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Paleomagnetic modeling of seamounts near the Hawaiian–Emperor bend

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Abstract

The Hawaiian–Emperor Seamount chain records the motion of the Pacific Plate relative to the Hawaiian mantle hotspot for ~80 m.y. A notable feature of the chain is the pronounced bend at its middle. This bend had been widely credited to a change in plate motion, but recent research suggests a change in hotspot motion as an alternative. Existing paleomagnetic data from the Emperor Chain suggest that the hotspot moved south during the Late Cretaceous and Early Tertiary, but reached its current latitude by the age of the bend. Thus, data from area of the bend are important for understanding changes in plume latitude. In this study, we analyze the magnetic anomalies of five seamounts (Annei, Daikakuji-W, Daikakuji- E, Abbott, and Colahan) in the region of the bend. These particular seamounts were chosen because they have been recently surveyed to collect multibeam bathymetry and magnetic data positioned with GPS navigation. Inversions of the magnetic and bathymetric data were performed to determine the mean magnetization of each seamount and from these results, paleomagnetic poles and paleolatitudes were calculated. Three of the five seamounts have reversed magnetic polarities (two are normal) and four contain a small volume of magnetic polarity opposite to the main body, consistent with formation during the Early Cenozoic, a time of geomagnetic field reversals. Although magnetization inhomogene ties can degrade the accuracy of paleomagnetic poles calculated from such models, the seamounts give results consistent with one another and with other Pacific paleomagnetic data of approximately the same age. Seamount paleolatitudes range from 13.7 to 23.7, with an average of 19.4 ± 7.4 (2σ). These values are indistinguishable from the present-day paleolatitude of the Hawaiian hotspot. Together with other paleomagnetic and geologic evidence, these data imply that the Hawaiian hotspot has moved little in latitude during the past ~45 m.y.

Keywords: Hotspot; Paleomagnetism; Hawaiian seamounts; Emperor seamounts; Pacific plate

1. Introduction

The Hawaiian–Emperor Seamount chain is arguably the clearest and most-studied example of a volcanic chain produced by plate motion over a hotspot,

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which is assumed by many to be a mantle plume. Indeed, the westward aging of Hawaiian volcanic edifices was considered such an obvious expression of plate motion that it was considered fundamental evidence used to promote the theory of plate tectonics (Wilson, 1963). So firmly rooted is this idea that more than a generation of students and scientists has learned from Earth science textbooks that the chain shows Pacific plate motion over the hotspot, and furthermore, that the bend where Hawaiian and Emperor Seamount chains meet (Fig. 1) represents a large change in the direction of plate motion. At the foundation of both observations is the assumption that the volcanic chain records the motion of the plate over a melting anomaly that is more-or-less fixed relative to the mantle. This assumption has been extended to create a global network of hotspots that has been used as an absolute reference frame for measuring plate motions (Morgan, 1971; 1972; 1981; Duncan and Clague, 1985; Müller et al., 1993; Harada and Hamano, 2000). In contrast, recent studies of paleomagnetic and other data have suggested that the bend resulted not from a change in plate motion, but a change in the motion of a plume that was not fixed

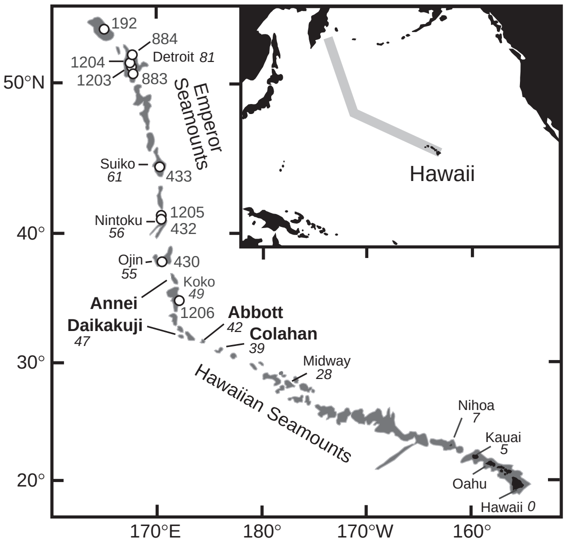

Fig. 1. Volcanoes and seamounts of the Hawaiian–Emperor chain in the central Pacific Ocean. Gray areas represent depths above ~4 km depth in the chain. Numbers in italics are radiometric dates in Ma; other numbers are drill site identifiers. Inset shows location relative to Pacific-bordering continents.

(Sager and Bleil, 1987; Norton, 1995; Tarduno et al., 2003).

Paleomagnetic data from the Hawaiian–Emperor Chain are important because they show the location of the hotspot relative to the spin axis and can distinguish between changes in plate or plume motion. Although more such data exist from this chain than any other hotspot track, the number of data is still small and many gaps remain to be filled. Data from Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) boreholes on seamounts in the Emperor seamounts give paleolatitudes that are significantly farther north than the present location of the hotspot (19.5°) for the northern part of the chain (Kono, 1980; Tarduno and Cottrell, 1997; Sager, 2002), but not for the southern chain (Tarduno et al., 2003). These observations imply that the Hawaiian hotspot drifted south until the time of the bend, but has remained at a constant latitude since. Data from the area of the bend and the early Hawaiian seamounts are, however, few.

One way to derive paleomagnetic data from seamounts is to perform an inversion for the mean magnetization direction of the seamount rocks using maps of the volcano shape and magnetic anomaly (Richards et al., 1967; Parker et al., 1987). Assuming the mean magnetization direction is the same as the mean magnetic field direction during the time the seamount formed, these data can be used to calculate a paleomagnetic pole and paleolatitude. Seamount magnetic anomaly models can be biased by geologic factors, suggesting that such results should be interpreted with caution. Nevertheless, these data are important because there are few reliable paleomagnetic data for most of the Hawaiian–Emperor Chain—especially the interesting region near the bend.

In this study, we examined magnetic anomaly data from five seamounts in the vicinity of the Hawaiian–Emperor Bend that have been recently surveyed to collect multibeam bathymetry soundings and magnetic data with GPS positioning. By providing better constraint of the seamount shape and position of magnetic anomaly measurements, these new data make it possible to construct more detailed and reliable magnetic models. Despite modeling complications, all five seamounts give results that are consistent with a hotspot paleolatitude that has not significantly changed since the time of the bend.