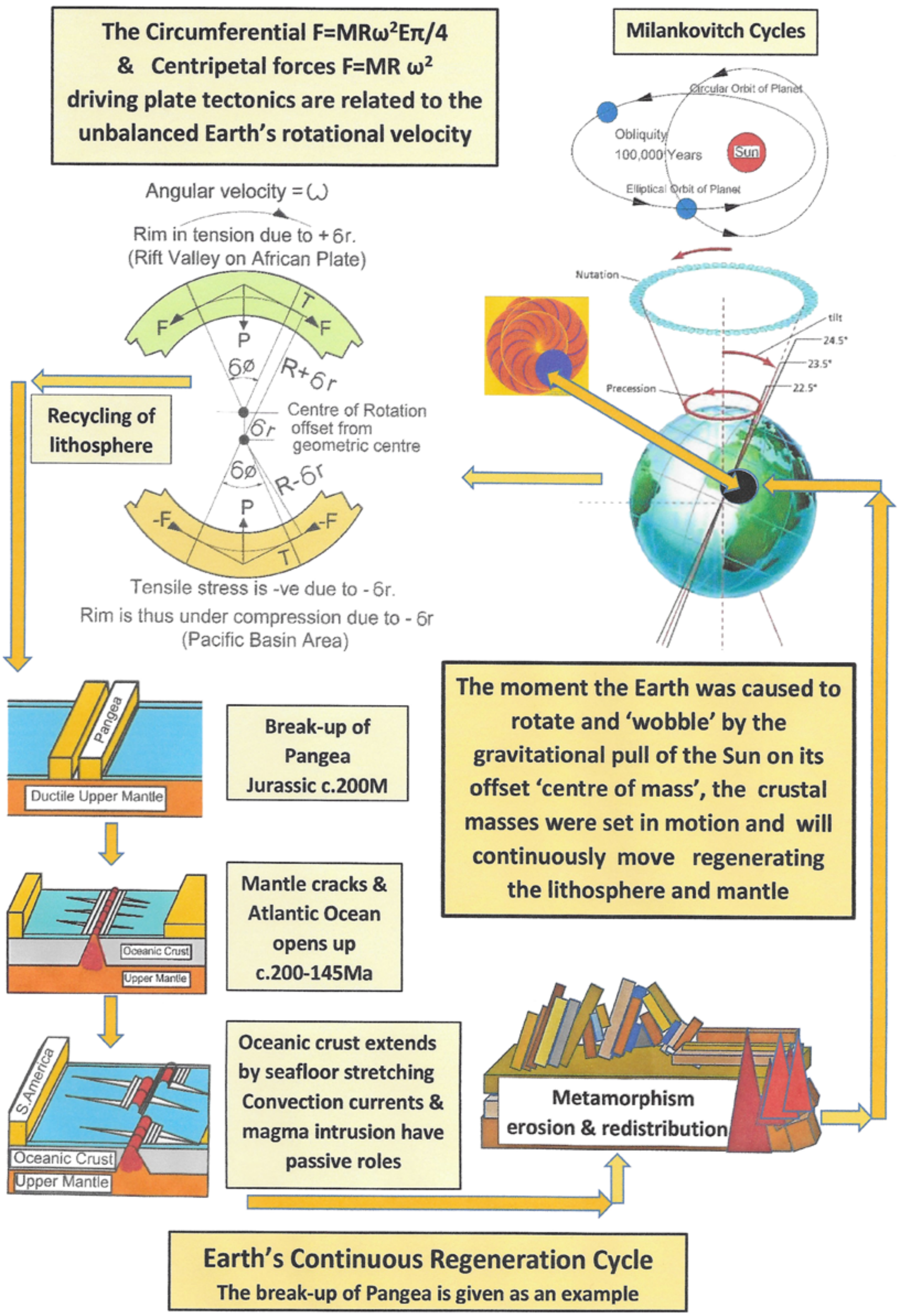

Fig 31 / ©2020 R. Maurer

The vibrational patterns known as the Milankovitch cycles which are associated with the rotating/orbiting and unbalanced tilted planets will create circumferential stress patterns in the outer rim. These stresses will cause the crustal masses to move from the heavier to the lighter side. In doing so, they will undergo continuous changes in size via boundary changes, travel direction and topography. Typical types of force-driven metamorphic and topographical changes which include orogenic and volcanic activity, igneous pluton formation, and changes in mineral composition, are illustrated in Fig 31. The formation of new plates and their subsequent denudation over geological time due to erosion will cause the ever-changing lithosphere to be redistributed over the Earth's surface. Taken together with the continuous and constant Earth's rotation, the lithosphere will be continuously recycled as has always been the case since its formation.

