Geodynamics - Homework 1

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August 2016

All problems extracted from Turcotte et al. [2002]

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1.1 Problem 1.4

First, the radius that should be taken is the located in the core - mantle boundary:

$$r_{mcb} = 6371Km - 2891Km = 3480Km \tag{1}$$

Then:

$$|\vec{B}| = \frac{\mu_0.m}{4\pi r_{mcb}^3}(1 + 3\cos^2(\theta_m))^{\frac{1}{2}}) \tag{2}$$

$$\frac{dB}{d\theta} = \frac{\mu_0.m}{4\pi r_{mcb}^3}\frac{1}{2}(1 + 3\cos^2(\theta_m))^{\frac{-1}{2}})(-6)\cos(\theta_m)\sin(\theta_m) \tag{3}$$

$$\frac{dB}{d\theta} = (-3)\frac{\mu_0.m}{4\pi r_{mcb}^3}\frac{\cos(\theta_m)\sin(\theta_m)}{(1 + 3\cos^2(\theta_m))^{\frac{-1}{2}}} = 0 \qquad \theta_m \in ((2n+1)\frac{\pi}{2} \ \cup \ (n\pi)) \tag{4}$$

Then: If $\theta_m = 0$:

$$|\vec{B}| = \frac{\mu_0.m}{2\pi r_{mcb}^3} = 380 \ \mu T \tag{5}$$

1.2 Problem 1.18

In order to calculate the relative plate velocity between the Nazca plate an South American plates at Lima, we have to localize the rotation pole:

$$Nazca - SouthAmerica = 56^oN, -94^oE \qquad Lima, Peru = 12^oS, 77^oW \tag{6}$$

Also we know that the angular velocity of the plates is:

$$\omega = 0,72 \ deg/Myr = 12,5 * 10^{-3} \ rad/Myr \tag{7}$$

Using the formula 1.18 given in the book we can calculate Δ but first we have to fund the lineal velocity and we need to recalculate the poles to north latitude and East longitude.

$$v = w * r * \sin\Delta \tag{8}$$

$$[\cos(\Delta) = \cos\theta\cos\theta^{'} + \sin\theta\sin\theta'\cos(\phi - \phi')] \tag{9}$$

$$\theta = 34^o \quad \phi = -94^o \quad \theta^{'} = 102^o \quad \phi^{'} = 283^o \tag{10}$$

$$[\cos(\Delta) = \cos(31)\cos(102) + \sin(34)\sin\theta(102)\cos(-0.94 - 283)] \tag{11}$$

$$\Delta = 69,47^o \tag{12}$$

$$v = 74,58mm/yr \tag{13}$$

Finally we calculate the direction of the vector

$$\beta = \frac{\pi}{2} + \arcsin(\frac{(\cos\lambda_p\sin(\theta_p - \theta))}{(\sin\Delta)}) \tag{14}$$

$$\beta = \frac{\pi}{2} + \arcsin(\frac{(\cos(56)\sin(-266 - 283))}{(\sin 69.47)}) \tag{15}$$

$$\beta = 95.36^o \tag{16}$$

1.3 Problem 1.22

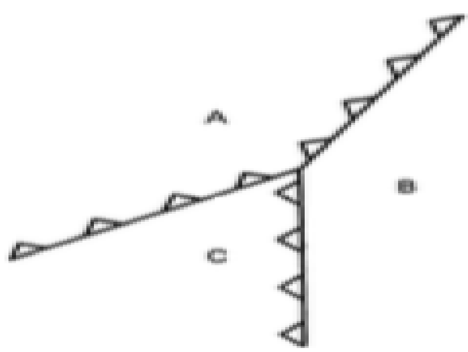

Figure 1: Triple junction problem 1.22

For solve this problem, we have to make a vectors diagram give in the Figure 2.

