

## Studying Oceanic Plate Motions with Magnetic Data

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The geocentric axial dipole hypothesis states that the geomagnetic field, when averaged over hundreds of thousands of years, corresponds to that of a dipole located at Earth's center and along Earth's rotation axis. Accordingly, paleomagnetic poles, which are estimates of the position of the dipole axis, give past positions of the Earth's rotation axis relative to a sample locality. From the paleolatitude of the sample, the paleolatitude of the sample can be derived. Using this hypothesis, paleomagnetists have reconstructed paleogeographies for the continents that span several hundreds of million years. Such data are essential for understanding plate and terrane motions, mantle convection, paleoclimates, geomagnetism, as well as many other subjects.

Paleomagnetic data are typically obtained from the magnetization directions estimated from samples collected from rock exposures, such as the layers of rocks exposed along stream banks, layers of volcanic flows exposed along the flanks of volcanos. For oceanic plates, such as the Hawaiian Islands, rock exposures are limited to a few young islands. Even for continental plates, most of the rock exposures are very limited in the range of ages they span. Paleomagnetic poles must be estimated by other techniques.

One technique with great promise uses the shapes of marine magnetic anomalies. Marine magnetic anomalies are the highs and lows in the intensity of the magnetic field measured by magnetometers towed behind ships or low-flying airplanes, typically along profiles roughly perpendicular to the direction of seafloor spreading. The highs and lows are produced by the upper portion of the oceanic lithosphere, which becomes magnetized parallel to the direction of seafloor spreading upon its formation at a seafloor spreading center. The information we extract from these anomalies is referred to as skewness data because the asymmetry or skewness in the magnetic anomaly is related to paleolatitude.

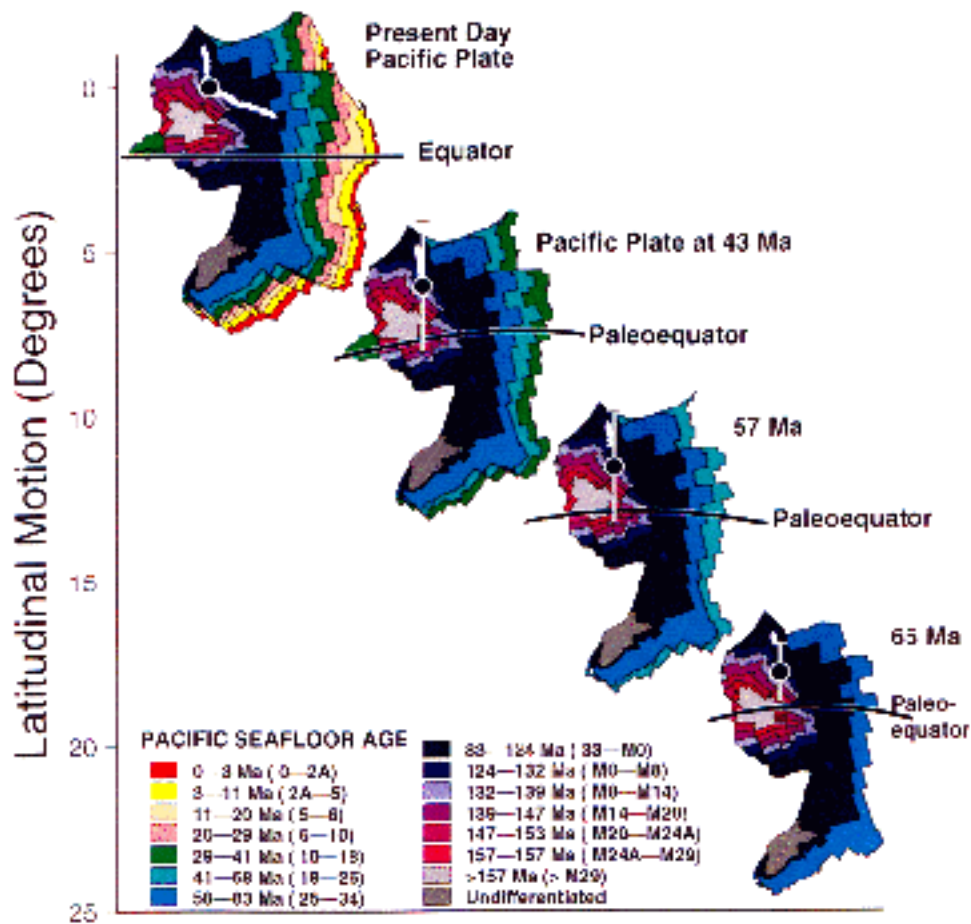
This method is especially practical because magnetic anomaly profiles already exist for large parts of the oceans and can be inexpensively obtained from the U.S. National Geophysical Data Center. Oceanic plates generally have anomalies that are distributed over large regions and span a long time; and the relative ages of magnetic anomalies are known exactly and the apparent magnetic poles are known well.