14. CONCLUSIONS

This conceptual research work investigating the sustained unrelenting unidirectional movements of tectonic plates away from the 'heavier' African plate since the break-up of Pangea in the Jurassic period, has resulted in some unexpected findings and conclusions:

1. The development of the equation relating the circumferential stress forces (F) causing tectonic movements to the radius of (E) eccentricity provides the initial platform for estimating the forces responsible for tectonic, orogenic and metamorphic processes. These calculations are based on the observation that the tilt and precession movements of the planets closely mimic the behaviour of unbalanced rotating bodies where the centre of mass (COM) is not coincident with the axis of rotation.

2. The validity of mathematically modelling the Earth as an unbalanced rotating body on a 'fixed gravitational axis' has in the past been challenged as being totally incorrect in that the Earth and other planets are considered to be 'freely rotating bodies about the centre of mass with zero Moment of Inertia'. This assumption was made despite Kepler's second law clearly showing that both the orbital and rotational velocities of planets, especially whilst travelling in an elliptical orbit, are rigidly controlled by the mutual gravitational pull between the Sun and planets (Section 7). The objections to the proposed mathematical model are unfounded as the model used is both viable and validated.

3. Furthermore, for the planet to be rotated about a stable axis by the gravitational pull of the Sun, the COM of the planet must be offset from that axis to allow the gravitational pull to yield a 'torque' force. If the COM was positioned on the axis of rotation, the gravitational force would just 'pull' the planet as distinct from causing it to rotate.

4. This above observation resulted in the totally unexpected conclusion that from (3) above, the establishment of the axis of rotation of the planets is a direct consequence of the COM being offset from a symmetrical position.

5. This above stated observation, which is applicable to all the rotating bodies, may well explain why the planets (except Venus and Uranus) all rotate with the same hand as does the Sun and exhibit a similar tilt angle to the Earth and in many cases a similar rotation period.

6. The 'wobble' of the Sun may well be caused by the continuously variable but mutually gravitational pull of the planets on the asymmetrical and possibly moving COM.

7. The initial northward movement and break-up of Pangea may well result from the centripetal upward and outward forces separating Antarctica from Pangea followed by the differential circumferential stress forces acting in concert with the radial centripetal forces at the higher latitudes, in moving the continental plates towards the Pacific Basin

8. The simple vector diagram (Fig 24A) given in the text demonstrating the radial centripetal forces causing the circumferential divergent mid-ocean ridge, will have the same appearance as if these boundaries were created by convection currents. It may thus be feasible that the centripetal radial forces and the circumferential tensile forces which can act either in opposition or in unison (Fig 27) can be used to replace the present conventional circulating current forces

9. The determination that the forces primarily driving tectonic plate movements are directly related to the rotation of the planet Earth has by implication made convection currents and magma intrusion a consequence of tectonic activity and as such have a passive rather than an active role

10. The forces involved in the 'Cycle of Planet Regeneration' shown in Fig 31 allows each stage to be examined and where possible estimated.

11. The introduction of the following new terms into the geological vocabulary is proposed: 'Differential Circumferential Stress Forces '(DCSF) 'Pushed Continental Crust' (PCC), 'Radius of Eccentricity', 'Gravitational Crank Coupling; (GCC) and 'Cycle of Continuous Lithosphere Regeneration' (CLR)

APPENDIX 1 - CONSIDERATION OF THE ROTATIONAL BEHAVIOUR OF THE SUN AND PLANETS

Table 1 Planet Data – NASA Source

Planet	Density (kg/m3)	Equatorial Diameter (km)	Distance from Sun (106 km)	Length of Day (hrs)	Orbital Period (Earth days)	Orbital Velocity (km/s)
Mercury	5427	4879	57.9	1407.5	88.0	47.4
Venus	5243	12,104	108.2	5832.4	224.5	35.0
Earth	5513	**12,756**	149.6	23.93	365.2	29.8
Mars	3934	**6779**	227.9	24.6	687.0	24.1
Jupiter	1326	**139,822**	778.3	9.9	4330	13.1
Saturn	687	**116,464**	1426.7	10.7	10,748	9.6
Uranus	1270	**50,724**	2870.7	17.2	30,666	6.8
Neptune	1638	**49,244**	4498.4	16.1	60,149	5.4
Data: NASA General Info						

It is noted that apart from Venus and Uranus all the planets rotate in the same anti-clockwise direction as does the Sun[35]. Table 1 also shows that despite the wide range of planet diameters, their rotation period is within a 10-24-day hour envelope (except for Mercury and Venus). This immediately suggests that the rotational velocity is controlled by the rotation of the Sun. The inner core of the Sun is reportedly rotating on its axis every 5 Earth days[35]. However, as the Sun itself displays a measurable 'wobble' (Fig 34) as measured between 1944 and 2020 different scenarios can be contemplated. The first scenario is that the wobble is linked to the variable gravitational pull from all the planets as they move around the Sun in their elliptical orbits as shown in Fig 31. Fig 32[36] shows that the Sun's own COM is continuously and cyclically offset from its axis of rotation.

