Exam *Geodynamics* course (Part II) ; 15-04-2013
Teachers: Spakman & van Hinsbergen.

- *Write clearly. If we cannot read it, we cannot judge it!*
- *You may answer in Dutch or English.*
- ***Be extensive** in presenting your argumentation using scientific reasoning such that you demonstrate your understanding of the subjects.*
- *All 4 questions are of equal weight*
- *There is one **bonus question.** This may only help those that did not score sufficiently on the first 4 questions.*

Question 1 *(10 points)*:
This question concerns the general scientific reasoning underlying delay-time (or travel-time) tomography. Four basic tomography steps lead from observation to Earth model. This is schematically displayed in the figure below and was presented in detail during the course.
Discuss in a schematic way the assumptions and approximations involved in these steps. You can use formulas to illustrate your analysis.

Tomography steps (schematically)

~20 million integral equations (source-station rays) $d_i = \int_{L_i} \Delta s \, dl + \ldots \quad i = 1, \ldots, M_{ray}$

⇩

Mantle model parameterization (e.g. ~ 400,000 cells)

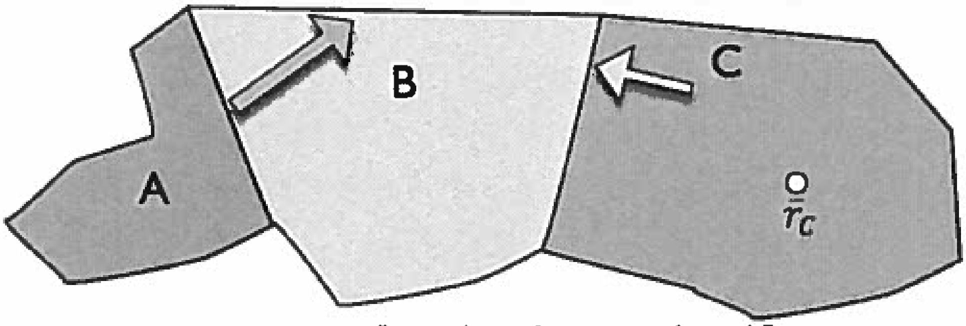
⇩

Forward problem: Matrix equation: $\mathbf{Am} = \mathbf{d}$

⇩

Inverse problem for model **m**: $\mathbf{m} = \mathbf{A}^{-}\mathbf{d}$
(iterative regularized Least Squares using CG)

Question 2 *(10 points)*:
Usually we only know the relative motion between adjacent plates. Consider 3 plates A, B, and C. Arrows indicate the relative motion of that plate relative to the adjacent plate (to the left).
Explain the equation below the figure and how we can derive this equation (all symbols are as used in course-materials).



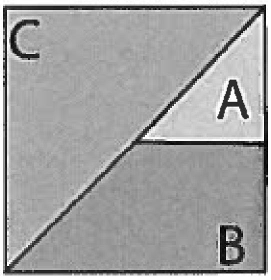
$$\bar{r}_{AC} = \bar{r}_{AB} + \bar{r}_{BC} = [\boldsymbol{R}_{AB}(\Omega_{AB}) + \boldsymbol{R}_{BC}(\Omega_{BC})]\bar{r}_C$$

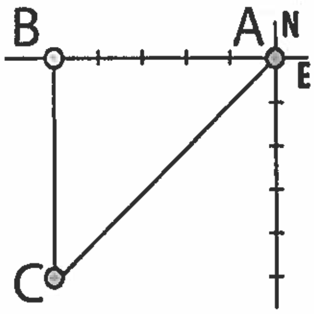
Question 3 *(4 + 4 + 2 points)*:

a) Plate rotations are described by rotations about an Euler pole somewhere on the globe. Paleomagnetic data record motions of plates with respect to the Earth's dynamo, which coincides with the North pole. Paleomagnetic vectors have a deviation from the North (or South) pole, known as declination: if the declination measured in a rock is pointing to 030° that means that that rock has undergone a vertical-axis rotation component of 30° clockwise. The deviation of the paleomagnetic vector from the Earth's surface is known as the inclination and is a measure of latitude (vertical at the poles, horizontal at the equator).
Suppose that a plate rotated over 30° clockwise around an Euler pole between two moments in time, e.g. 50 and 20 Ma. You have obtained an excellent paleomagnetic record from a section of rocks on that plate, the lower part of that section being 50 Ma old, and the upper part 20 Ma old.

