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THE DYNAMICS OF AFRICA AND SOUTH-AMERICAN PLATE BOUNDARYFROM PAST SEISMIC EVENTS.

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Abstract

This paper titled, "The dynamics of African and south-American plate boundary," discusses on plate tectonics and the type of boundary between Africa and South-American plate. A quantitative analysis was carried out with Surfer 13, Coordinate-UTM converter 1.0 and Microsoft excel 2007 softwares in determining the seismodynamics of the plates. The study covered the African plate and its boundary with South American plate and utilizes the secondary earthquake data of past events from the year 1990 to 2017. The study showed that Africa and South American plates are diverging with resultant relative motion of 17.73mm/yr at an angle of 50.52^0 due west from the year 1990 to 2000. The resultant relative motion decreases from 17.73mm/yr to 13.40mm/yr at an angle of 36.94^0 due west from the year 2000 to 2010. The research findings have shown that the current resultant relative divergence of the South American plate from the African plate has increased to 20.68mm/yr at an angle of 36.46^0 due west and the average relative motion over 30 years is 17.27mm/yr. The paper was related with previous work followed by discussions which could serve as a guide for further work.

Keywords: Africa, Dynamics, Plates, Relative, Velocity, Seismic and Tectonics

1. INTRODUCTION

The theory of plate tectonics proposes that the lithosphere is divided into eight major plates (North American, South American, Pacific, Nazca, Eurasian, African, Antarctic, and Indian-Australian) and several smaller plates (e.g., Arabian, Scotia, Juan de Fuca) that fit together like the pieces of a jigsaw puzzle. These plates are mobile, moving in constant, slow motion measured in rates of centimeters per year. The movements of plates over millions of years resulted in the opening and closure of oceans and the formation and disassembly of continents. The theory links Earth's internal processes to the distribution of continents and oceans; it is the big picture view of how Earth works [1].

The rates and directions of plate motions were originally determined by computing the distance of oceanic floor of a known age from the oceanic ridge system. Rates were computed by dividing age (years) by distance (centimeters). Such simple but effective calculations were compared to motion rates determined using the age of volcanic islands formed above mantle hot spots. Some volcanic islands in the interiors of plates form above fixed plumes of magma rising from the mantle. The locations of these mantle plumes are known as hot spots. The islands form as the plate moves over the magma source, much like a tectonic conveyer belt. Islands are progressively older with increasing distance from the hot spot. The relationship between age and distance yields the rate of plate motion [2].

The dynamic processes taking place within the earth are manifested on the plates through various means, namely: volcanic eruptions, earthquakes, tremors for example the Kaduna 2016 tremors which affected about 300 houses [3] also, BBC reported that, Kenya 2018 rift is an indication of the strong diverging forces splitting the plate as the depth reach several

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kilometers, ocean flow changes, mineral resources creation and other geologic structures creates seismic plate motions and other hazardous consequences [4]. In the past, scientist employs few locations as their data sources. Nowadays, with advent of computers and satellites, the technology has made data available at global scale through the use of observatories. The introduction of cloud computing has greatly enhanced the interoperability of information and software utility such that nowadays data are available in well processed form in such a way that they can be directly interpreted at various scales to generate understanding of an activity or process(es). There are various types of observatories typically: magnetic observatories, seismic observatories, helio observatories etc. For this study, the data from seismic observatories (United State Geologic Survey) was utilized. The negative repercussion of the dynamical process of the plates is enormous as generally there is no region which is hundred percent free from earth shake, 2016 Kaduna tremor [3] is a good example and thus the dare need to follow-up studies at various scales.

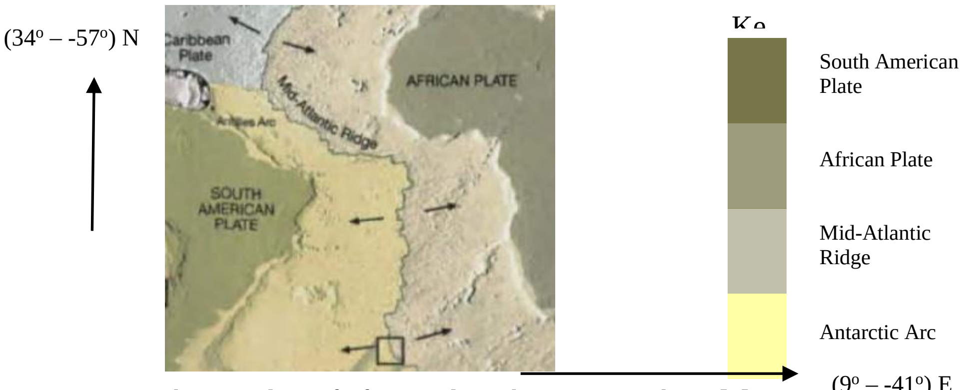

Figure 1; The Boundary of Africa and South-American Plates [5]

