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IMPROVED ABSOLUTE PLATE MOTION MODELING IN THE PACIFIC

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INTRODUCTION

In studies of Relative Plate Motion (RPM), the model constraints are conjugate magnetic isochrons identified in marine magnetic anomalies. The model is a finite rotation that rotates an isochron on plate A such that the rotated segment matches the conjugate isochron on plate B. Chang (1987; 1988) solved for such rotations using nonlinear spherical regression and developed statistical confidence regions for the resulting rotations. Because conjugate data can be optimally superimposed using a single, finite rotation, it was natural to define the model in terms of total reconstruction rotations. In studies of Absolute Plate Motion (APM), the constraints are the surface expressions of hotspot seamount chains and their measured ages. The traditional approach is to model coeval segments of seamount chains as small circles about stage poles of rotation found by minimizing the distances from each seamount to its locally best–fitting, small circle about a candidate pole. The opening angles are typically found by trial and error. Given the age range of a particular set of copolar segments, opening rates can be determined. Because the data portray small circles, it was natural to define the model in terms of stage rotations.

The traditional APM modelling approach has many limitations, including (1) shorter segments, possibly reflecting APM changes, are difficult to identify and correlate across several chains; (2) short small–circle segments become indistinguishable from great circles and hence reliable poles cannot be determined; (3) without easily identifiable kinks between chain segments, ages are needed to make the correlation and these are often lacking; and (4) unlike RPM modelling, rigorous methods for estimating APM uncertainties are only now being developed. Wessel and Kroenke (1997) developed a method to derive optimal hotspot locations from seamount data if the APM is known, whereas Harada and Hamano (2000) introduced a technique to determine total reconstruction rotations if hotspot locations are known. We improve the modelling of APM by combining these two complimentary methods into a self–consistent hybrid technique. The hybrid technique allows us to determine (1) the best location for hotspots, (2) a high–resolution APM model, and (3) covariance matrices for each rotation. We present a self– consistent Pacific APM with confidence regions for each rotation pole and reconstructed points. The new model is contrasted with traditional models, and the implications of the model for drift within the Pacific hotspot group and the origin of the Hawaii–Emperor bend is addressed.

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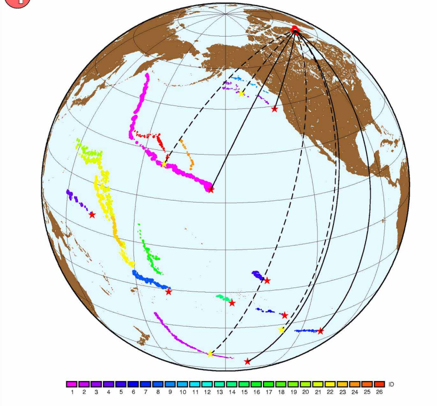

Modeling Technique. We have refined the Polygonal Finite Rotation Method (PFRM) [*Harada and Hamano*, 2000] to use the seamount catalog of *Wessel* [2001]. Seamounts in a chain are given a chain ID (see color). Hotspots for these trails (red stars) define the (possibly fixed) hotspot reference frame. We seek finite rotations of the entire reference frame that moves the chosen hotspots onto the corresponding trails. The case ω = 18±1° is illustrated. Because trails are not continuous, we determine all rotations that successfully place two or more hotspots onto the corresponding chain (yellow stars). This cluster of poles (red dots) defines the population of poles for this range of opening angles, with the mean pole of rotation shown by a white circle. While the rotation works geometrically we do not know if it is consistent with available ages.

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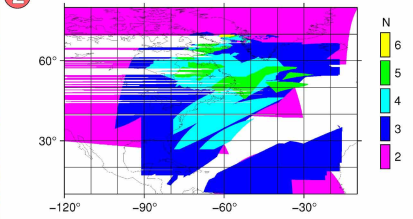
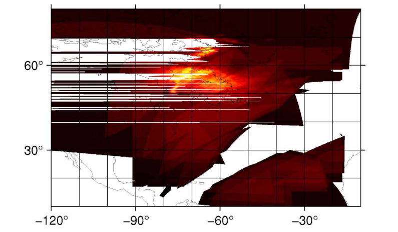


Rotation poles for all opening angles, color coded according to the maximum number of chains that were fit (geometrically) by the rotation poles.



Density of Rotation poles for all opening angles, with most poles (hot colors) being close to traditional estimates of Pacific rotation poles. Note outliers.