The second scenario is to give consideration of the possibility that the sun itself may have a faster rotating inner layer of the core with an approximate 24-hour rotation velocity mode. If this prediction can be postulated, then the concept of a 'gravitational crank coupling' (GCC) is worth consideration. Under these circumstances

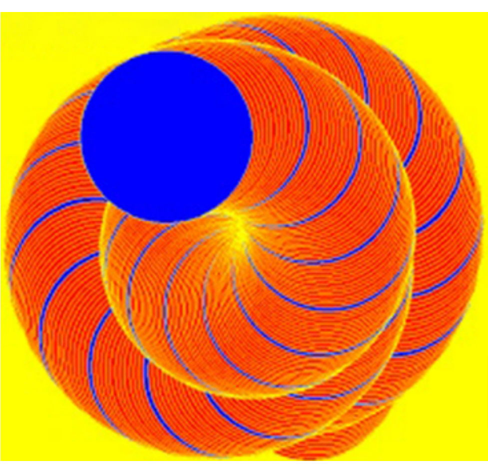

Fig 32

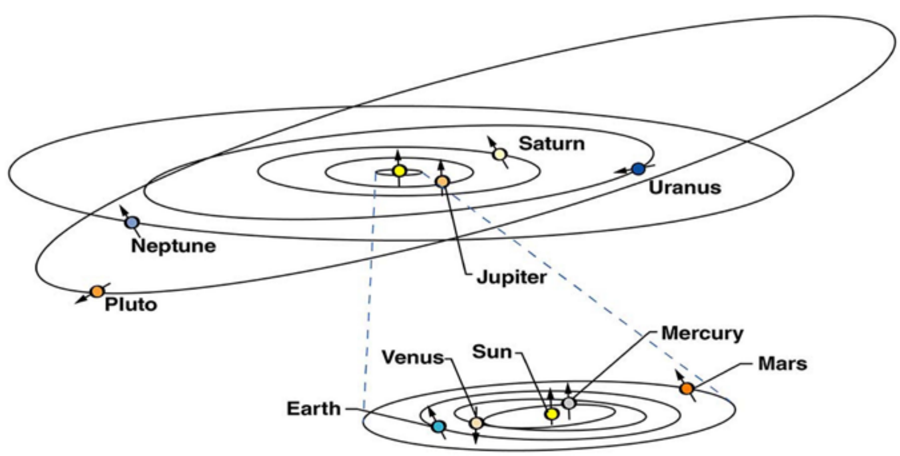

Fig 33

a nominal 1:1 daily rotational ratio between the Sun and the planets does not seem that far-fetched. The gravitational effects of the moons on the various planets are not considered at this point.

Mercury with its almost zero tilt and extremely low daily rotational velocity suggests that the COM is almost coincident with the N-S rotational axis making it more likely to be 'pulled' around in orbit, rather than be rotated around an axis. The higher orbital velocity of Venus within the lower orbital velocity of the Earth, causes it to overtake the Earth as they orbit the Sun. Furthermore, Venus's inclined orbital path causes the planet to move above and below the Earth's orbital path. It is outside the remit of this research programme to find a resultant gravitational pull from the Sun and Earth that explains the slow retrograde rotation of what appears at first sight to be an 'upside down' planet given its axial tilt of 177.3°.

APPENDIX 2 - CALTECH AND THE EARTHBYTE PROJECT

(Use of Equation 2 relating the Circumferential Stress to the Radius of Eccentricity)

Title of publication – An analysis of the effects of Angular Momentum and Tectonic Plate Movement

Abstract: The Earth's center of gravity is dynamic, and its location varies based on exertions of mass on the crust on behalf of continental plates. These shifts, however minute, over a long enough period of time have significant influence on periodic axial rotation, convection cell dynamics, and continental rotation. This investigation considers a number of dimensions influenced by dynamic changes in

This difference in localized mass, calculated as being, effectively, a change in crustal depth and area, may be enough to cause a shift in the Earth's center of mass, and thus on its rotational dynamics. By adopting the formula used by R. Maurer (Maurer, 2001) for the angular momentum of tectonic plates and solving it for the eccentricity of the center of mass, we can then discern the fluctuations in such eccentricity.

$$F = \frac{M\,r\,E\,\pi\,w^3}{4}$$

$$\frac{4F}{M\,r\,\pi\,w^2} = E$$

Where M is the mass of the object, F is the centrifugal force in newtons, r is the radius in km, w is the rotational velocity of the Earth represented in radian form, and E is the eccentricity of the center of mass. If we consider these formulas acting with any amount of centrifugal force in the system, a significant difference in eccentricity results from even minor changes in mass (Table 2).

