Übung 29.10.2009

Exercises on Plate Motions

The surface plates are rigid to a first approximation and are in relative motion with respect to each other. The relative motion between two adjacent rigid plates can be described by Euler's theorem. The theorem states that any line on the surface of a sphere can be translated to any other position and orientation on the sphere by a single rotation about a suitably chosen axis passing through the center of the sphere. In terms of the Earth this means that a rigid surface plate can be shifted to a new position by a rotation about a uniquely defined axis. The point where this axis intercepts the surface of the Earth is known as the pole of rotation. This is illustrated in Figure 2.28, where plate B is rotating counterclockwise with respect to plate A at the angular velocity ω about the pole of rotation P. Ridge segments lie on lines of longitude emanating from the pole of rotation. Transform faults lie on small circles with their centers at the pole of rotation.

The relative motion between two adjacent plates is completely specified when the latitude and longitude of the pole of rotation together with the angular velocity of rotation are given. These quantities for the NUVEL-1 model of DeMets et al. (1990) are given in Table 1. The plate geometry upon which this model is based consists of the 12 rigid plates illustrated in Figure 2.29. The plate rotation vectors are also shown. The best-fitting plate rotation vectors in this model were obtained using 1,122 data points from 22 plate boundaries. The data include 277 spreading rate determinations based on magnetic anomalies. An example of the magnetic profiles for the spreading boundary between the Cocos and Pacific plates is given in Figure 2.30. The NUVEL-1 model also uses 232 transform fault azimuths and 724 earthquake slip vectors. The authors found, however, that earthquake slip vectors at ocean trenches systematically misfit whenever convergence is oblique.

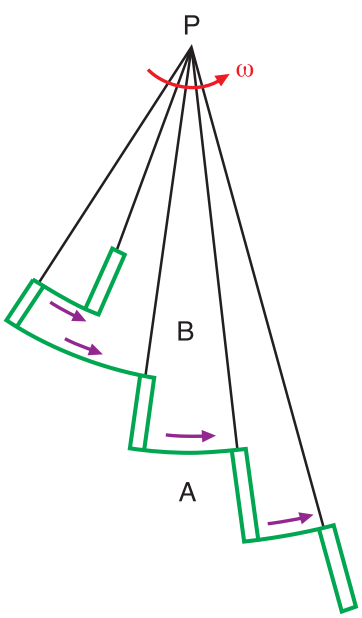


Illustration of Euler's theorem. Plate B is moving counter- clockwise relative to plate A. The motion is defined by the angular velocity ω about the pole of rotation P. Double lines are ridge segments, and arrows denote direction of motion on transform faults

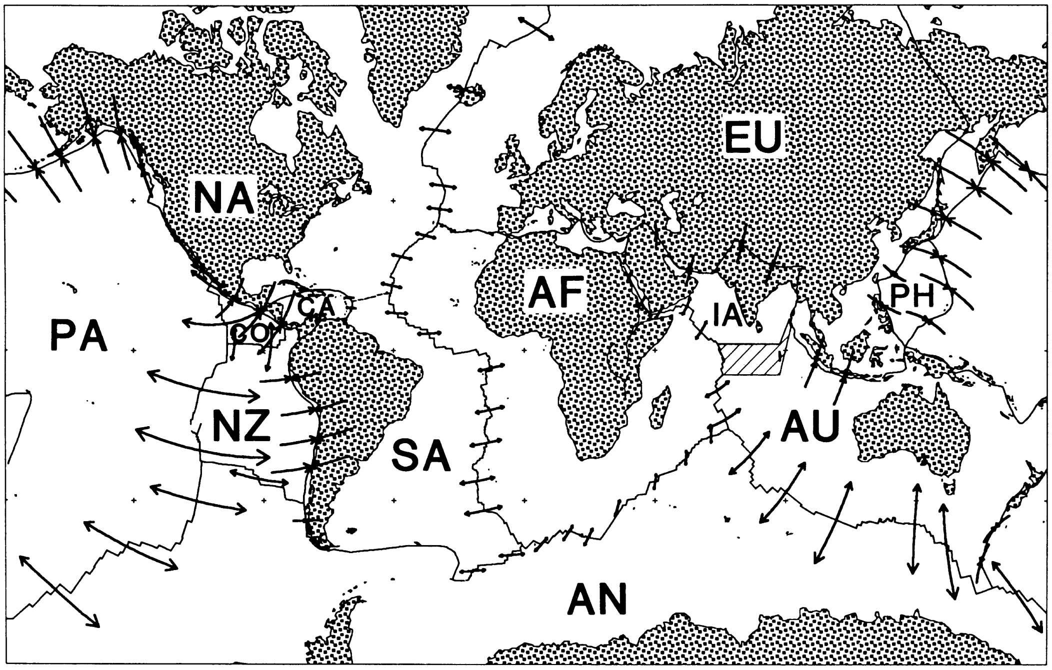
Revisions to the geomagnetic time scale have necessitated some recalibration of the NUVEL-1 global plate motion model. The changes consist largely in a reduction of the angular velocities. The revised plate motion model is referred to as NUVEL-1A (DeMets et al., 1994). Angular velocities for model NUVEL-1A are given in Table 1.

