

Indications of Hotspot Movement

The prominent bend in the Hawaiian-Emperor hotspot chain has previously been attributed to a significant change in the motion of the Pacific plate. The magnitude of a shift in plate motion large enough to create the bend present in the Hawaiian-Emperor chain would likely be present in other deposits in the Pacific, which due to recent mapping of magnetic anomalies has not been observed. This leads to the hypothesis that the Hawaiian hotspot as well as the Pacific plate may be in motion.

“One approach to examine hotspot fixity is to determine the age and paleolatitude of volcanoes that form a given hotspot track. For the Hawaiian hotspot, the paleolatitudes of extinct volcanic edifices of the Emperor chain should match the present-day latitude of Hawaii (~19° N) if the hotspot has remained fixed with respect to Earth's spin axis. The most reliable indicators of paleolatitude are basaltic rocks, but enough time must be spanned by any section such that geomagnetic secular variation is sampled. Recovery of such samples requires ocean drilling technology, and only a few seamounts have been sampled to date. Paleomagnetic analyses of 81-million-year-old basalt recovered from Detroit Seamount (Site 884) yielded a paleolatitude of ~36° N (10) that is discordant with Hawaii. Data from ~61 million-year-old basalt (9) from Suiko Seamount define a paleolatitude of 27° N (11). These data suggest that the Emperor Seamounts record southward motion of the hotspot plume in the mantle (10).”

The Ocean Drilling Program (ODP) tested several seamounts in the Hawaiian-Emperor chain for paleolatitude data. Analysis of the data lead to varying latitudes of seamount formation which indicates that hotspot motion.

“Paleolatitude history. The inclination groups, averaged by site, form a progressive sequence of decreasing paleolatitudes with time (Fig. 3) that is inconsistent with the fixed-hotspot hypothesis. We did not recover coral reef material north of Koko Guyot (nor find evidence of such material as sedimentary debris). This is consistent with the idea that the hotspot was once located farther north, beyond the latitudinal zone supporting reef growth (22).”

Substantial evidence from Detroit seamount indicates that there has been rapid movement of the hotspot in the southward direction before the time of the bend. With the current evidence the bend in the Hawaiian-Emperor chain can be explained completely by hotspot motion, meaning that a change in plate motion may have played no part in the formation of the bend.

“Implications of Hotspot Motion. The hotspot motion defined by the new paleomagnetic and radiometric age data has implications for a wide variety of issues, including true polar wander (TPW) (31), the morphology of the past geomagnetic field, and the history of plate motions. Some investigators (e.g. 32) have proposed that as much as 30° of TPW (rotation of the entire solid earth) has accumulated during the last 200 million years. But a fixed hotspot reference frame is used to define TPW in these studies. The data presented here, together with other tests (e.g. 33-34), indicate TPW has been overestimated; the Earth has been relatively stable with respect to the spin axis since the Early Cretaceous. Similarly, some changes in the morphology of the geomagnetic field with time (35) that have relied on fixed hotspots to anchor data from global sites are probably artificial. One recent analysis that has not relied on the fixed hotspot reference frame has called for a significant axial octopole contribution (g30) to the time averaged field [36]. This conclusion is controversial, but if correct it would imply that our paleolatitude calculations underestimate the true hotspot motion.

Backtracking the position of early Tertiary and older Pacific basin sites, an essential aspect of some paleoclimate and tectonic studies, requires rethought as prior efforts have also relied on fixed hotspots. The northerly position of the Late Cretaceous Hawaiian hotspot (24) casts doubt on the southern option for the Kula-Farallon ridge [a plate configuration that is typically called upon to create high rates of northward transport for tectonostratigraphic terranes in Alaska and British Columbia (37-38)].

The fixed hotspot interpretation of the Hawaiian-Emperor bend implies that huge plates can undergo large changes in direction rapidly. But such changes cannot be associated with internal buoyancy forces (e.g. subducting slabs) because these require many millions of years to develop. This has led to the suggestion that plate boundary forces might be responsible (39). The new paleolatitude and radiometric age data (9) suggest that changes of plate motion at the time of the Hawaiian-Emperor bend were much smaller and more gradual than previously thought. Given the central role the Hawaiian-Emperor bend has played as an example of plate motion change, these observations now question whether major plates can undergo large changes in direction rapidly, and whether plate boundary forces alone can play a dominant role in controlling plate motion.

The similarity of the Hawaiian and Louisville hotspot tracks implies that the motion we are tracking by the new paleomagnetic data is of large scale. This Late Cretaceous to early

Tertiary episode of hotspot motion was not isolated; motion of the Atlantic hotspots relative to those in the Pacific occurred at similar rates during mid-Cretaceous times (40). These data sets indicate a much more active role of mantle convection in controlling the distribution of volcanic islands. At times, it is this large scale mantle convection that is the principal signal recorded by hotspot tracks.”

Implication of hotspot motion reach farther than the associated seamounts and volcanoes, but impact all application which rely on hotspots as a fixed reference point for other global movement.