Fig 34

rotation, angular momentum and gravitational influence through the use of mathematical modelling of the Earth's rotation using an Euler-Liouville formula as described by Akulenko [57] in 2007, the variations in the Earth's periodicity of acceleration by the application of a Morlet wavelet transform proposed by Duhau[58] in 2006, a geographic information system with raster data visualization capabilities and plate tectonic reconstruction software that was developed by an international team from the Earthbyte Project, the Geological and Planetary Sciences Division at Caltech, and the Center for Geodynamics at the Norwegian Geological Survey: and a modified form of the equation for the center of mass of an obsculating sphere as used by Maurer 2001[45].

The results of this modelling show that seismic activity and tectonic activity increase with fluctuating periods of acceleration in the Earth's rotational velocity, and that the aggregation of plates has a significant impact on the Earth's centre of mass, confirming the hypothesis that gradual changes in the Earth's rotational axis and velocity, largely ignored in plate tectonics, have a significant impact on seismic events and tectonic movement.

Table 2 CALTEC-Earthbyte Project used Equation 2 to derive this table

Angular Momentum and Plate Tectonics 15

Density (g/m^3)	Centrifugal Force Tested (N)	Eccentricity (km)
2.76	10	0.001185
2.78	10	0.001195
2.76	100	0.011846
2.78	100	0.01195
2.76	1000	0.118462
2.78	1000	0.119503
2.76	10000	1.184621
2.78	10000	1.195033

Table 2: This table illustrates that changes in effective density of even just .879% generate significant changes in eccentricity

APPENDIX 3 - ESTIMATION OF THE MAGNITUDE OF THE CIRCUMFERENTIAL FORCES DRIVING TECTONIC MOVEMENTS

The mathematical analysis is based on the concept of the outer rim being allowed to slide relative to the main rotating body (Figs 17b, 18a, &19).

In order to determine the forces postulated as being responsible for tectonic movement the model used is one in which the thin crust can slide relative to the solid body at the crust /mantle interface. By way of illustration Fig 18a shows that if an unbalanced disc with an outer annular ring containing fluid is rotated about its principal axis, the liquid will move to the 'lighter' side. Fig. 18b shows an analogous situation with the sliding continental plates.

If we consider the crust as being able to move relative to the mantle, albeit it over a long geological time span, then a simple force diagram (Fig 17B & 19) can be constructed by making the following assumptions: (a) the crust is a thin shell that is able to slide relative to the mantle, (b) the forces owing to eccentricity are superimposed on the stress caused by the general rotation and gravity, and (c) the stress that is of interest for the purposes of tectonic movement is the differential stress owing to this eccentricity.

By approaching the problem in terms of a thin shell moving relative to the mantle, it is possible to consider what increments of the tensile force are responsible for putting the Pacific Basin under compression and the African Plate under tension. The Rift Valley, in Africa, would be a case in point. The calculations which follow are based on the consideration of the eccentrically induced loads on the thin crust.

In calculating the effects of the circumferential tensile forces (F) at the surface of the earth due to the centre of mass being offset from the principal axis of rotation, the term 'radius of eccentricity' (E) is introduced to denote the magnitude of the offset.

The magnitude of the derived circumferential stress (F) will be dependent on the distance between the geometric centre and the centre of mass, i.e. (E) the 'radius of eccentricity'. In a limiting case, if the 'radius of eccentricity' is zero, the rotating body will be balanced, and the centripetal forces will be zero.

Consider a thin shell cut across the Earth's diameter at the Mid-Atlantic ridge (Fig 19). The force tending to cause this half of the shell to part is the 'vertical' component of the centripetal forces generated by the eccentricity. This is similar in concept to that in thin shell circular vessels subjected to an internal pressure.[7] Figure C in figure 19 shows this concept of 'vertical force'. As the semi-circle is symmetrical there are two sides resisting the parting force. Thus, only one side needs to be considered for integration of the 'vertical' forces from 0 to $\pi/2$.

Fig C in Fig 19 shows the force and vector diagrams used to determine the magnitude of the circumferential stress in the direction of the maximum effective radius. For ease of understanding the force diagram is superimposed on the major geological features on the equatorial belt.

Notation	**Value**
M = Mass per unit length of crust (kg)	2.8×10^6 kg
R = Radius of Earth. (m)	6.4×10^6 metres
E = Radius of eccentricity. (m)	1×10^3 metres
ω = Angular velocity. (rad s^{-1})	7.27×10^{-5} rads.sec^{-1}
θ = Angle. (rad)	
δe = Effective eccentricity at angle θ	
F = Total force at point X (cf. Fig.11) (N)	
F_1 = Radial force due to eccentricity at θ	

Then from the 'force vector diagram' at surface at an angle θ:

Vertical component of F_1 $\delta f = F_1 \text{Sin}\theta$

Effective eccentricity at angle θ $\delta e = E \sin\theta$

And Mass of segment $R\,\delta\theta = M\,R\,\delta\theta.$

Thus $F_1 = M.\,R\delta\theta.\omega^2.\,E \sin\theta = M.\,R.\,\omega^2.E.\,\text{Sin}\theta.\,\delta\theta$