Then, we can calculate the magnitude of the velocity vector, using the cosine law:

$$|V_{CB}| = (50^2 + 60^2 + 2(50)(60)\cos(45))^{\frac{1}{2}} \tag{17}$$

$$|V_{CB}| = 43.1\ mm/yr \tag{18}$$

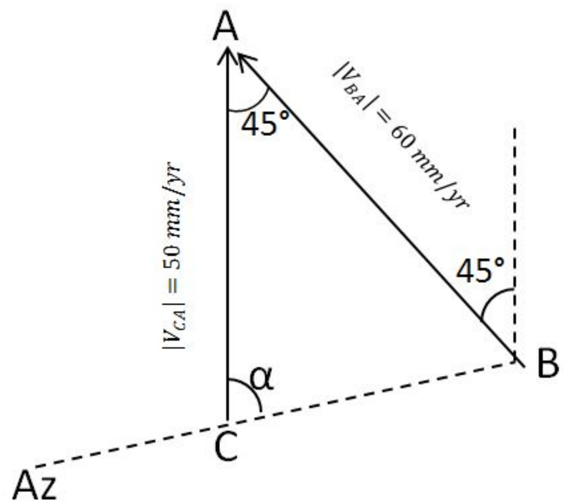

Figure 2: Vectors diagram

The azimuth can be calculated with de sine law, then:

$$Az = 180^o + \alpha \tag{19}$$

$$\alpha = \arcsin\left(\frac{60 \sin 45}{43.1}\right) \tag{20}$$

$$Az = 180^o + 79.86^o = 259.86^o \tag{21}$$

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2.1 Problem 1.13

The surface distances between the Earth's magnetic poles and geographic poles are:

North: 1890.31 Km
South: 2446.29 Km

All the equations are in the following link: `https://github.com/dforero0896/Geodynamics/blob/master/HW1/Tarea_1_Geodinamica.ipynb`.
This problems have been programmed in Python 2.7 whithin the IPython Notebook environment.

2.2 Problem 1.15

The distance between the paleomagnetic poles obtained from North American and European rocks as a function of time, could be plotted like:

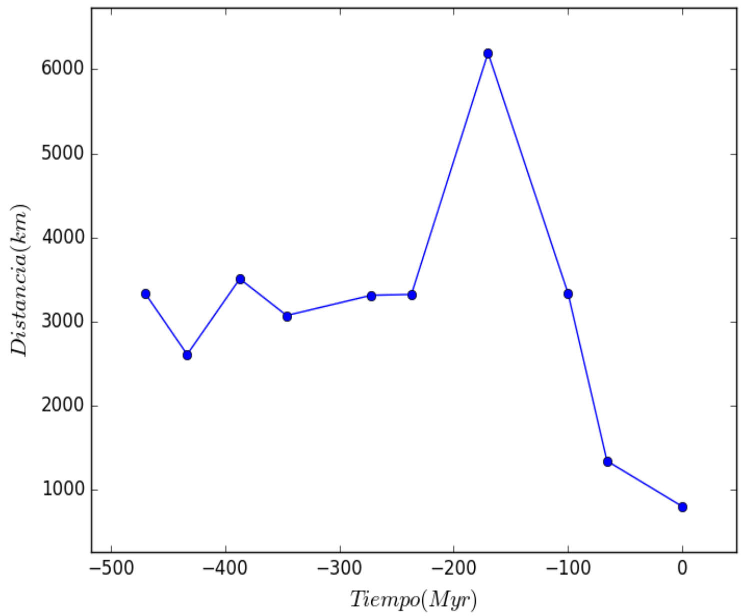

Figure 3: Distance between North magnetic poles measured in Europe and North America

It should be noticed that distance appears to remain constant, close to 3000 km up until around -200 Myr which seems to correspond to the Triassic. After, in the Jurassic was the Geologic period in which the Laurasia continent started to separate from North America and Europe. Then, though poles seem to be coming closer, this actually means that they are approaching their current position, so Laurentia and Eurasia are actually seaprating from each other. Also, we can see that between -500 Myr and around -200 Myr the distance is near to be constant. This event, could be explained by the presence of the rocks in the same location.
The graph is strong evidence in the side of continental drift showing how pole positions measured from the different continents vary with time reaching the current position.

