Challenges to Establishing a Global Paleolatitude Framework: Paleomagnetic Inconsistencies in the Plate Circuit Through Antarctica

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Abstract

The paleolatitude distribution of paleoclimate proxies and contintential landmass is an important constraint for modeling and understanding paleoclimate. True polar wander (TPW), which can produce large, potentially rapid changes in paleolatitude, is a necessary component in paleolatitude reconstructions. Prior workers, e.g., van Hinsbergen et al. (2015), have created paleolatitude frameworks from global continental apparent polar wander paths (APWPs) drawn from running means of continental paleomagnetic studies (e.g., Torsvik et al. 2012). These are limited by the precision of the running mean, poor age resolution amplified by use of a running mean, and the uncertainties and the unknowns of ancient plate motion circuits. In particular, the Pacific Plate is linked to the global plate circuit through Antarctica. Early paleomagnetic tests of this circuit (Suarez & Molnar, 1980; Gordon & Cox 1980; Acton & Gordon 1994) indicated inconsistency of the circuit with paleomagnetic data such that the reconstructed Pacific plate did not move as far north as indicated by its indigenous paleomagnetic data. Some later work has asserted, however, that updated paleomagnetic data and plate reconstructions no longer indicate the inconsistency found before (Doubrovine & Tarduno 2008). Important progress has also been made in estimating the motion between East and West Antarctica from seafloor data (e.g. Granot & Dyment 2018). We revisit these questions here. We test the predictions of the global paleolatitude framework at points across the Pacific Plate using a well-constrained observed APWP constructed from indigenous Pacific plate data from skewness analysis of marine magnetic anomalies (Schouten & Cande 1976; Cox & Gordon 1980) and locations of paleo-equatorial sediments (Moore et al. 2004; Woodworth & Gordon 2018), which uniquely determine Pacific Plate paleolatitude independent of plate circuits. The misfit between the observed and predicted paleolatitude varies with longitude across the plate and is as large as ˜10±3°, with the largest misfit occurring between 40 and 60 Ma. Implications of this discrepancy will be discussed and an improved paleolatitude framework for the Pacific plate will be presented.

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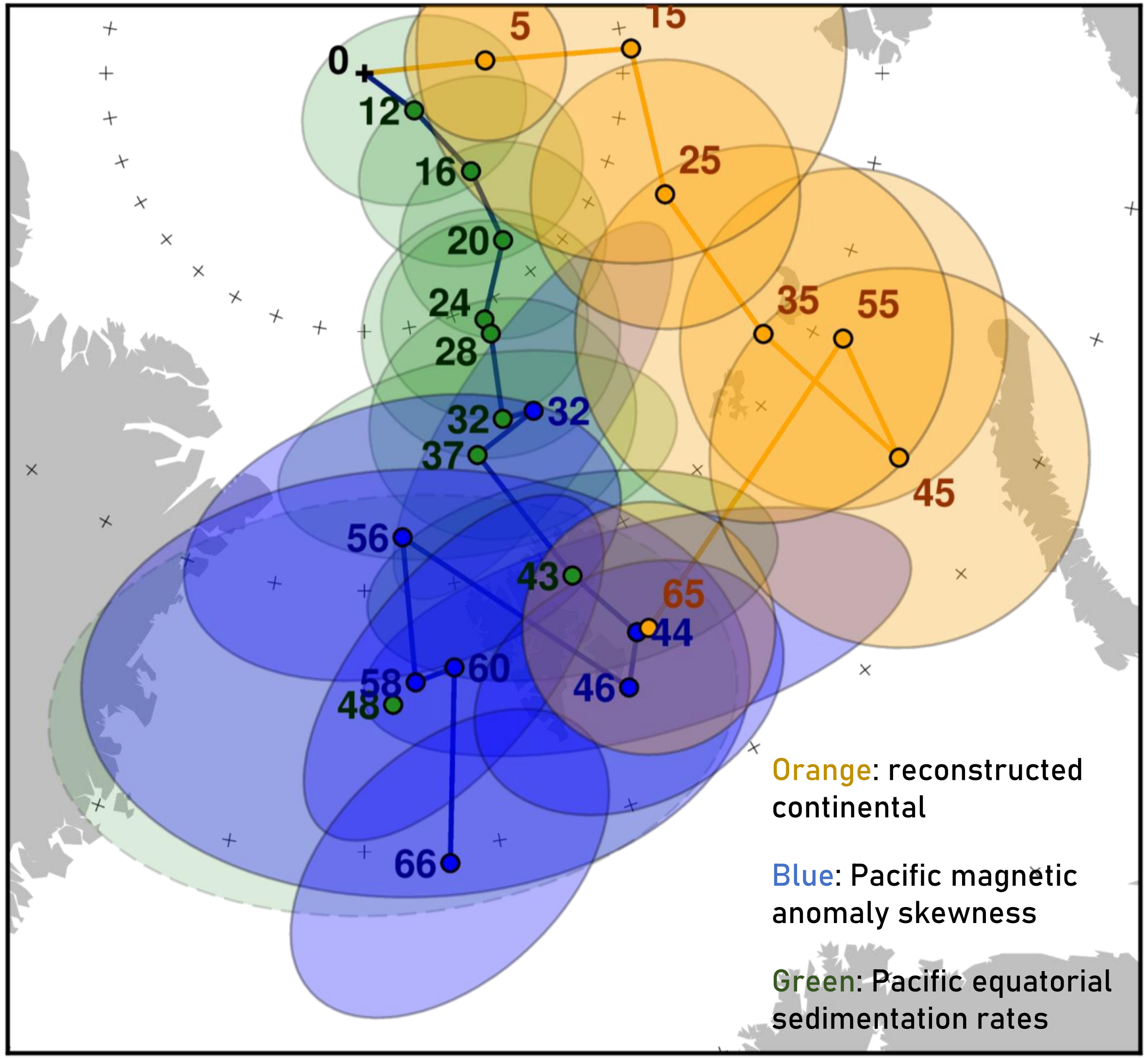