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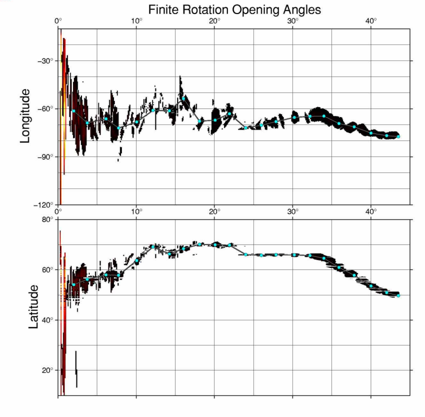

Smooth Geometric APM model. (upper) Color image represents all rotation pole longitudes as a function of opening angle. About every 2 degrees we have estimated the mean rotation pole location and plotted the mean longitude as cyan circles. (lower) Same illustration for the latitude of all rotation poles. Note that the latitudes appear to be more stable than the longitudes. There are several outliers in the polulation of rotations. We hope to use robust estimation techniques to determine the smooth APM model, thus minimizing the effect of outliers. Since no age information is used to reach this point we do not know if the model is a viable plate **motion** model; at this point it only satisfies the <u>geometric</u> constraints.

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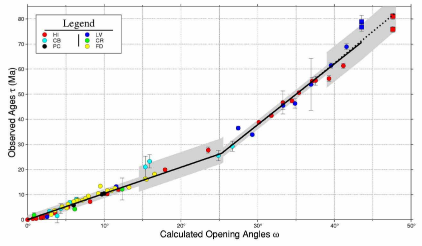
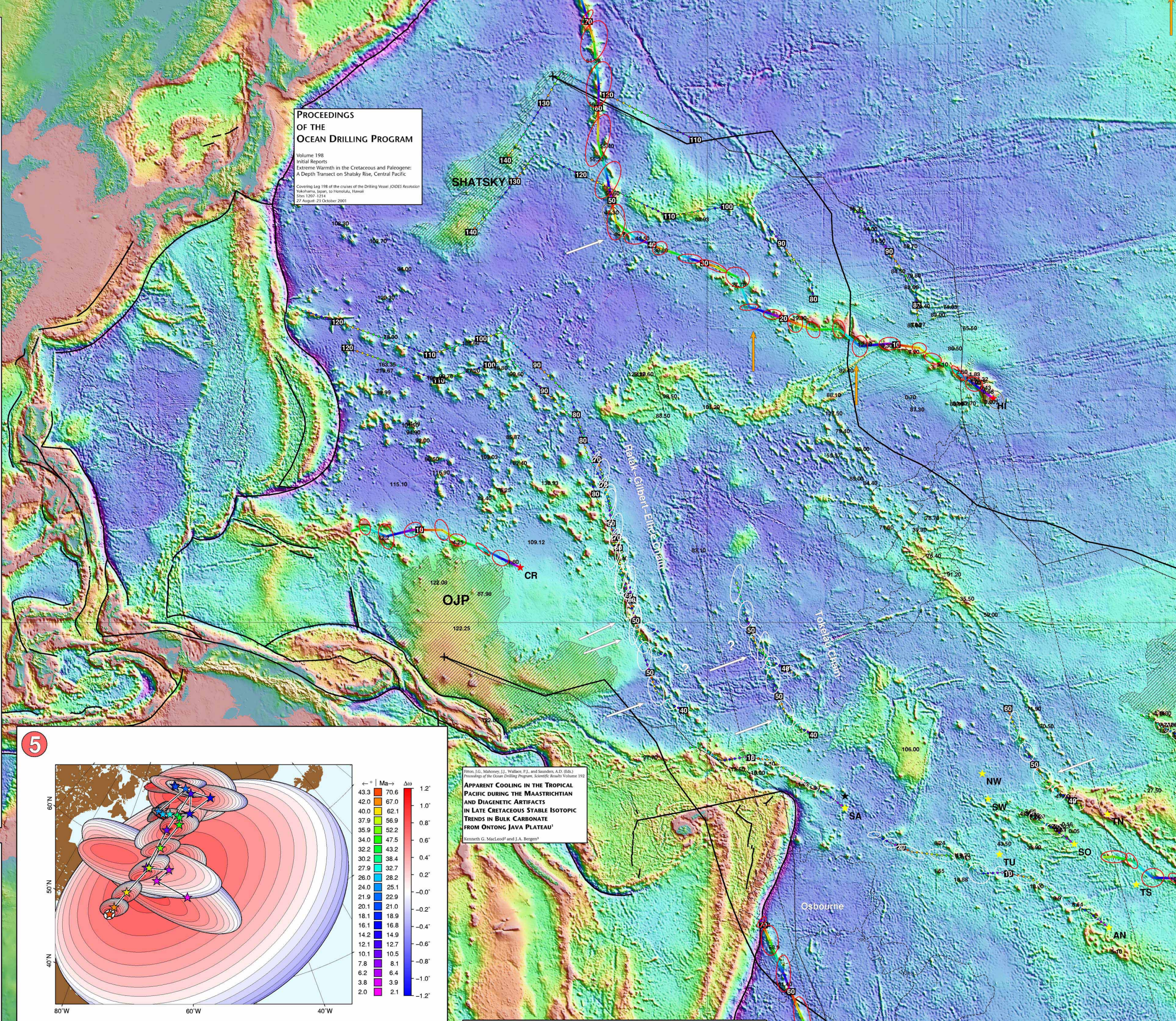


