Discussion of

Divergence between paleomagnetic and hotspot model predicted polar wander for the Pacific plate with implications for hotspot fixity

by

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4th January, 2007, Edward (Jerry) L. Winterer

Sager has rendered us a service by carefully segregating the three types of data used in making Apparent Polar Wander Paths (APWP) for the Pacific plate:

1. measurements of magnetic inclination on drill cores (mainly basalt cores, not subject to compaction, but including sediment cores),
2. seamount magnetism, which can yield inclination and declination for seamounts assumed to be uniformly magnetized (mainly those emplaced during the Cretaceous Normal Superchron) and,
3. skewness of magnetic anomalies. If True Polar Wander is not a chimera and actually exists, it cannot be detected using data from the Pacific plate.

Sager than compares this APWP with the results of the other approach to constructing a Polar Wandering Path, via the orientation and age sequences along age-progressive seamount chains—the so-called hotspot method. The difficulties here arise from assumptions about long-term fixity of hot spots (loci of melting in the upper mantle and eruption of seamount-constructing lavas). Many chains, e.g., Samoa, Ellice, Gilbert, Marshall, Puka Puka, are not age-progressive, and the rates of progression are inconsistent from one parallel chain to another. In at least one chain, the Emperors, the core data show that the volcanoes in the chain were each erupted at a different latitude—another violation of the fixity assumption. Sager supplies a plausible explanation for this in vectoring different motions of plate vs. mantle, plate vs. hotspot, and hotspot vs. mantle.

The Emperor data free hotspots from any notion of fixity during the period 80-49 Ma, and published data from other south-trending chains e.g., Ellice, Marshall, Line (Koppers et al, 2003, Davis et al, 2002), extend that age span back to at least 86 Ma. None of these chains is age progressive, and The Line Islands show two short bursts of volcanism (86-81 Ma and 73-68 Ma) on two parallel parts of the chain 1200 and >4000 km long. Plumes are totally inadequate sources for this style of volcanism, whereas tensional cracks, continuous and intermittent, opening through the lithosphere along south-trending lines and filled from fusible sources, e.g., eclogite, in the partially molten asthenosphere, easily answer the requirements. The timing of this era of N-S cracking is most plausibly the inception of subduction of the western edges of the

Pacific plate, as the adjacent plates to the west were consumed. The direction of Pacific plate motion during this epoch is hard to discover, but the Hawaii-parallel Line Islands Cross Trend is an obvious candidate, being consistent with the magnetic data for little latitude change during this time interval.

The end of this epoch at about 50 Ma, is the time of India-Eurasia collision, whose "escape" effects spread eastward to the Pacific, as well as the establishment of the Aleutian arc in the North Pacific and initiated a new dominant direction of Pacific plate motion (Natland and Winterer, 2005) and a new orientation of tensional stresses in the plate normal to the direction of plate motion. The switch-over between the two regimes is marked by the Hawaii-Emperor bend.

5th Febrnuary, 2007, William W. Sager

I thank Winterer for highlighting the existing uncertainty about the interpretation of Pacific seamount chains and plate motions as hotspots. He reminds us that many of the Pacific seamount chains do not have simple age progressions (if they have age progressions at all) and that published paleomagnetic data from the Emperor Chain imply that the Hawaiian hotspot (and others by implication) was not fixed in latitude. Further, Winterer suggests that stress cracking of the plate is an alternative that is not constrained to have simple age progressions nor to be fixed in any particular spot (Natland and Winterer, 2005).

Being keenly aware of the changing views of the hotspot hypothesis – and being uncertain myself of what mechanism is the best explanation – I chose to remain neutral about the mechanisms of the Hawaiian-Emperor chain formation. I say that we should consider alternative hypotheses, but I went no further, in part because I saw such an extrapolation to be beyond the scope of my study. It is interesting to consider what the Wessel et al. (2006) plate motion model entails and implies. That study is clearly an outgrowth of the fixed hotspot hypothesis, although the authors do not strictly make that assertion. Their model only requires that seamount chains are a fixed distance apart, but not that the melting anomalies have strictly linear propagation rates or that the anomalies are fixed relative to anything except one another. Thus, one interpretation could be a constellation of plumes that maintain nearly fixed distances from one another, yet shift relative to other plumes (e.g, Tarduno and Gee, 1995). Another might be a set of tensional cracks that form with a regular spacing (Natland and Winterer, 2005).