Paleolatitude and Paleoclimate

- Evaluating paleoclimate proxies requires accurate paleolatitude.
- Requires placing sites relative to the spin axis.
- Compilations of continental paleomagnetic poles have been used to estimate paleolatitudes globally (e.g. van Hinsbergen et al., 2015, who produced an easily accessible paleolatitude calculator: paleolatitude.org, shown at right)
- The van Hinsbergen method relies on
  1. The accuracy of the apparent polar wander path
  2. The accuracy of the plate circuit

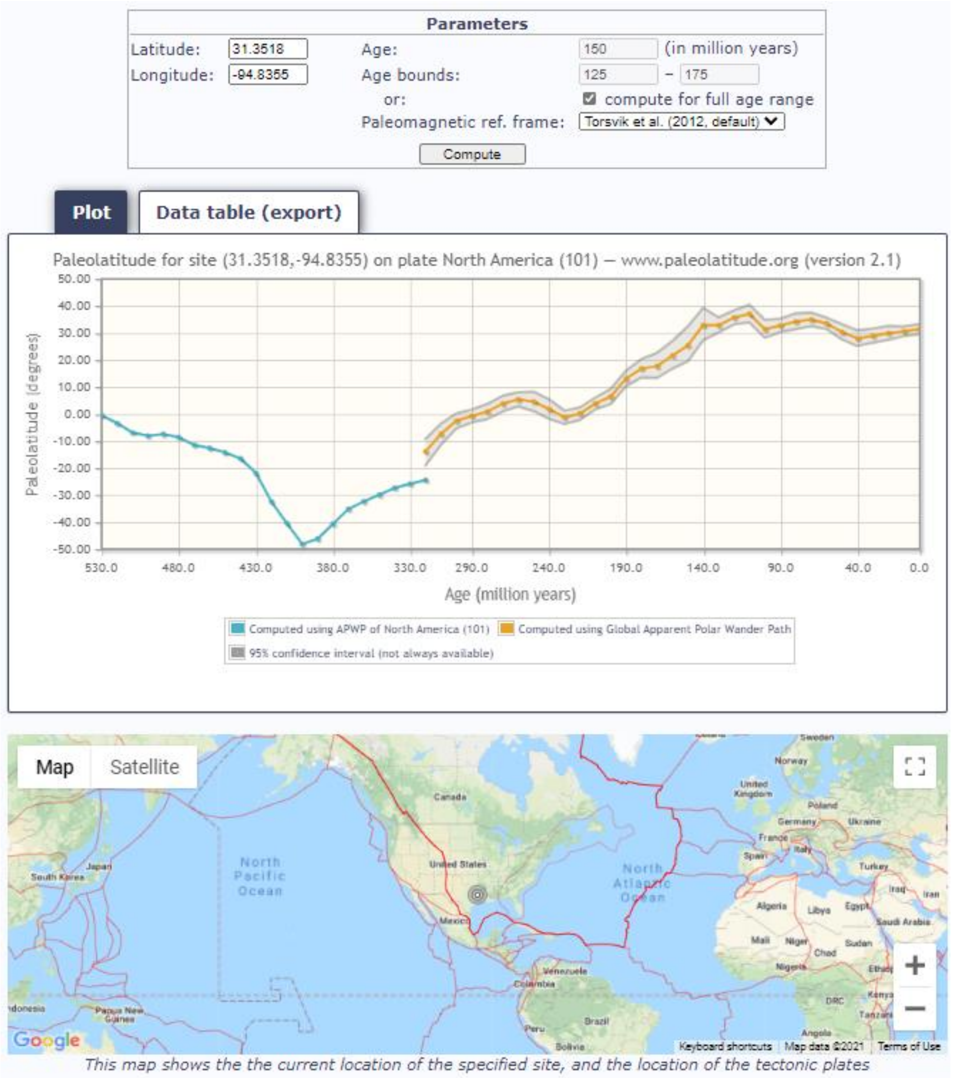
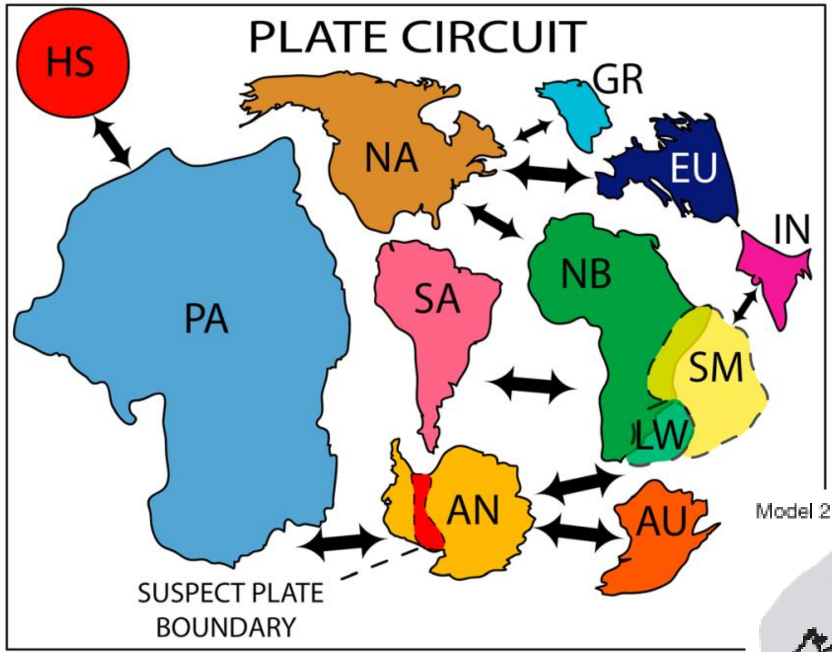
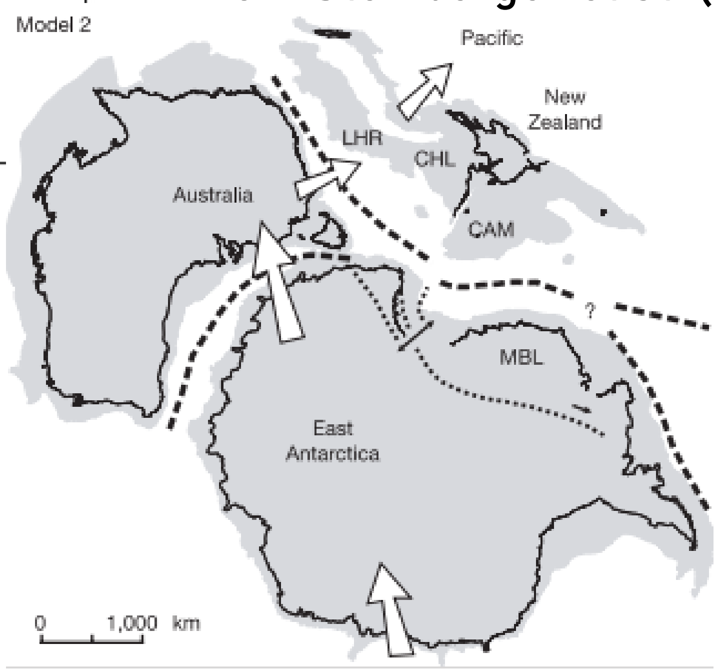