Temporal Constraints. The <u>originator</u> tool in GMT allows us to calculate the rotation opening angle to any dated seamount in the vicinity of the predicted track. We can therefore plot observed ages [Clouard and Bonneville, 2001] from all of the chains used in the analysis versus the calculated opening angles. Shown above is a τ(ω) plot for the 6 Pacific seamount chains used in the APM modeling. Here, the y coordinates are inferred ages from radiometric dating and are assumed to be fixed. The x coordinates depend solely on the geometric APM model (and hotspot locations) and are subject to change. Given the published age uncertainties, a linear spline routine determined that two sections were sufficient back to ~71 Ma (solid line) and automatically picked the knot point (at ~25°). Extending the model (dashed line) to the oldest seamounts along Emperor and Louisville (squares) using values recently published by Koppers et al [2004] will possibly yield a 3–segment model. Gray band represents the implied geological age uncertainty (95%), which typically exceeds published analytical uncertainties. There is a greater age scatter (Cobb chain) during the ~23–27 Ma period and during the late Louisville–Emperor stage. Overall, the model adequately explains both the geometric and chronologic data and thus is a reasonable fixed hotspot APM model for the Pacific, but more and better ages are needed during the time–periods of higher scatter. Note that some of the apparent scatter is a function of the particular choice of spline and could be reduced by using more parameters in the τ(ω) curve.



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APPARENT COOLING IN THE TROPICAL PACIFIC DURING THE MAASTRICHTIAN AND DIAGENETIC ARTIFACTS IN LATE CRETACEOUS STABLE ISOTOPIC TRENDS IN BULK CARBONATE FROM ONTONG JAVA PLATEAU[1]

Kenneth G. MacLeod[2] and J.A. Bergen[3]

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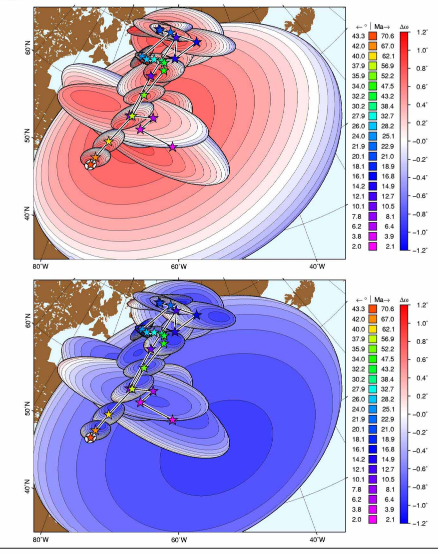

Confidence regions for rotations. Location of rotation poles (stars), with color–coded opening angles (and ages), and the projection of the upper and lower confidence bounds on each finite rotation. (upper) Upper surfaces of the 3–D 95% confidence region for each rotation, colored as deviations Δω from the mean opening angle (indicated by star color). (lower) Same illustration for the lower surface of opening angles.

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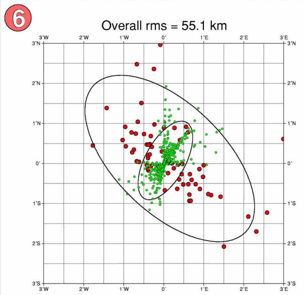

APM Model Residuals. Overall scatter–plot for back–tracked dated (red) and undated (green) seamounts, obtained by rotating all hotspots to a common (0°, 0°) origin. The ~50 km rms for undated seamounts is less than half the rms for the dated seamounts, suggesting that the geometric constraints are more consistent than the chronologic constraints.