The vertical force component $\delta f = F_1.\,\text{Sin}\theta$

$= M.\,R.\omega^2.\,E.\,\text{Sin}\theta.\,\text{Sin}\theta.\,\delta\theta$

$= M.R.\omega 2.\,E.\,\text{Sin}^2\theta.\,\delta\theta$ (1)

Thus, the total vertical force F $= \Sigma_0^{\pi/2}\ M.R.\omega^2 E.\text{Sin}^2\theta.\,\delta\theta$

$= M.R.\omega^2.E\ (½.\theta - ¼\text{Sin}2\theta)^{\pi/2} - (½.\theta - ¼\ \text{Sin}2\theta)^{0}$

$= M.R.\omega^2.E\ (\pi/4 - ¼.0) - (½.0 - ¼.0)$

$= M.R.\omega^2.E\pi/4.$ (2)

The derivation of the equation of the total force at the maximum effective radius allows for the determination of the circumferential tensile stress on the crust. The approach given above considers the forces developed as a direct function of the radius of eccentricity.

If we take into eq. 2 the crust to be 1000 meters thick with

an average density of 2.8×10^3 kgm-^{3} then for a 1metre x 1-metre-wide strip,

The mass per unit area of crust (m) is = 1000 x 1 x1 x $2.8 \times 10^3 = 2.8 \times 10^6$ kg:

The radius of the Earth (r) = 6400 km

The angular velocity of the Earth[55] at the equator (ω) = 7.27×10^{-5} rads.sec^{-1}

The radius of eccentricity at the Core (E) = 1 km.

Hence substituting into equation 2 we have

F= $2.8 \times 10^6 \times 6.4 \times 10^6 \times (7.27\times10^{-5})^2 \times 10^3 \times \pi /4 = 6.64 \times10^7$ N.

Since, the magnitude of the circumferential stress is Force/Area

this becomes $6.64\times10^7 / 1 \times10^3$: and hence

the circumferential tensile stress is = 6.64×10^{-2} Nmm^{-2}, 0.644 Bar or c. 9.7 $lbs.in^{-2}$

It is also possible to look at the addition of the vertical component of E to the radius of the Earth to determine the expression of the forces in the direction of the maximum effective radius. Fig. 35 is used for this analysis. Fig 36 shows the relationship between the Radius of Eccentricity and the circumferential stresses. Fig 37 shows the relationship between F, E and μ.

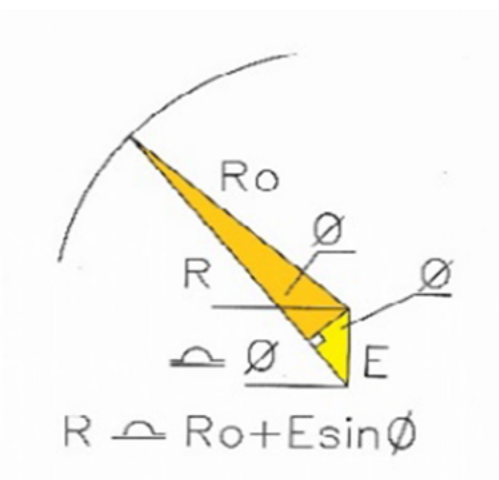

Fig 35

As above

the mass of the segment R δθ = M R δθ

the radial force F_1 = Mass.R.ω^2

the radial force F_1 = (M R δθ). R. $\omega^2 = M \omega^2 R^2 \delta\theta$.

Thus δf = $M \omega^2 R^2 \sin\theta\delta\theta$.

With reference to Fig. 35 R = R0 + Esinθ.

thus, δf = $M \omega^2 (R_0+E\sin\theta)^2 \sin\theta \, \delta\theta$

which approximates to

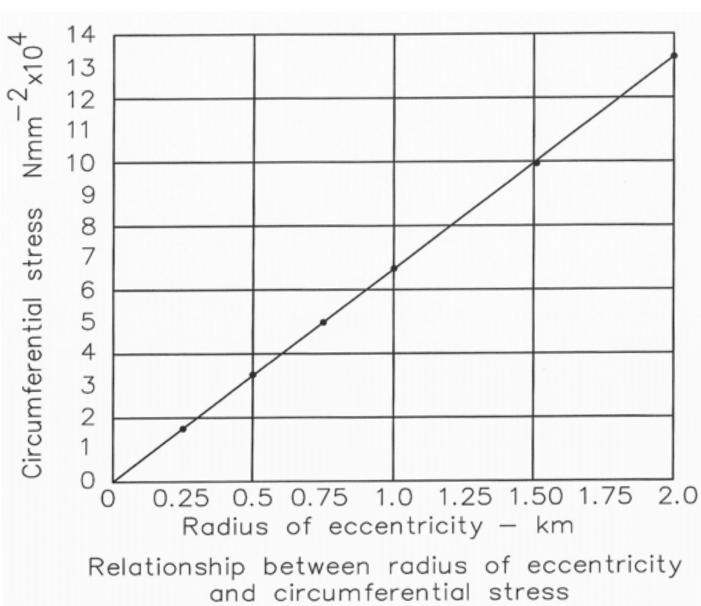

Fig 36: Relationship between the radius of eccentricity & the circumferential stresses