Plate Circuit Reliability



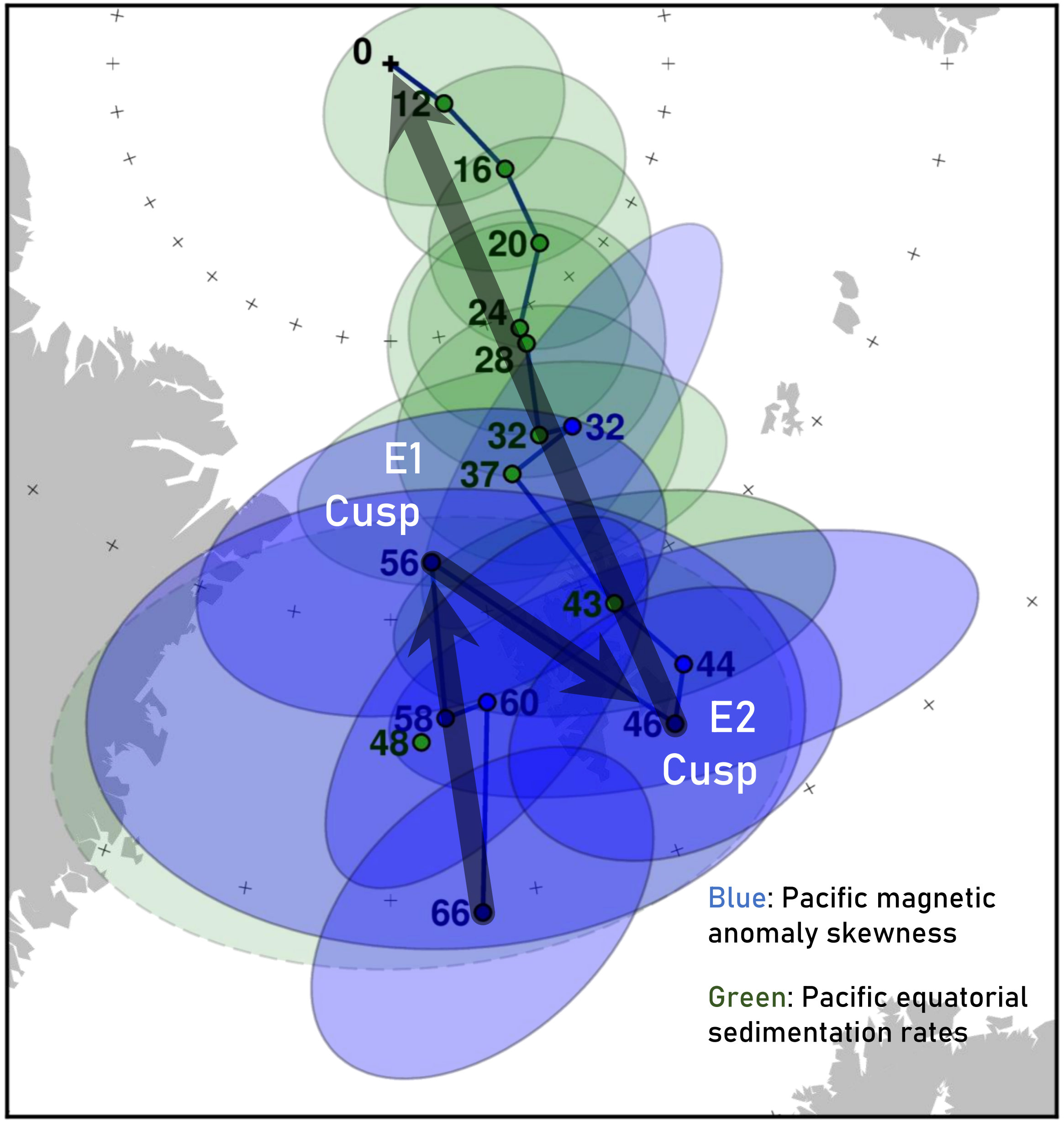
From Koivisto et al. (2014)