The skewness method consists of finding a phase shift - an angle that describes the asymmetry of the magnetic anomaly - which gives the anomaly a shape that would be expected if the anomaly was produced by oceanic lithosphere that formed and remained at the North pole. A single skewness measurement restricts the paleomagnetic pole to lie along a great semi-circle or within a skewness lobe.

region bounding the great semi-circle - when uncertainties in the phase shift are incorporated, a paleomagnetic pole is obtained from two or more skewness data giving skewness lune: intersect. From a set of skewness data, we estimate a best-fitting paleomagnetic pole, a 9 ellipse, and data importances from a maximum-likelihood inversion.

The inversion procedure [Petronotis et al., 1992] also allows us to estimate the size of a and remove biases caused by it. The additional asymmetry in an anomaly caused by an thought to arise from non-vertical reversal boundaries in the oceanic lithosphere or fr in the magnetization intensity within a polarity interval. For example, if the intensity of field decayed over a time interval when the field had a constant normal or reversed po lithosphere formed during this interval would give rise to magnetic anomalies with a Thus, the estimates of anomalous skewness help to better understand the source of ma anomalies and properties of the geomagnetic field.

Our new paleomagnetic poles suggest that Earth's largest plate, the Pacific plate, moved northward over a 26-m.y. period from the Late Cretaceous to the late Eocene and another over a 39-m.y. period since then (Figure 1). In detail, the poles indicate that the Hawaii about 900 km southward between 45 and 33 m.y.a., which is consistent with a large, fair true polar wander [Petronotis et al., 1994; Petronotis, 1993].



**Fig. 1.** Three new paleomagnetic poles define the northward motion of the Pacific plate present-day position. Black dots (with standard error bars) show the change in latitude in the Hawaiian-Emperor island and seamount chain. For example, it is estimated that the Pacific plate moved 17.8 degrees (1980 km) northward in the past 65 m.y. The Pacific plate seafloor age map interval (43 Ma, 57 Ma, and 65 Ma) illustrates the growth of the Pacific plate while the orientation of the equator through time shows that the dominant motion has been not clockwise rotation between 57 and 43 Ma and a small counterclockwise rotation between present.

The new poles are also being used in paleomagnetic tests of global plate reconstructions [1994], which indicate that there is a significant error in reconstructions through the South Antarctica. The implications are far reaching for circum-Pacific plate and terrane motion hotspot motion studies that use these reconstructions. In particular, prior estimates that Pacific hotspots move relative to other hotspots at rates of 10-20 mm/yr are probably too low or more.

Our skewness analyses have also shown that magnetic anomaly profiles from near paleo very sensitive to the position of the paleomagnetic pole and to geocentric axial quadrupole. These quadrupole components are likely the dominant non-dipole part of the time-averaged field and thus probably contribute the most to the deviations from a pure geocentric axial field observed in some paleomagnetic data. The large gradients in skewness that occur near the Clipperton fracture zones in the Pacific had not been recognized previously [Acton and Petronotis et al., 1994].

Where comparisons can be made, the independent results being obtained from skewness with other types of paleomagnetic data. Where other types of data are sparse or nonexistent have the potential to give high quality paleomagnetic observations with fine age resolution.

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