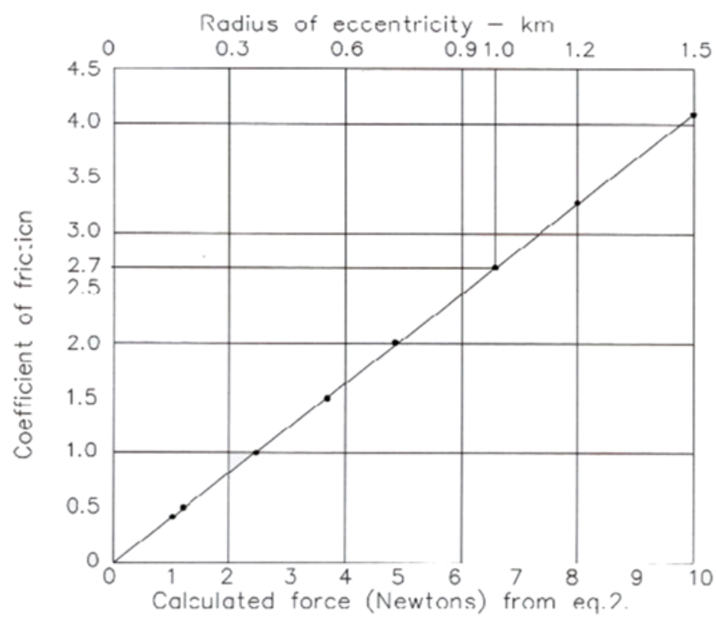

Fig 37: Relationship between the force (Newtons) needed to move a 1km x 1m x 1m element of crust and the coefficient of friction at the crust/mantle interface

$\delta f \quad = M\,\omega^2\,(R_0^{\,2}+2E\,R_0\,\sin\theta)\,\sin\theta\;\delta\theta$

$= M\,\omega^2\,(R_0^{\,2}+2E\,R_0\,\sin\theta)\,\sin\theta\;\delta\theta.$

Thus, the increase of

$\delta f \quad = \delta f - M\,\omega^2\,Ro^2\,\sin\theta\;\delta\theta$

$= M\,\omega^2\,(R_0^{\,2}+2E\,R_0\,\sin\theta)\,\sin\theta\;\delta\theta - M\,\omega^2\,Ro^2\,\sin\theta\;\delta\theta$

$= M\,\omega^2\,\sin\theta\;\delta\theta\,(R_0^{\,2}+2E\,R_0\,\sin\theta - Ro^2)$

$= M\,\omega^2\,\sin\theta\;\delta\theta 2E\,R_0\,\sin\theta$

$= MR_0\,\omega^2\,2\,E\sin^2\theta\;\delta\theta \quad$ (Eq. 3)

This equation has the same form as (Eq. 1) above. As E is small in comparison to R, and R_0 and R have essentially the same values, the factor 2 that appears in (Eq. 3) does not invalidate (Eq. 1). Hence the derivation of (Eq. 1) from the force diagram (Fig 19 and 20) is considered valid for determining (Eq. 2) by integrating between 0 and $\pi/2$.

APPENDIX 4 - EFFECT OF RADIAL OR CENTRIPETAL FORCES ON THE EARTH'S CRUST

From Appendix 2 consider a $1M^3$ of crust with an average density of 2.8×10^3 $Kg.m^{-3}$.

Taking the same values used in Appendix 2

ρ	= Average density of the crust	2.8	$kg.m^{-3}$
M	= Mass of $1M^3$ of element of crust	2.8×10^3	kg
R	= Radius of Earth (m)	6.4×10^6	metres
ω	= Angular velocity (rad s^{-1})	7.27×10^{-5}	$rads.sec^{-1}$

Thus Fr = Radial Outward Force (N)

$= M\,\omega^2.R$

$= 2.8 \times 10^3 \times (7.27 \times 10^{-5})^2 \times 6.4 \times 10^6$

= 94.71 N

= c 9.65 kgf

Thus, for every 1 Tonne of Crust, the Outward Force at the Equator due to the rotational velocity = 9.65/ 2.8 = c. 3.4 kg

This is equivalent to a 0.034% reduction in weight compared with that at the poles, where the rotational velocity is zero. This is enough to cause the crustal plates to move around the Earth surface on a frictionless mantle.