From Steinberger et al. (2004)



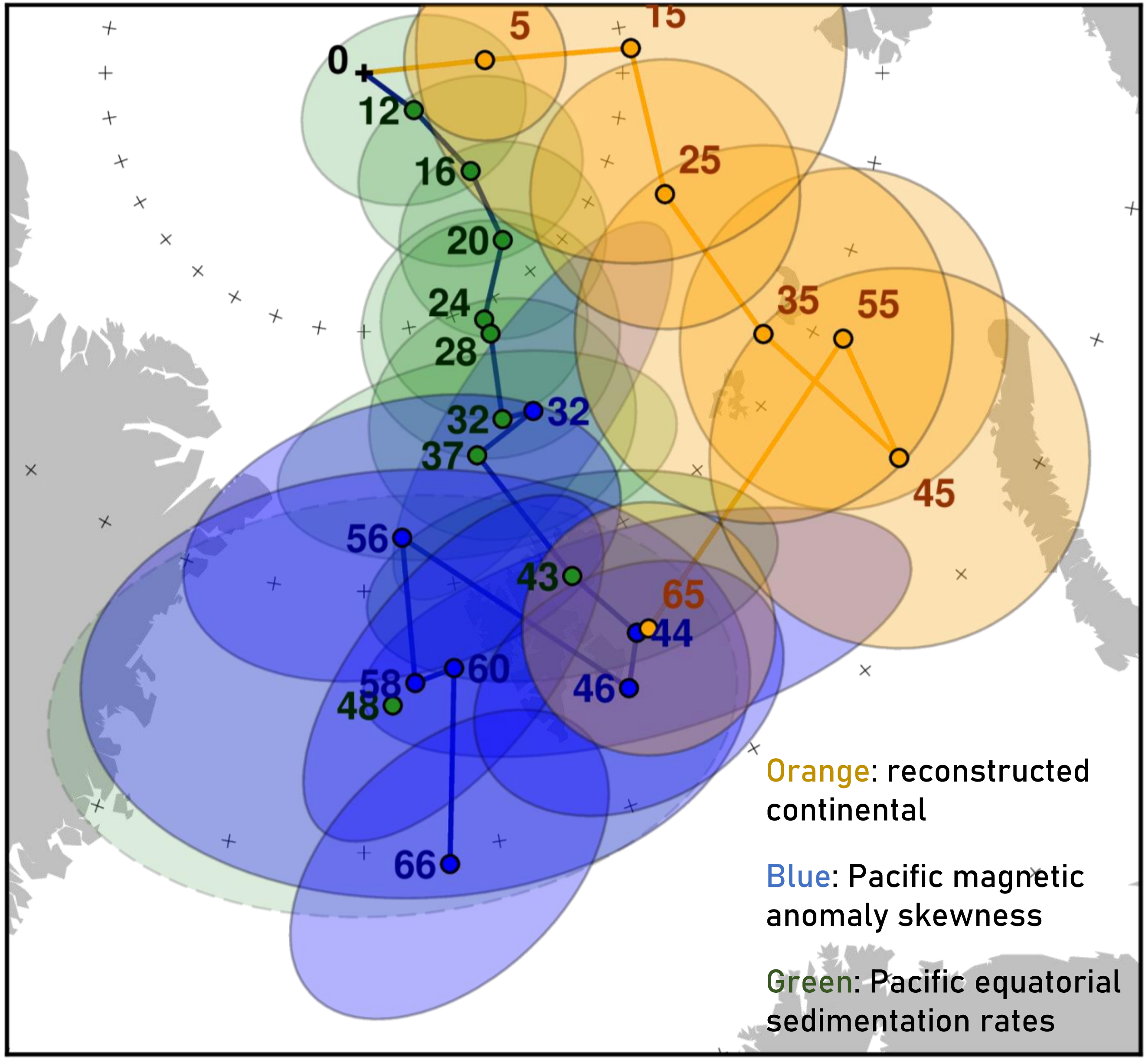
- Reliability of the plate circuit through Antarctica has been questioned.
- Inconsistencies between Pacific and Indo-Atlantic paleomagnetic data may suggest flaws in the plate circuit.
  - May result from unidentified plate boundaries, including diffuse boundaries (e.g., Wiens et al. 1985), or intraplate deformation (e.g., Kumar & Gordon 2009; Kreemer & Gordon 2014; Mishra & Gordon 2016).
  - Current estimates of East-West Antarctica motion (e.g., Granot & Dyment 2018) may not capture all distributed deformation.
- A plate circuit through Australia and the Lord Howe Rise may be an alternative (e.g., Steinberger et al. 2004).

