Terrestrial Planet Hotspots and Secular Whole-Mantle Shift

Executive Summary

by Douglas W. Zbikowski

Draft 1.0 - posted 19 Dec 2012

[1]
The distribution of hotspots on Earth's surface is not random and appears from this work to contain an encrypted order. Previous theorists have proposed that mantle plumes which underlie hotspots, originate at the core-mantle boundary (CMB). The spatial-statistical method utilized here, postulates this CMB connection to infer information about outer core (OC) convection from patterns of hotspot locations. To begin, we posit a similarity between Earth's OC convection in its equatorial zone, and the general appearance of convection-cell arrays, as generated in a computer-simulated analog of the geodynamo [Glatzmaier and Roberts, 1995]. Our method borrows only the characteristics of equatorial alignment and approximate regularity of size of the modeled cells to statistically test for the probable equatorial cell size in the actual OC. The cited simulation and previous Glatzmaier & Roberts' simulations of OC convection have robustly shown a narrow equatorial zone of highest heat transfer, increased by rotational effects of the spinning planet. Thus, if plumes originate at the CMB, it is probable that they begin within this zone. The modeled cell arrays also exhibit a uniformity and apparent stability of cell size. Our method infers actual OC cell size by deriving the cell-array spacing pattern that most strongly correlates to a spherically normalized population of geocentric separation angles (GSAs) determined by each pair combination possible from a set of 49 hotspot locations.

[2]
Many of the hotspot pairs that have GSAs fitting Earth's statistically prominent array pattern (formed by ten 36° cells), occupy two location points on the surface that, when included with the center of the Earth, determine planes whose poles form a uniformly changing and apparently continuous curved path around the globe. If hotspots are rooted to plumes radially embedded in the lower mantle, such continuity of pole path suggests that the lower mantle has regularly shifted as a whole, relative to any common zone of plume initiation. Thus, it is hypothesized that the hotspot pole path reveals secular whole-mantle shifting relative to the equatorial zone of the OC and, therefore, Earth's spin axis.

[3]
When two true polar wander (TPW) paths, developed from worldwide paleomagnetic studies [Livermore, Vine, and Smith, 1984; Andrews, 1985], were plotted with this hotspot pole path, the combination appeared to collocate the dissimilar pole data into closely related spherical spirals (see Figures below). The paleomagnetic TPW poles follow a loxodromic spherical spiral that crosses all meridians at an angle of 66.5°. The hotspot poles follow a linear spherical spiral that is synchronized to, and closely overprints, the loxodromic spiral for global latitudes of +/- 70°. (This overlap zone results from using filtering windows of +/- 2.1° on the 36°-cell-array template.) Where the two pole paths separate, the lithosphere, as averaged by the paleomagnetic sample sites selected in the studies, while still riding with the lower mantle, appears to decouple from it to show additional shift. This increased effect on the *exterior* of the planet and the apparent geometrical regularity of its secular movement, hints to a celestial cause of the shifting. Because the spin axis of the Earth tilts at an angle of 23.5° from a normal to the ecliptic, an angle of 66.5° results between the axis and that plane. Therefore, because the forces of the effect seem to be consistently directed from within the ecliptic, gravitational attractions with other Solar System bodies are suspected to be involved.