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In order to calculate the relative plate velocity between the Nazca plate an South American plates at Sierra Negra, we have to localize the rotation pole:

$$Nazca - SouthAmerica = 56^oN, -94^oE \qquad SierraNegra = 18.98^oN, -97.32^oE \tag{22}$$

Also we know that the angular velocity of the plates is :

$$\omega = 0,72 Deg/Mgr = 12,5 \times 10^{-3} rad/Myr \tag{23}$$

$$\theta = 34^o \quad \phi = -94^o \quad \theta^{'} = 71.02^o \quad \phi^{'} = -97.32^o \tag{24}$$

Using equation 9:

$$\Delta = 37.1^o \tag{25}$$

$$v = 47.93 mm/yr \tag{26}$$

The azimuth could be calculated with the equation 14, then:

$$\beta = \frac{\pi}{2} + \arcsin(\frac{(\cos(56)\sin(-266 - 262.68))}{(\sin 37.1)}) \tag{27}$$

$$\beta = 79.51^o \tag{28}$$

Based on this Azimuth and velocity, we can conclude that the Galapagos islands will collide with the South american continent approximately at the boundary between Ecuador and Colombia, at the coordinates $1^o N \quad 78^o W$.

If we calculate the distance between Galapagos and the point given, we can see that the time could be calculated like:

$$\Delta = 0,244 \ rad \tag{29}$$

$$s = \Delta * r = 1555,62 Km \tag{30}$$

$$time = \frac{1555,62 \ Km}{47,93 \ Km/Myr} = 32,46 \ Myr \tag{31}$$

These calculations might differ from what will actually happen as we are assuming that one of the two plates is static in order to make them. Also, the subduction between this two plates could affect the colission.

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Plates	Velocity (mm/yr)	Azimuth (^{o})
Cocos-Nazca	39.52	8.90
Nazca-Pacific	124.63	98.14
Cocos-Pacific	129.1	80.86

Table 1:
Velocities and azimuths calculated using spherical trigonometry.

Furthermore, when we calculated Cocos and Pacific velocity and Azimuth by means of flat trigonometry we are able to find that the velocity of the plates is 130.25 mm/yr and azimuth is equal to 115.8 ^{o}. At first glance it's easy to notice that the speeds obtained with the different methods are quite similar, as expected. As we can see, the only variable that change is the Azimuth. This could be explained by the conversion between the 2D geometry and spherical geometry.

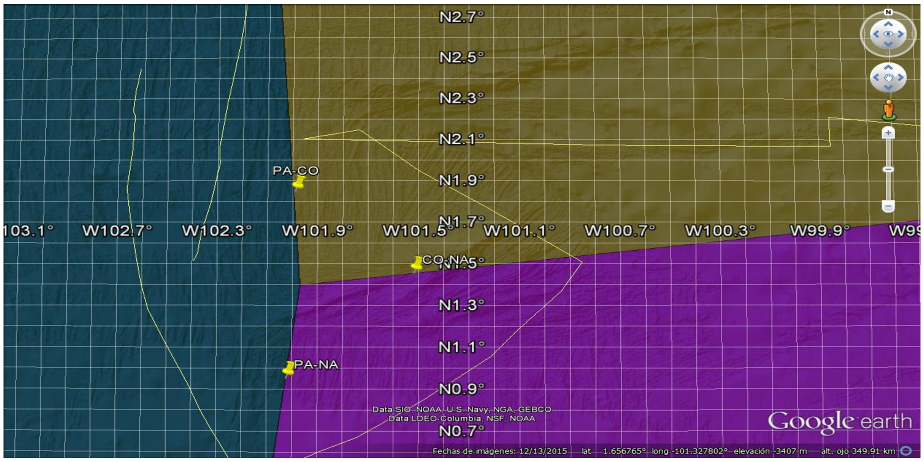

Figure 4: Triple junction problem 1.22

References

Donald Lawson Turcotte, Gerald Schubert, and Donald Lawson Turcotte. *Geodynamics*. Cambridge University Press, 2002.