Pacific Apparent Polar Wander



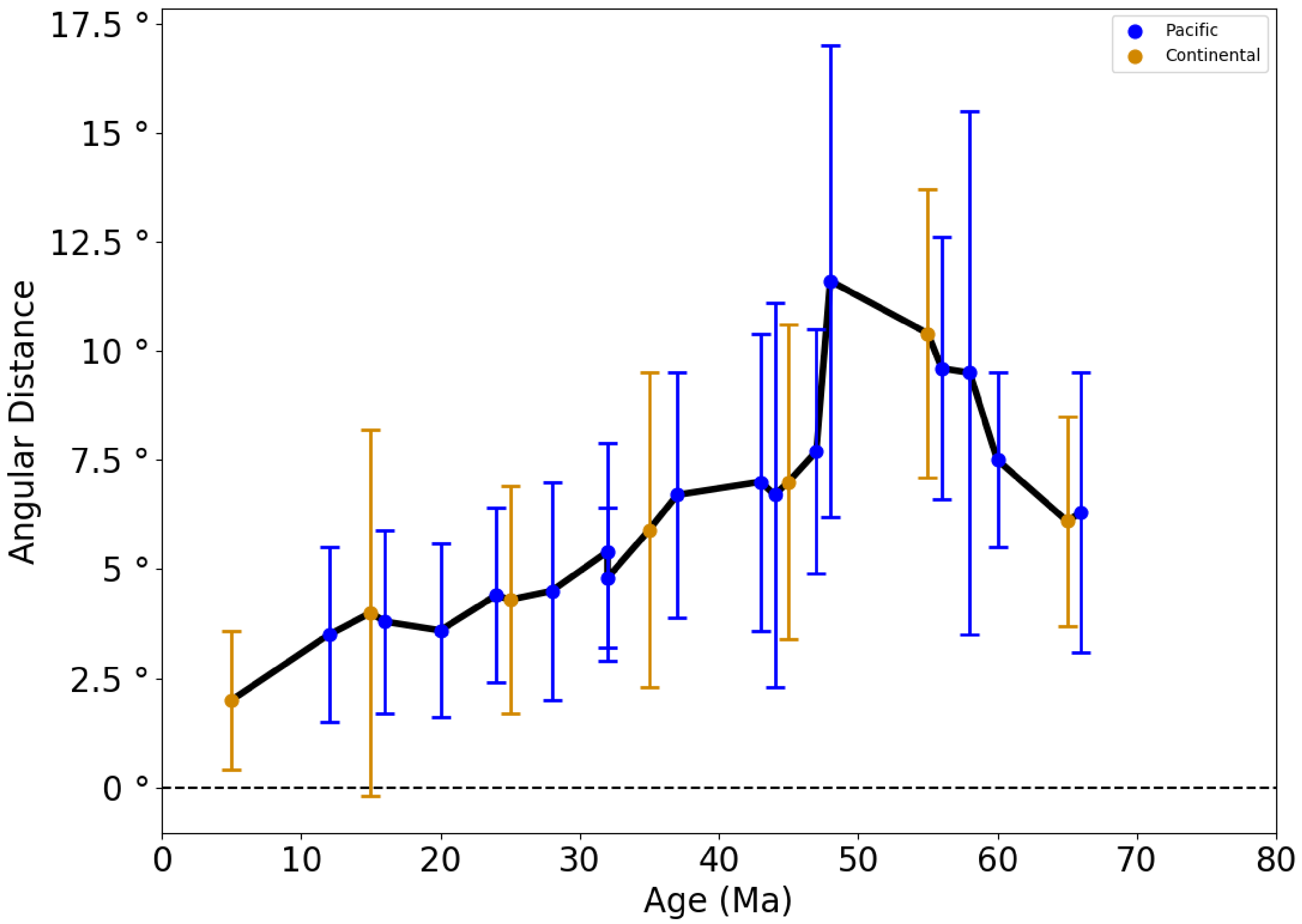
- Using both magnetic anomaly skewness and sediment accumulation rates improves temporal resolution.
  - Magnetic anomaly skewness determines paleopole location (blue).
  - Paleo-equatorial sediment bands independently locate the paleo-spin axis (green).
- Pacific apparent polar wander defines at least three tracks.
  - 66-56 Ma: northward motion
  - 56-46 Ma: southward motion and clockwise rotation
  - 46-0 Ma: northward motion and counter-clockwise rotation
- Separated by two cusps, E1 and E2.