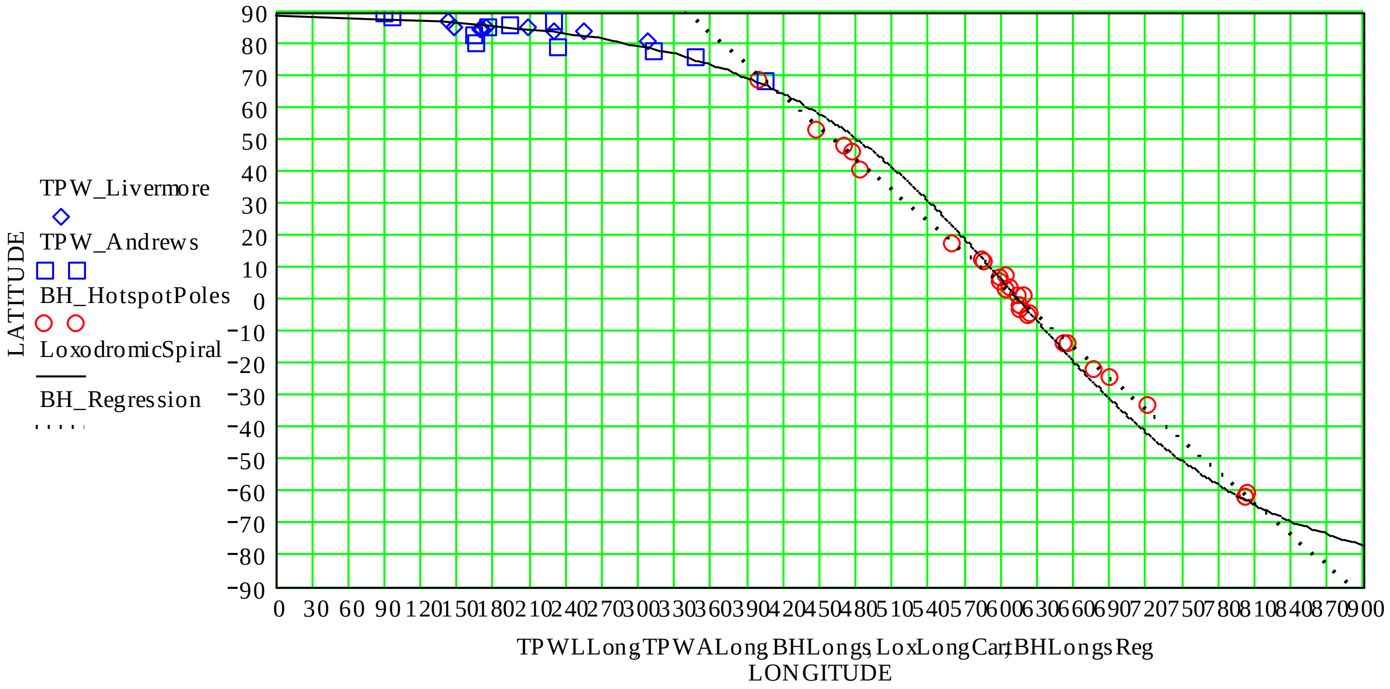
[4]
A temporal calibration of the hotspot-pole sequence was attempted, including multiple physical interpretations of the accrued time. Using the resulting speculated chronology of particular plume alignments and the known timing of plume-involved continental separations that began the Atlantic Ocean basin, the average velocity of the participating plumes in their presumed initial rise through the mantle was constrained to a minimum of 0.5 cm/year.

[5]
Application of the same spatial-statistical method to the Moon, Mars, and Venus—all analyzed by using the locations of prominent volcanic edifices for hotspots—also reveals clear convective patterns and tenable pole paths for each. All hotspot pole paths appear to reflect the celestial mechanics experienced by each respective planetary body. The most recent portion of Earth's pole path shows a (Δ Lat/Δ Long) ratio of -0.326, which implies only a slight angle from the ecliptic. This near coincidence is evidently controlled primarily by the Moon and Sun. The pole path of the Moon (eleven equatorial cells) seems to symmetrically oscillate about an attractive axis at 180° longitude. This past behavior fits the scenario of a satellite now in synchronous rotation with a planet-side bulge. Mars (eleven equatorial cells) and Venus (ten equatorial cells) appear to have pole paths that are oriented more polarly. While Mars' pole path clearly shows a (Δ Lat/Δ Long) ratio averaging -1.494, the pole path of Venus is vaguely indicated, and tends to a general polar orientation. It is speculated that a celestial-mechanically driven shifting of the solid, outer layers of a spinning terrestrial planet probably results from gravitational torques applied to those layers by other Solar System bodies. A complete description of a planet's shifting processes, as it gravitationally interacts with neighboring celestial bodies, certainly involves a complex analysis of its composition, structure, shape, spin, and orbital parameters as they evolve over geological time.