APPENDIX 5 - MATHEMATICAL ANALYSIS FOR A ROTATING RIGID BODY SUCH AS RIM TYPE FLYWHEELS

In contradiction to the analysis given in Fig 17B & 19 and Appendix 2, this analysis simply considers the Earth as an eccentrically rotating solid body such as an unbalanced flywheel. As such it does not describe the circumferential forces which are thought to be linked to the tectonic forces resulting in plate movements, but does describe the situation that would occur if the lithosphere were treated as a thin shell sphere subjected to an internal pressure with a developed 'vertical force P' (Fig C within Fig 19).

Notation			**Value**	
R =	Radius	m	$6.4\text{x}10^6$	metres
Δr =	Eccentricity	m	1.0	metres
T =	Thickness	m	1.0	metres
ρ =	Density	kgm^{-3}	$2.8\ \text{x}10^3$	kgm^{-3}
ω =	Angular velocity	$radsec^{-1}$	$7.27\text{x}10^{-5}$	$radsec^{-1}$
σ =	Hoop Stress	Nm^{-2}		

Consider a cylinder of mean radius r and thickness t rotating at an angular velocity ω about its axis (Fig.17A):

The mass of the portion $R\delta\theta = \rho R\delta\theta.t$

The radial force on the element = mass x acceleration = $(\rho R\delta\theta.t)\ R\omega^2$

This will produce the Hoop Stress σ

Resolving radially

$2\sigma t.\sin\frac{1}{2}\delta\theta = \rho R^2\omega^2.t\delta\theta$ (as $\sin\frac{1}{2}\ \theta \rightarrow \frac{1}{2}\theta$)

Therefore $\sigma = \rho R^2\omega^2$

If the centre of rotation is displaced δr from the centre of mass (Fig 9) then the tensile force on the 'heavier side' will be increased by the following amount:

Thus, the increase in tensile stress $= \rho\omega^2\ ((R+\delta r)^2-R^2)$

$= \rho\omega^2\ ((R^2+2\delta r.R+\delta r^2)-R^2)$

$= \rho\omega^2\ (2\delta r.R+\delta r^2)$

Substituting the values stated above:

The additional Tensile Stress = $2.5\ \text{x}\ 10^3\ \text{x}\ (7.27\text{x}10^{-5})^2\ \text{x}\ (2\text{x}10^3\ \text{x}\ 6.4\ \text{x}\ 10^6 + 10^6)$

$= 1.89\ \text{x}\ 10^5\ Nm^{-2}$

On the opposite side the decrease in the Tensile Stress will be as follows:

Thus the 'decrease' in tensile stress = $\rho\omega^2 ((R - \delta r)^2 - R^2)$

$$= \rho\omega^2 ((R^2 - 2\delta r.R + \delta r^2) - R^2)$$

$$= \rho\omega^2 (\delta r^2 - 2\delta r.R)$$

Substituting the numerical values, Tensile Stress will have a negative value

The Tensile Stress is thus = -1.89×10^5 Nm^{-2}

This Negative Tensile Stress is the Compression Stress = 1.89×10^5 Nm^{-2}

As stated above, the rigid body approach while clearly demonstrating the differential stress due to eccentricity is not considered as the model for tectonic movement. The model for tectonic movement as defined in Section 7 is based on having relative movement between the outer rim or crust and the main body or mantle.

APPENDIX 6 - NASA SCIENCE, SOLAR SYSTEM EXPLORATION. UPDATED SEPT 2019

Kepler's First Law: each planet's orbit about the Sun is an ellipse. The Sun's center is always located at one focus of the orbital ellipse. The Sun is at one focus. The planet follows the ellipse in its orbit, meaning that the planet to Sun distance is constantly changing as the planet goes around its orbit.

Kepler's Second Law: the imaginary line joining a planet and the sons sweeps equal areas of space during equal time intervals as the planet orbits. Basically, that planets do not move with constant speed along their orbits. Rather, their speed varies so that the line joining the centers of the Sun and the planet sweeps out equal parts of an area in equal times. The point of nearest approach of the planet to the Sun is termed perihelion. The point of greatest separation is aphelion, hence by Kepler's Second Law, a planet is moving fastest when it is at perihelion and slowest at aphelion.

