ON THE WESTWARD DRIFT OF THE LITHOSPHERE

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There have been a number of papers describing the westward drift of the lithosphere relative to the mantle (e.g., Bostrom, 1971), which is proven by independent data sets such as the hotspot reference frame (e.g., Ricard et al., 1991), space geodesy and asymmetries of subduction and rift zones (Doglioni et al., 1999; 2003). Gripp and Gordon (2002) computed an average net rotation of the lithosphere of up to 4.9 cm/yr, using classically accepted hotspot reference frame.

There still are doubts about 1) what is generating the westward drift, and 2) whether it affects the entire lithosphere or it is rather only a mean value, with most of the lithosphere moving "west" due to the dominant effect of the Pacific plate, but part of it still moving in the opposite direction relative to the mantle.

Paradoxically, the hotspot reference frame in which the westward drift was originally computed, is the strongest limitation to the westward drift itself. In fact there are plates that move eastward relative to hotspots, suggesting a mantle moving westward, such as the Nazca plate. However plates, which would move eastward relative to hotspots, they still move westward relative to Antartica (Knopoff and Leeds, 1972).

We question the hotspot reference frame because it includes volcanic tracks permanently located on ridge zones that are detached from the underlying mantle by kinematic constraints. It is evident that oceanic ridges surrounding Africa moved away from the craton during the opening of the Atlantic and Indian oceans. This indicates that hotspots steadily located on oceanic ridges cannot be considered as fixed with respect to any global reference frame. Moreover there are a number of growing evidences suggesting that the so-called hotspots on which the 'absolute' plates motion has been computed, are rather superficial features, sourced either from the asthenosphere, or the lithosphere base itself (Bonatti, 1990; Smith and Lewis, 1999; Anderson, 2000; 2001; Harpp et al., 2002), possibly unrelated to deep mantle sources.

Therefore the asthenospheric or lower lithospheric mantle sources are unfixed relative to each other, and the hotspots appear not be a suitable reference frame for plates motion. When recomputed the westward drift disregarding those hotspots (e.g., Africa, Galapagos, Easter Island, etc.), the net rotation is affecting the whole lithosphere and it amounts to about 9 cm/yr, becoming one of the most intriguing elements of geodynamics. Moreover, geological and geophysical signatures of subduction and rift zones show a global signature, suggesting a global relative 'eastward' motion of the mantle relative to the lithosphere. Plates are moving along a sort of mainstream, which is not E-W, but it rather depicts a sinusoid (Doglioni et al., 1999). Along this flow, west-directed subduction zones are steeper than the E- or NE-directed, and the associated orogens are respectively characterized by lower structural and topographic elevation, backarc basin, and in the other side by higher structural and morphological elevation and no backarc basin. The asymmetry is striking when comparing western and eastern Pacific subduction zones, and it has usually been interpreted as related to the age of the downgoing oceanic lithosphere, i.e., older, cooler and denser in the western side. However this interpretation fails because these differences persist elsewhere regardless the age and composition of

the downgoing lithosphere, e.g., in the Mediterranean Apennines and Carpathians vs Alps and Dinarides, or in the Banda and Sandwich arcs, where even continental or zero-age oceanic lithosphere is almost vertical along west-directed subduction zones.

Rift zones are also asymmetric, being in average the "eastern" side more elevated of about 100-300 m worldwide (Doglioni et al., 2003). A test of these asymmetries is in Fig. 1 where the mean topographic and bathymetric elevations are reported for West vs East- or Northeast-directed subduction zones, and for the western and eastern flanks of rift zones.

Mantle anisotropy also provides evidence of mantle flow, e.g. beneath western North America (Silver and Holt, 2002) and beneath the southern Pacific rise (Wolfe and Solomon, 1998). Kennedy et al. (2002) have shown how mantle xenoliths recorded a shear possibly located at the lithosphere-asthenosphere interface. This supports the notion of a flow in the upper mantle and decoupling at the base of the lithosphere.