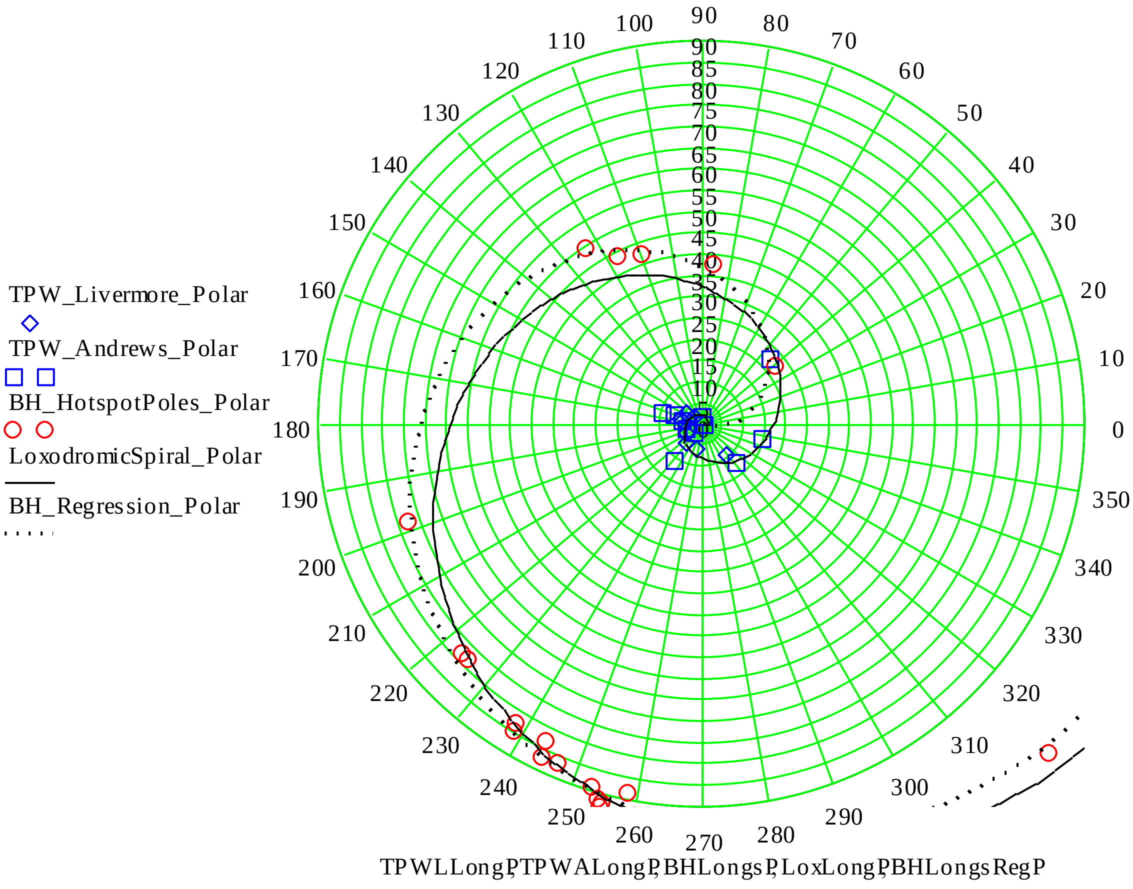
[6]
When this method was applied to Jupiter's moon, Io, the correlation did not indicate a principal, statistically strong convective pattern as found with the other planetary bodies, but rather a waveform showing statistical strengths in cyclical peaks and troughs (about 4–6° cycles) over a wide range of cell sizes. Such a result seems consistent with regularly repeated strain or fracture domains produced within a thin, solid mantle by tidal stresses that are generated by gravitational interaction with Jupiter. Such weaknesses could localize and control volcanic expression at statistically spaced intervals.

[7]
Thus, the use of spherical spatial statistics to correlate surficial patterns of planetary geologic features to aspects of modeled interior dynamics may augment direct observation and test that model and related ideas about evolutionary terrestrial planet processes.

Loxodromic (solid) and Linear (dashed) CCW Spirals Fit to TPW [Livermore,1984; Andrews,1985] and the "B+H" Hotspot Poles



Loxodromic (solid) and Linear (dashed) CCW Spirals Fit to TPW [Livermore,1984; Andrews,1985] and the "B+H" Hotspot Poles (only "B" Poles showing)



Earth's Spherical Spiral Pole Paths

Descriptions and Interpretations

[8]

The linear spherical spiral -

$\text{Longitude}_{\text{rad}} := -3.059(\text{Latitude}_{\text{rad}}) + 10.70$ is a path of rotational pole positions that are each calculated from two hotspot locations, the GSA of which, passes through the windows of a filter template made for 36°-cell arrays. Each rotational pole position is inferred, because its hotspot plumes are postulated to have been initiated at the CMB during a period of equatorial alignment.

[9]

Alignment of the poles into a narrow linear path and the apparent continuity of that path over geologic time, when fully considered, may represent two billion years of record, seems to indicate a structural and positional integrity of mantle plumes within a context of whatever lateral mantle flows result from large-scale convection patterns. There are, however, global regions devoid of any pole paths, which may indicate that the OC convection dynamics during the durations represented did not support a 36°-cell stability, or that, in the plume-array zones that determine these regions to be polar, either: 1.) CMB conditions were not conducive to plume initiation; 2.) a compositional and/or structural barrier above the CMB is deflecting plumes or impeding their rise altogether; or 3.) lateral mantle flows or lithospheric dynamics are sufficiently deflecting rising plumes from a vertical path so that the filter template rejects them. Interestingly, the 36° filtering template with +/- 1.5° windows, which was first applied, did not reveal any poles at latitudes greater than 70°. Consistent with our method, this barren polar cap represents unaccepted plume pairs in an equatorial zone of +/- 30° latitude. As the template windows were opened wider, poles became indicated beyond 70° in a commensurate progression toward the axial pole. Thus, it appears that the closer a plume is to the equator, the more the vertical accuracy of its rising is temporarily affected. It is speculated that the final reaches of the plume path may be deflected by rotational effects and/or deformations of the lithosphere/upper mantle that are related to the migration and evolution of the equatorial bulge.

