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Dynamics of longitudinal Hawaiian hotspot motion and the formation of the Hawaiian-Emperor Bend

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The Hawaiian-Emperor Chain in the North Pacific features a conspicuous 60° bend that has been the subject of multiple interpretations, including an abrupt change in Pacific plate motion in the Eocene (~47 Ma), a rapid southward drift of the Hawaiian hotspot before the formation of the bend, or a combination of the two factors. The latest geodynamic model has proposed that 30-35° of the Hawaiian-Emperor Bend (HEB) was caused by the sudden westward movement of the Pacific Plate at the latitude of Hawaii around 50 Ma, which occurred as a result of the cessation of the slab pull force generated by intraoceanic subduction in the northern Pacific. The remaining 25-30° of the bend is attributed to the southward movement of the Hawaiian hotspot. But according to geometric analysis and back extrapolation of plate reconstructions, a stronger westward component in the motion of the Hawaiian hotspot is required to achieve a better fit of the HEB. However, there is no geodynamic justification for a significant westward component in the drift of the hotspot.

Here, using geometric analysis with constraints from plate kinematics, we show a significant longitudinal hotspot motion is required to fit the Hawaiian-Emperor Chain. Further application of global mantle convection models reveals a westward (by ~6°) and then an eastward (by ~2°) hotspot drift in addition to the southward motion before and after the bend, with the westward motion primarily controlled by the intraoceanic subduction in Northeast Pacific. While both the westward and southward motion are required to fit the seamount chain, the former contributes ~20 degrees to the bend angle, larger than the later, challenging traditional views. Combining geodynamically-predicted Pacific Plate motion change at 47 Ma, our model provides a nearly perfect fit to the seamount chain, suggesting plate-mantle reorientation as the ultimate cause. It also suggests that the Hawaiian plume conduit is tilted towards the southwest, solving the long-lasting debate on the source of the Hawaiian plume among seismological studies.