The westward drift of the lithosphere can result from the Earth's rotation (Scoppola et al., 2003) assuming three coexisting processes (Fig. 2): i.e., 1) Earth's rotation is decelerating mainly due to tidal torques; 2) The downwelling of the denser material toward the bottom of the mantle and in the core opposingly provides an acceleration of the Earth's rotation, partly counterbalancing the tidal drag; 3) The decoupling at the base of the lithosphere occurs over a convective underlying mantle, with ferromagnetic properties, where both phenomena decrease relative friction. The variable relative "westward" decoupling between lithosphere and asthenosphere may explain plate tectonics.
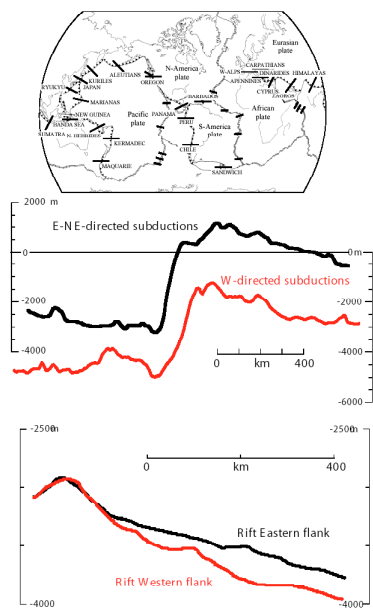

Fig. 1. Mean elevation profiles of subduction and rift zones. Both geodynamic settings show higher topography and bathymetry in the eastern or northeastern side providing evidence for a geographic polarity in global tectonics.

"westward drift of the lithosphere" = (ω2−ω1)

Breaking exerted by tidal drag slowing down Earth's rotation

ω1
ω2

LITHOSPHERE

UPPER MANTLE

-ω_1

EARTH'S ROTATION

ω

LOWER MANTLE

2890 km
3000°-4000°C

MANTLE & CORE

+ω_2

670 km

SOLID INTERNAL CORE

5150 km

LIQUID EXTERNAL CORE

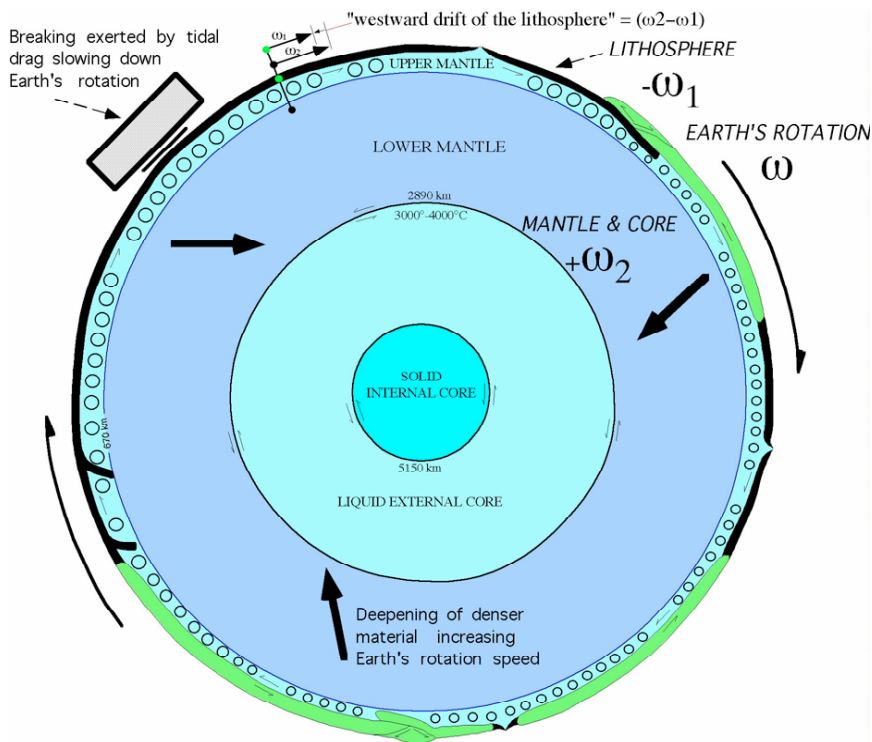Deepening of denser material increasing Earth's rotation speed

Fig. 2. Model Earth in which the westward drift is interpreted as due to different processes such as the break exerted by the tidal drag, the downwelling of heavier masses toward the interior of the Earth, and simplified rolling convection in the upper mantle related to the toroidal flow of the lithosphere. In order to decouple the lithosphere, the coexistence of these processes needs a viscosity of the asthenosphere close to the values we presently know.

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