APPENDIX 7 - STATISTICAL CALCULATIONS RELATING TO THE TENSILE FORCES

Determination of the circumferential stress on the continental and oceanic crusts to a 95% confidence level

	Density Continent crust **Dc** kg/m3	Density Oceanic crust **Do** kg/m3	Equatorial radius **R** 10x exp3 km	Rotational velocity **w** 10exp-5 rad/sec	Stress on Continental crust **Fc =** 0.7854.Dc.R.w.w. /10 (N x 10exp.7) Random values	Stress on Oceanic crust **Fo =** 0.7854.Dc.R.w.w. /10 (N x 10exp.7) Random Values		Stress on Continental crust **Fc =** 0.7854.Dc.R.w.w. /10 (N x 10exp.7) Sorted in ascending order	Stress on Oceanic crust **Fo =** 0.7854.Dc.R.w.w /10 (N x 10exp.7)
1	2.715	2.8745	6.370	7.2731	71.841	76.073	1	68.689	74.763
2	2.63	2.8331	6.363	7.2889	69.830	75.216	2	68.731	74.774
3	2.779	2.8491	6.367	7.2794	73.639	75.498	3	68.785	74.811
23	2.873	2.8416	6.373	7.2803	76.217	75.382	23	69.137	74.964
24	2.74	2.8696	6.367	7.2779	72.569	76.008	24	69.138	74.970
25	2.728	2.8524	6.373	7.285	72.463	75.771	25	**69.139**	**74.970**
26	2.691	2.8532	6.373	7.2775	71.345	75.641	26	69.142	74.972
27	2.893	2.885	6.370	7.2721	76.530	76.326	27	69.146	74.976
498	2.651	2.8565	6.371	7.2869	70.430	75.899	498	72.954	75.858
499	2.84	2.8887	6.360	7.2858	75.310	76.600	499	72.959	75.861
500	2.729	2.8601	6.375	7.2849	72.524	76.001	500	**72.968**	**75.865**
501	2.828	2.8569	6.367	7.27	74.750	75.515	501	72.974	75.867
502	2.668	2.8783	6.360	7.2713	70.454	76.020	502	72.980	75.869
972	2.744	2.8815	6.371	7.2857	72.889	76.539	972	76.697	76.687
973	2.607	2.8327	6.370	7.2879	69.265	75.271	973	76.727	76.688
974	2.609	2.842	6.368	7.2845	69.245	75.420	974	76.729	76.691
975	2.886	2.8369	6.369	7.2708	76.323	75.020	975	**76.735**	**76.691**
976	2.684	2.8398	6.362	7.2833	71.133	75.274	976	76.744	76.702
977	2.811	2.8508	6.370	7.2916	74.762	75.827	977	76.757	76.707
978	2.811	2.8413	6.368	7.2843	74.604	75.408	978	76.782	76.707
979	2.893	2.8804	6.375	7.2846	76.862	76.525	979	76.798	76.713
997	2.719	2.8686	6.367	7.2798	72.054	76.020	997	76.965	76.870
998	2.806	2.8876	6.378	7.2917	74.723	76.906	998	76.993	76.885
999	2.815	2.8762	6.367	7.2728	74.463	76.074	999	77.059	76.906

Density of continental crust (Dc) - kg/m3	2.6 to 2.9
Density of oceanicl crust (Do) - kg/m3	2.83 to 2.89
Radius of Earth from pole to equator - 10exp-3 km	6.3567 to 6.3781
Rotational velocity 10exp-5 rad/sec	7.27 to 7.292

Thus the mean value of the circumferential stress (Fc) acting on the Continental crust is
Fc = 72.968 (69.139, 76.735)x 10exp.6 N to a 95% confidence limit

Thus the mean value of the circumferential stress (Fo) acting on the Oceanic crust is
Fo = 75.865 (74.970, 76.691)x10exp.6 N to a 95% confidence limit

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NOTE. The apparently old references used in the sections dealing with an overview of tectonic movements as being a function of subduction forces is justified as the original arguments have been continuously, and still are, current wisdom. The bulk of the paper deals with the mathematically related conceptual work in which tectonic movements are shown to be a derivative of the forces associated with the rotation of the Earth. There is a noticeable absence of published work on this aspect of tectonic movements.

Illustrations

As this is a zero-profit publication, use has been made of information gleaned from published NASA publications and those of the Geological Society as published on the internet and displayed by Google. Once again, most of the illustrations seem to be been repeatedly copied with minor variations by different educational and scientific organisations.

The author made several attempts (without success) to get permission for reproducing some of the illustrations dealing with the plotted motions of unbalanced shafts.

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This work explores the nature and origin of the forces responsible for the unrelenting unidirectional movements of continental sized masses away from what was Pangea c. 275 Ma years ago to their present positions.

The analysis given demonstrates that the forces responsible for tectonic movements are related to the rotational velocity of the Earth which is dependent on the Sun's gravitational pull on the asymmetrical positioning of the Earth's centre of mass.

The resultant unbalanced rotation gives rise to the Earth's wobble and the significant circumferential forces that move the continental masses. It is these tectonic movements in which continental and oceanic crusts are continuously forced into the mantle, that forever ensures that the lithosphere is recycled and regenerated.

Furthermore, the offset 'centre of mass' gives rise to the generated and tilted N-S principal axis of rotation that applies to all the planets. This action also yields a viable explanation regarding why all the planets (Venus apart) rotate in the same direction as the Sun.

To understand something,
you must be able to measure it" — Anon