Table 1. Euler Vectors for Pairs of Plates Sharing a Boundary Based on the NUVEL-1 Model of DeMets et al. (1990) and the NUVEL-1A Model of DeMets et al. (1994);the First Plate Moves Counterclockwise Relative to the Second Plate

Plate Pair	**Latitude (°N)**	**Longitude (°E)**	**ω, NUVEL-1 (deg Myr^{-1})**	**ω, NUVEL-1A (deg Myr^{-1})**
EU-NA	62.4	135.8	0.22	0.21
AF-NA	78.8	38.3	0.25	0.24
AF-EU	21.0	−20.6	0.13	0.12
NA-SA	16.3	−58.1	0.15	0.15
AF-SA	62.5	−39.4	0.32	0.31
AN-SA	86.4	−40.7	0.27	0.26
NA-CA	−74.3	−26.1	0.11	0.10
CA-SA	50.0	−65.3	0.19	0.18
NA-PA	48.7	−78.2	0.78	0.75
CO-PA	36.8	−108.6	2.09	2.00
CO-NA	27.9	−120.7	1.42	1.36
CO-NZ	4.8	−124.3	0.95	0.91
NZ-PA	55.6	−90.1	1.42	1.36
NZ-AN	40.5	−95.9	0.54	0.52
NZ-SA	56.0	−94.0	0.76	0.72
AN-PA	64.3	−84.0	0.91	0.87
PA-AU	−60.1	−178.3	1.12	1.07
EU-PA	61.1	−85.8	0.90	0.86
CO-CA	24.1	−119.4	1.37	1.31
NZ-CA	56.2	−104.6	0.58	0.55
AU-AN	13.2	38.2	0.68	0.65
AF-AN	5.6	−39.2	0.13	0.13
AU-AF	12.4	49.8	0.66	0.63
AU-IN	−5.6	77.1	0.31	0.30
IN-AF	23.6	28.5	0.43	0.41
AR-AF	24.1	24.0	0.42	0.40
IN-EU	24.4	17.7	0.53	0.51
AR-EU	24.6	13.7	0.52	0.50
AU-EU	15.1	40.5	0.72	0.69
IN-AR	3.0	91.5	0.03	0.03

Abbreviations: PA, Pacific; NA, North America; SA, South America; AF, Africa; CO, Cocos; NZ, Nazca; EU, Eurasia; AN, Antarctica; AR, Arabia; IN, India; AU, Australia; CA, Caribbean. See Figures 2.1 and 2.29 for plate geometries.

Exercise 1



We assume that the entire relative velocity between the rigid Pacific and North American plates is accommodated on the San Andreas fault.

a) What kind of movement is it?

b) From the NUVEl-1 model, determine the relative velocity $\mathbf{u_{rel}}$ along the fault at San Francisco (37.8°N, 122°W).
Knowing

$$u_{rel} = \omega^{'} \cdot a \cdot sin\Delta$$

$$cos\Delta = cos\Theta \cdot cos\Theta' + sin\Theta \cdot sin\Theta' \cdot cos(\Psi - \Psi')$$

with ω' is in radian per unit time, a earth's radius (6370 km), and Θ & Θ' colatitude, Ψ & Ψ' east longitude.

Exercise 2:

Reconstruction of the movement of India

a) Where was India at 52 Ma and 92 Ma?

b) Determine the position of the different pole of rotation

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