MAP LEGEND

- Confidence ellipse (modeled tracks)
- ★ Hotspot location (modeled tracks)
- Confidence ellipse (predicted tracks)
- ★ Hotspot location (predicted tracks)

Age modulo 10 (Myr): 0 2 4 6 8 10

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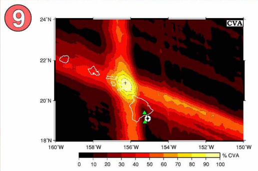

Hawaii Hotspot Location. Hotspotting reveals the hotspot location that is consistent with the APM model and geometric markers. However, for many published APM models the stated hotspot location (bulls eye) does not coincide with the implicit location, such as for the KMMS model in Figs 7–8. Active volcanism marked by green triangles.

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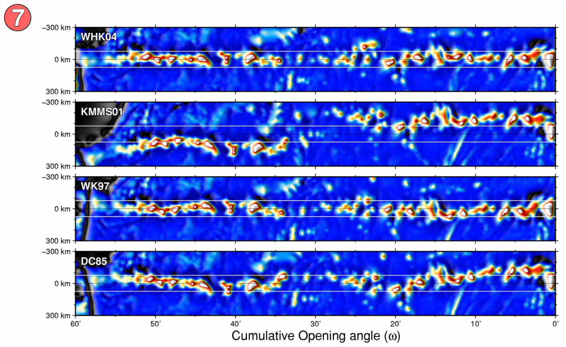

APM projection for Hawaii. We have implemented a new map projection which maps the small–circle segments of a hotspot trail (as defined by a particular APM model) onto the Equator. What we see is the "straight" hotspot trails that would result if the hotspots were located at the Equator and the (single) rotation pole coincided with the North Pole. Higher–resolution models should produce a straight chain close to the black line (Equator). The projections shown are based on the APM models of Duncan & Clague (DC85), Wessel & Kroenke (WK97), Koppers et al. (KMMS01), and our present model (WHK04).

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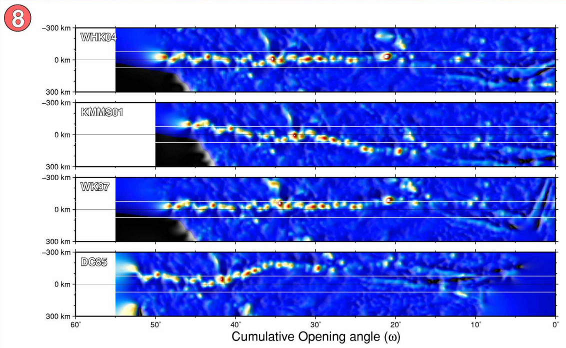

APM projection for Louisville. The same APM map projection as above, but this time showing the situation for the Louisville hotspot. Because the location of the Louisville hotspot is controversial there are clearer discrepancies between the models here than for Hawaii. The large mismatch for DC85 is explained by a lack of information about the Louisville chain in the early 1980s. There is also the tendencies for authors to tabulate their hotspot locations separately from their APM model. Hotspotting reveals large systematic differences between the stated hotspot location and the CVA maximum (see Fig. 9).

GEOMETRY VERSUS CHRONOLOGY

Inferring absolute plate motions relative to hotspots involves the analysis of geological markers (seamounts, islands) that are thought to represent locations that in the past were directly above a (fixed) hotspot. The markers provide us with their present position (longitude, latitude) and, very infrequently, we have radiometric estimates of age.

An absolute plate motion model must satisfy <u>both</u> the geometric and chronologic data constraints. While there are issues with both kinds of data, the geometry is the strongest constraint because it is available for all chains and at (almost) all times. Where ages exists they can be used to test for a systematic age progression. This is why we emphasize geometry (Figs. 1–3) prior to ages (Fig. 4).

Ongoing work involves choosing times based on relative plate motions (i.e., Chrons) and iterating the procedures in Figs. 3–4 until we obtain rotations for the chosen times, and then to adjust the width of the smoothing windows in Fig. 3 to account for the uncertainties in age derived from Fig. 4. Also, because the location of the hotspots affect the rotation estimates, we need to find optimal locations using hotspotting. Ultimately, the final rotation estimates with their covariance matrices will be the optimal absolute plate motion given the data constraints.

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