2. METHOD

Within the scope of this work, a secondary (processed) earthquake data was acquired through the net from Seismic Observatories (United State Geologic Survey) for Africa and that of the South-America and African plate boundary from the year 1990 to 2017 and utilized. The data comprised of the date of occurrence, place of occurrence, time, latitude, longitude, depth and magnitude of the earthquake event.

The data was sourced from the United State Geologic Survey Agency (USGS), the International Seismological Center (ISC), National Geophysical Data Center and African Array Network through the Internet [6].

The data for this study was processed and analysed using a geophysical software SURFER 13 and EXCEL 2007 for plotting maps and tabulating the data respectively. In order to estimate the quantitative relative movement of the African plate along its boundaries, the coordinates (latitudes and longitudes) were converted to UTM (Universal Transverse Mercator) using the software UTM-Coordinates converter 1.0. This allows for the conversion of coordinates in degrees to distances in meters. The software reads from the spread sheet and takes the values in X as longitudes, Y as latitudes and Z takes the magnitude values of the earthquake respectively.

The plot of the relative motion of Africa and South-American plate was achieved by takinginterval of ten years earthquake data from 1990-2017 and classed 1, 2 and 3 respectively. Surfer 13 was used to plot the contour map taking the classed values as the Z-values.

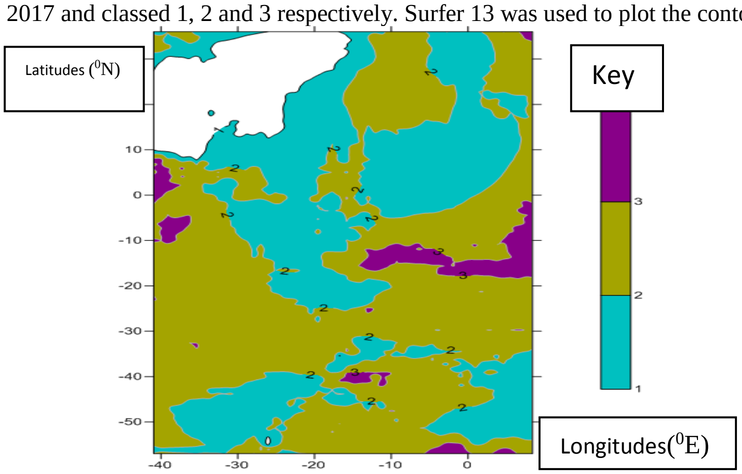

Figure 2; Relative motion of African plate with South-American plate [7] where the keys 1 to 3 are in the period range of ten years from 1990 to 2017 accordingly. From Figure 2 above, 1 shows the relative velocity from 1990-2000, 2 shows the relative velocity from 2000-2010 and 3 shows the relative velocity from 2010-2017.

The relative velocity is a quantity involving distance and time. Hence, the relative velocity cannot be easily measured from the Figure 2 and therefore some conversions have to be made at this point.

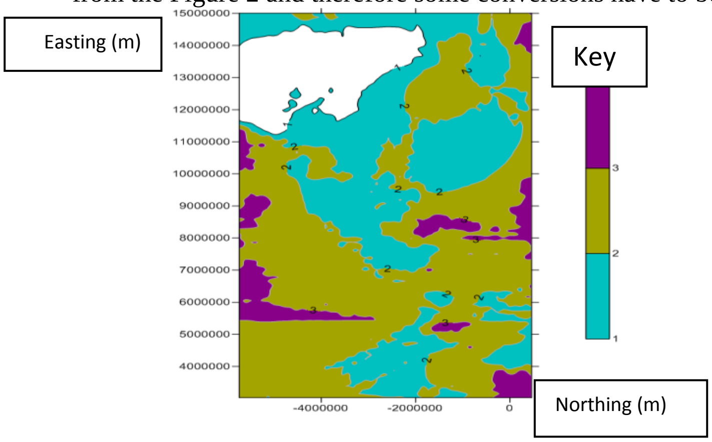

Figure 3; Africa South-American relative velocity with converted coordinates (universal transverse marcator) [7].

where the keys 1 to 3 are in the period interval of ten years from1990 to 2017 accordingly.