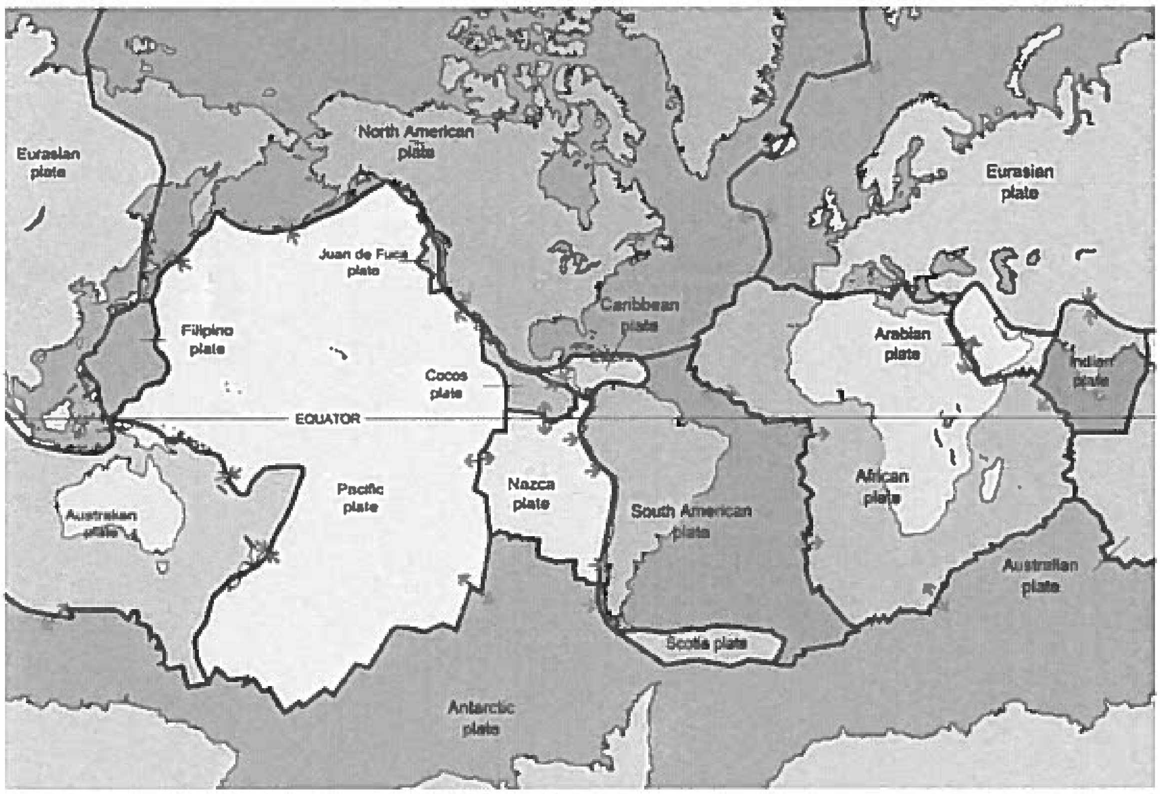
What is the difference between these paleomagnetic vectors if
I) the Euler pole is located at the equator, and your section is located exactly at that Euler pole?
II) the Euler pole is located at the north pole, and your section is located exactly at that Euler pole?
III) the Euler pole lies at the South Pole and is located 90° away from your section?
III) the Euler pole lies at the equator and is located 90° due west of your section at 50 Ma?

b)





Consider the plates above, and the associated velocity diagram. Indicate the nature of the plate contacts. Indicate the different options for subduction polarity. Do all options lead to a stable triple junction ABC



c)

A Mexican geologist wants to know the rate of subduction of the Cocos plate below the North American plate since, say, the Miocene. He or she has access to all magnetic anomalies and fracture zone patterns of the world's oceans. Which plate circuit should he build?

Question 4 *(10 points)*:

A paleoceanographer studies the influence of insolation of the sun on the Earth's surface on paleoceanographic currents. He wants to calculate whether paleobathymetry changes as a result of dynamic topography may influence these currents in the Early Cenozoic (55 Ma), in the Jurassic (190 Ma), and in the Carboniferous (320 Ma). He realizes that dynamic topography is a result of mantle flow (e.g. due to sinking slabs below his oceanic plates, or rising plumes), and he has a method to calculate dynamic topography from mantle tomography throughout the plate circuit he has at his disposal.
In which reference frame(s) should he calculate the dynamic topography and the insolation effects?

Question 5 *(bonusquestion, 2 points)*:

What process is Earth undergoing to annoy this poor field geologist?