[10]
Also, the hotspot locations of sequential poles along the path appear to imply that the underlying cells show significant array congruency. That is, from pole to neighboring pole, the respectively implied cell arrays tend to show little change in their radial orientations. A natural consequence of this would be a noticeable carry-over of cell involvement, which is, in fact, indicated by repeating hotspot partners in pairs determining adjacent poles.

[11]
From the compelling coherence and tenability of the above observations, it seems that the hotspot pole path represents a real physical passage of the rotational axis. To the extent that the evolving mantle may be represented as a whole within a framework of plume conduits, it is hypothesized that the hotspot pole path indicates whole-mantle shifting.

[12]
The loxodromic spherical spiral -
$\text{Longitude}_{\text{rad}} := -\left[\tan(66.5\,\text{deg})\cdot\left(\ln\left(\tan\left(\frac{\pi}{4}+\frac{\text{Latitude}_{\text{rad}}}{2}\right)\right)-\ln\left(\frac{\pi}{4}\right)\right)\right]-1.30$ follows a path of calculated past magnetic poles, which from evidence and theory collocate Earth's coeval rotational poles as well. These pole positions have increasingly less material relevance as one follows along the path to positions determined for poles further back in time. That is, the present pole position is certainly real, and calculated pole positions near to it surely hosted the rotational pole recently, but the older the pole, the more virtual its calculated position. This scenario follows because each pole site is inferred from paleomagnetic readings taken from a selection of rocks on highly mobile crustal plates, whose positions and orientations are estimated for the time of rock magnetization. Because the plates of the lithosphere are constantly rearranging, a rock of today, on a path position that corresponds to a pole from a deeply distant time, probably did not actually host the rotational pole of the Earth then. Thus, the loxodromic pole path does not specify a real movement of a whole lithosphere, but rather, it delineates a calculated path on the modern coordinate globe of increasingly virtual poles over time.

[13]
It seems evident, from the formula that describes this loxodromic path, that the net movement and rearrangement of the lithospheric plates are driven, in part, by a combination of gravitational attractions with other Solar System bodies, primarily the Moon and Sun. This gravitational interaction produces tidal torques applied to Earth, an ellipsoid of revolution with an equatorial bulge. Such torques and any celestial resonances related to them are speculated to create a forcing function that results in the secular shifting of mobile planetary layers over geologic time.

Conclusion

[14]
Novel results of this analysis are that the net movement, over geologic time, of Earth's mosaic of lithospheric plates includes two components additional to the conventionally theorized number one below.

1. Independent movement of plates, with respect to the mantle, driven by regionally relevant plate-tectonic processes (e.g. slab pull, ridge push, and basal traction from lateral components of sub-lithospheric convection currents).

2. Whole-mantle shifting, with respect to the inertial reference frame of the metallic core, driven by gravitational torques applied to the lithosphere and mantle of the Earth by other Solar System bodies, primarily the Moon and Sun.

3. Interplate shifting, with respect to the mantle, driven by gravitational torques applied to the lithosphere of the Earth by other Solar System bodies, primarily the Moon and Sun.

References

[15]
Andrews, J. A. (1985). True Polar Wander: an analysis of Cenozoic and Mesozoic paleomagnetic poles, *J. Geophys. Res.*, 90(B9): pp. 7737–7750.

Glatzmaier, G. A., and P. H. Roberts (1995). A three-dimensional convective dynamo solution with rotating and finitely conducting inner core and mantle, *Phys. Earth Planet. Inter.,* 91: pp. 63–75.

Livermore, R. A., F. J. Vine, and A. G. Smith (1984). Plate motions and the geomagnetic field – II. Jurassic to Tertiary, *Geophys. J. Roy. Astron. Soc.,* 79: pp. 939–961.

Acknowledgments

[16]
I wish to thank Amelia A. McNamara, Ph.D. candidate in Statistics at UCLA, for illustrative graphics; Dr. Debra J. Blake for non-technical editing; Daniel S. Helman, MS candidate in Geology at CSULB, for comments; and the University of Minnesota's Department of Earth Sciences for many stimulating and inspiring free seminars.