The coordinates were converted to Universal Transverse Marcator which takes the units of meter for easy quantifying the relative motion and a new map in Figure3 was plotted with the UTM values.

From the map in Figure 3, eighteen (18) different profiles were taken out of which nine profiles are horizontal and the other nine profiles are vertical. Three different profiles from the first, second and third ten (10) years was taken for both the horizontal and vertical respectively. The average of each three slopes for ten years interval was taken and tabulated to obtain the relative velocity.

Slope was taken from each of the profiles as follows;

$$slope = \frac{\Delta y}{\Delta x} \quad (1)$$

Determination of the Angular Direction of Relative Velocity

Equation 1 was applied to both the horizontal and the vertical profiles obtained from Figure 3 in analyzing the slope after which the results of the horizontal and vertical relative motion of the Africa and South-American plates were obtained and presented in Table 1, Average of each three slopes of three consecutive profiles was taken. The reciprocal of the averages was taken and the values of the relative velocity were obtained and presented in Table 2.

To determine the direction of relative velocity of the plates, we name the horizontal relative velocities as V_{x1}, $V_{x2}$and V_{x3} respectively and that of the vertical relative velocities as V_{y1}, V_{y1} and V_{y3} respectively.

Therefore,

V_{x1} = 18.38mm/yr V_{y1} = 22.32mm/yr

V_{x2} = 22.19mm/yr V_{y2} = 16.68mm/yr

V_{x3} = 34.22mm/yr V_{y3} = 25.29mm/yr

Two vectors pointing in different directions are said to obey the following relation which is used for calculating the angle between them [8].

$$\tan\theta = \frac{V_y}{V_x} \quad (2)$$

From which the angle θ was made to be the subject of the equation and was determined as [8];

$$\theta = \tan^{-1}\frac{V_y}{V_x} \quad (3)$$

Where, V_x and V_y are the horizontal and the vertical relative velocity of the plate respectively.

Determination of the Resultant Relative Motion

The resultants of the horizontal and the vertical relative velocity were calculated using the parallelogram law of vector resolution which was presented in the following mathematical relation [8];

$$V^2 = V_x{}^2 + V_y{}^2 - 2V_xV_y\cos\theta_n \quad (4)$$

Where V_1, V_2 and V_3 are the resultants of the relative velocities of the plates, θ is the angle of relative velocity and n is an integer while V_x and V_y are the horizontal and the vertical relative velocities respectively. The results of the calculated angles of the relative velocity and the resultants of the horizontal and the vertical relative velocities of the Africa and South-American plate were presented [8].

3. RESULTS AND DISCUSSION

Table1 is for the horizontal relative velocity of Africa and South-American plate. Nine horizontal profiles named A to I were taken from Figure 3 where the profiles A, B and C were taken from the contour of the data from 1990 to 2000. Profiles D, E and F were taken from the contour of 2000 to 2010 and the profiles G, H and I were taken from contour of 2010 to date. On the third column is the slope taken from each profile and the average of every three profiles are taken on the fourth column. The reciprocal of the average yields the horizontal relative velocity of the two plates.

Table1; Horizontal Relative Motion of Africa and South-American Plate

Horizontal Profiles					
S/N	Profile	Slope (yr/m)	Average (yr/m)	$V = \frac{1}{Average}$ (μm/yr)	$\frac{V}{1000}$ (mm/yr)
1	A	2.535×10^{-5}	1.305×10^{-4}	18376.72	18.38
2	B	3.290×10^{-5}			
3	C	1.050×10^{-4}			
4	D	4.615×10^{-5}	4.506×10^{-5}	22192.63	22.19
5	E	4.286×10^{-5}			
6	F	4.615×10^{-5}			
7	G	4.110×10^{-5}	2.922×10^{-5}	34223.13	34.22
8	H	3.530×10^{-5}			
9	I	1.125×10^{-4}			

Table 2 is for the vertical relative velocity of Africa and South-American plate. Nine horizontal profiles named J to R were taken from Figure 3 where the profiles J, K and L were taken from the contour of the data from 1990 to 2000. Profiles M, N and O were taken from the contour of 2000 to 2010 and the profiles P, Q and R were taken from contour of 2010 to date. On the third column is the slope taken from each profile and the average of every three profiles are taken on the fourth column. The reciprocal of the average yields the horizontal relative velocity of the two plates.