It is also interesting to note that the Wessel et al. (2006) model is mostly based on two seamount chains, Hawaiian-Emperor and Louisville, and not on many of the other seamount chains mentioned by Winterer in his comment. Some of those other seamount chains may be copolar (fit the same small circle trends) with the Hawaiian-Emperor and Louisville chains, but do not show the same simple age progressions. It is only in the Cenozoic that their model is able to use more than those two chains. Although this model is at times representative of broader motion, mostly it is a Louisville and Hawaiian-Emperor model. Those two seamount chains, at least, seem to behave most coherently in the manner ascribed to plate motion over hotspots.

Two of the most important implications of my study are (1) the Wessel et al. (2006) “hotspot” model does a decent job of predicting the overall plate motion recorded by paleomagnetism and (2) the Hawaiian-Emperor bend is not what we thought for over three decades. Overall, the shapes of paleomagnetic and hotspot-predicted APWP are similar. Thus, the plate motion model seems to be recording plate motion in some manner; although, I leave it to the reader to infer what that might be (especially if not fond of the hotspot hypothesis).

The second point is very important in that it represents a wholesale overturn of accepted Pacific plate motions and because it must say something important about the behavior of the Hawaiian melting anomaly. A few years ago, like almost everybody else, I thought that Pacific plate motion was nearly north-south during the period of the Emperor Chain formation. But new paleomagnetic data (Tarduno et al., 2003; Sager, this volume) suggest otherwise. The paleomagnetic data are consistent with little or no northward motion during that time, so the bend does not represent much of a change in plate motion. There may have been a small change in plate motion as noted by changes in fracture zone trends corresponding to about 45-50 Ma (Atwater, 1989), but nothing like the ~60° change implied by the Hawaiian-Emperor Bend. This apparent, large change in plate motion is woven into many western Pacific tectonic interpretations and now must be culled out. Furthermore, I find it interesting that the oldest (northern) end of the Emperor chain, where it changes trend from southeast to south-trending, is approximately the same age as a change recorded in seafloor magnetic lineations during Chron 33 (Atwater, 1989) and so is the Hawaiian-Emperor bend. The simplest explanation for this set of coincidences is that the melting anomaly responded to changes in plate motion, which is essentially the thesis of the paper by Ian Norton (Norton, this volume) and the views expressed by Winterer. I must admit that the two contentions above seem to be in conflict. The one suggests the plate motion model is mostly correct and the other suggests that at least one part is highly flawed. I can only hope that future data will help solve this apparent paradox.

References

Atwater. T., 1989, Plate tectonic history of the northeast Pacific and western North America, in Winterer, E. L., et al., eds., The Eastern Pacific Ocean and Hawaii: Boulder, Colorado, Geological Society of America Decade of North American Geology v. N, p. 21-72.

Davis, A.S., Gray, L.B. and Clague, D.A., 2002, The Line Islands revisited: New 40-Ar/39-Ar geochronologic evidences for episodes of volcanism due to lithospheric extension: Geochemistry, Geophysics, Geosystems,v.3, doi: 10.1029/2001GC000190.

Koppers, A. A. P., Staudigel, H., Pringle, M. S., and Wijbrans, J. R., 2003, Short-lived and discontinuous intraplate volcanism in the South Pacific: hot spots or extensional volcanism?:Geochemistry, Geophysics, Geosystems, v. 4, 1089, doi: 10.1029/2003GC000533.

Natland, J. H., and Winterer, E. L., 2005. Fissure control on volcanic action in the Pacific, in Foulger, G. R., et al., eds., Plates, plumes, and paradigms: Boulder, Colorado, GeologicalSociety of America, Special Paper 388, p. 687-710, doi: 10.1130/2005.2388(39).

Tarduno, J. A., Duncan, R. A., Scholl, D. W., Cottrell, R. D., Steinberger, B., Thordarson, T., Kerr, B. C., Neal, C. R., Frey, F. A., Torii, M., and Carvallo, C., 2003, The Emperor Seamounts: Southward motion of the Hawaiian hotspot plume in the Earth’s mantle: Science, v. 301, p. 1064-1069, doi: 10.1126/science.1086442.

Tarduno, J. A., and Gee, J. 1995. Large-scale motion between Pacific and Atlantic hotspots: Nature, v.78, p. 477-480.

Wessel, P., Harada, Y., and Kroenke, L. W., 2006, Toward a self-consistent, high-resolution absolute plate motion model for the Pacific: Geochemistry, Geophysics, Geosystems, v. 7, Q03L12, doi: 10.1029/2005GC00100.