Table 2; Vertical Relative Motion of Africa and South-American Plate

Vertical Profiles					
S/No	Profile	Slope	Average	$V = \frac{1}{Average}$ (μm/yr)	$\frac{V}{1000}$ (mm/yr)
1	J	4.494×10^{-5}	4.480×10^{-5}	22321.43	22.32
2	K	2.424×10^{-5}			
3	L	6.522×10^{-5}			
4	M	4.000×10^{-5}	5.996×10^{-5}	16677.79	16.68
5	N	4.898×10^{-5}			
6	O	9.091×10^{-5}			
7	P	5.217×10^{-5}	3.954×10^{-5}	25290.84	25.29
8	Q	3.158×10^{-5}			
9	R	3.488×10^{-5}			

Table 3 contain the directions of the relative velocity of the two plates which was obtained by applying equation 3 to the values in columns 2 and 3. The directions were obtained in the unit of degrees due west in an interval of ten years.

Table 3; Directions of Relative Motion of the Plates

Year	V_x (mm/yr)	V_y (mm/yr)	$V_y \div V_x$	Angle θ (degree)
1990	18.38	22.32	1.214	50.52
2000	22.19	16.68	0.752	36.94
2010	34.22	25.29	0.739	36.46

Table 4 contain the total relative motion of the South-America from the African plates which was obtained by applying equation 3 to the values of the horizontal and vertical relative velocities in Table 1 and Table 2 with the directions obtained in Table 3. The total relative velocities were obtained in the unit of mm/yr in an interval of ten years.

Table 4; Resultant Relative Motion of Africa and South-American Plate

Year	V_x (mm/yr)	V_y (mm/yr)	Angle θ (degree)	Resultant relative velocity (mm/yr)
1990	18.38	22.32	50.52	17.73
2000	22.19	16.68	36.94	13.40
2010	34.22	25.29	36.46	20.68

4. DISCUSSIONS

The results derived from geological data show that the half-spreading rate between the Africa-South American plate was relatively at 2cm/year over the past 80million years[9].

Jin and Zhu (2004) in their work however, re-estimated a new relative angular velocity of Africa-South American plate using the selected space geodetic station data through a new method. They found that, the angular velocity of the spreading Africa-South American plate over several years are similar in azimuth but significantly slower in rate than the NUVEL-1A (reference frame) predictions averaged over the past three million years. The implied rates of deceleration coincide with longer-term trends over the past 35million years and may reflect the effects of plate interactions and coupling of the two plates [10].

The motions of tectonic plates are well established components of plate tectonic theory. Yet, the manner in which plates interact, specifically how the forces driving adjacent plates are coupled to each other, is still uncertain. Plate interaction is most clear at a convergent margin. In a continent-continent collision, the leading edges of both plates are deformed and the velocities of both are constrained to be the same. Subduction represents a more subtle plate interaction, in which the overlying plate is deformed (producing marginal basins or cordilleran structures), although plate velocities are not obviously affected. Our interest in plate interactions for Atlantic basin plates is motivated by the issue of cordillera formation along the western edge of the American plates, and its relation to the forces responsible for South American Plate motion. It was suggested that Andean deformation is a result of the westward velocity of South America and the resistance to that motion by a more slowly retreating subducting Nazca slab.

For this work, geologic reference frame was adopted for it allows the estimation of the relative motion of two plates within a shorter range of years. The result of the work revealed the average rate of relative motion of the Africa-South American plate to be 17.27mm/year. This slow rate of the Africa-South American plates was due to spreading of the Africa-Nubian plate and the contraction of Africa and Europe.

5. CONCLUSION

From the results analysed in Table 4, it is concluded that, the South American plate has been diverging (moving away) relative to the African plate with a velocity of 17.73mm/year at an angle of 50.52^0W for the past thirty years. And in the past twenty years, the relative velocity decreases to 13.40mm/year at an angle of 36.94^0W. Also, from the result in the last ten years to date, shows that the relative velocity of the plate increases to 20.68mm/year at an angle of 36.46^0W and the average relative velocity of South-America from the African plate from 1990 to date is 17.27mm/year.

Therefore, the relative velocity of lithospheric plates is always dynamic and is responsible for the tectonic activities occurring on the plate and along the boundaries such as earthquakes and occurrence of volcanoes, collision zones and rifts on the continent and strike slip faults, oceanic ridges and trenches on the oceanic lithosphere. It could be said that, seismotectonic method provides a good reference for current and future studies of geodetic phenomena and geophysical processes along the Africa-South American plate boundary.

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