Apparent Polar Wander Comparison



- Mean continental paleomagnetic poles (non-overlapping 10-Ma windowed means determined from Torsvik et al. 2012 compilation) in orange
- Rotated through a plate circuit through Antarctica into the Pacific plate frame
- Continental paleopoles differ significantly (95% c.l.) from coeval Pacific plate poles for 65-25 Ma.
- Differences between indigenous Pacific plate poles and reconstructed continental poles(Suarez & Molnar 1980; Gordon & Cox 1980; Acton & Gordon 1994) require an explanation.

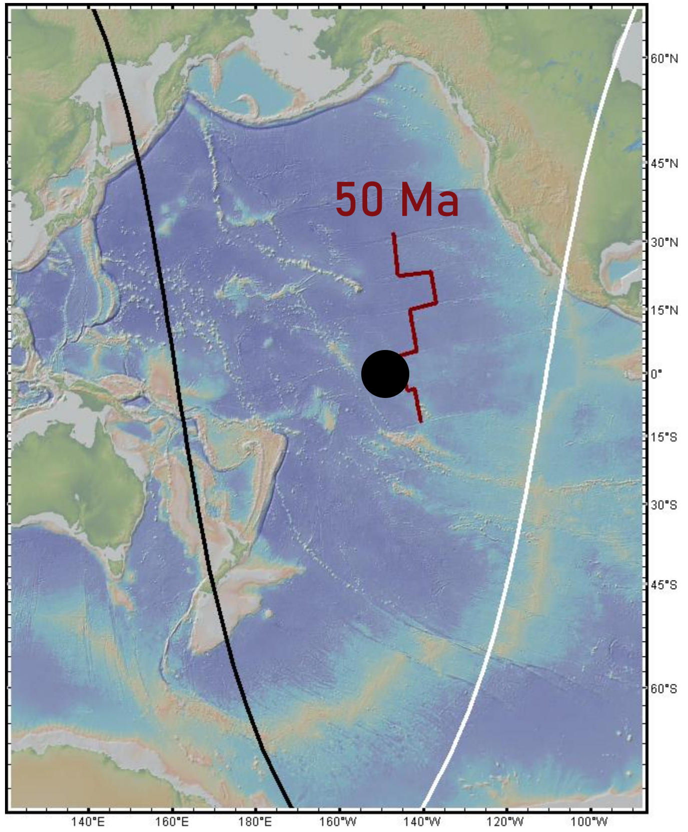
Evolution of Angular Distance Between APWPs
(Pacific Plate Reference Frame)

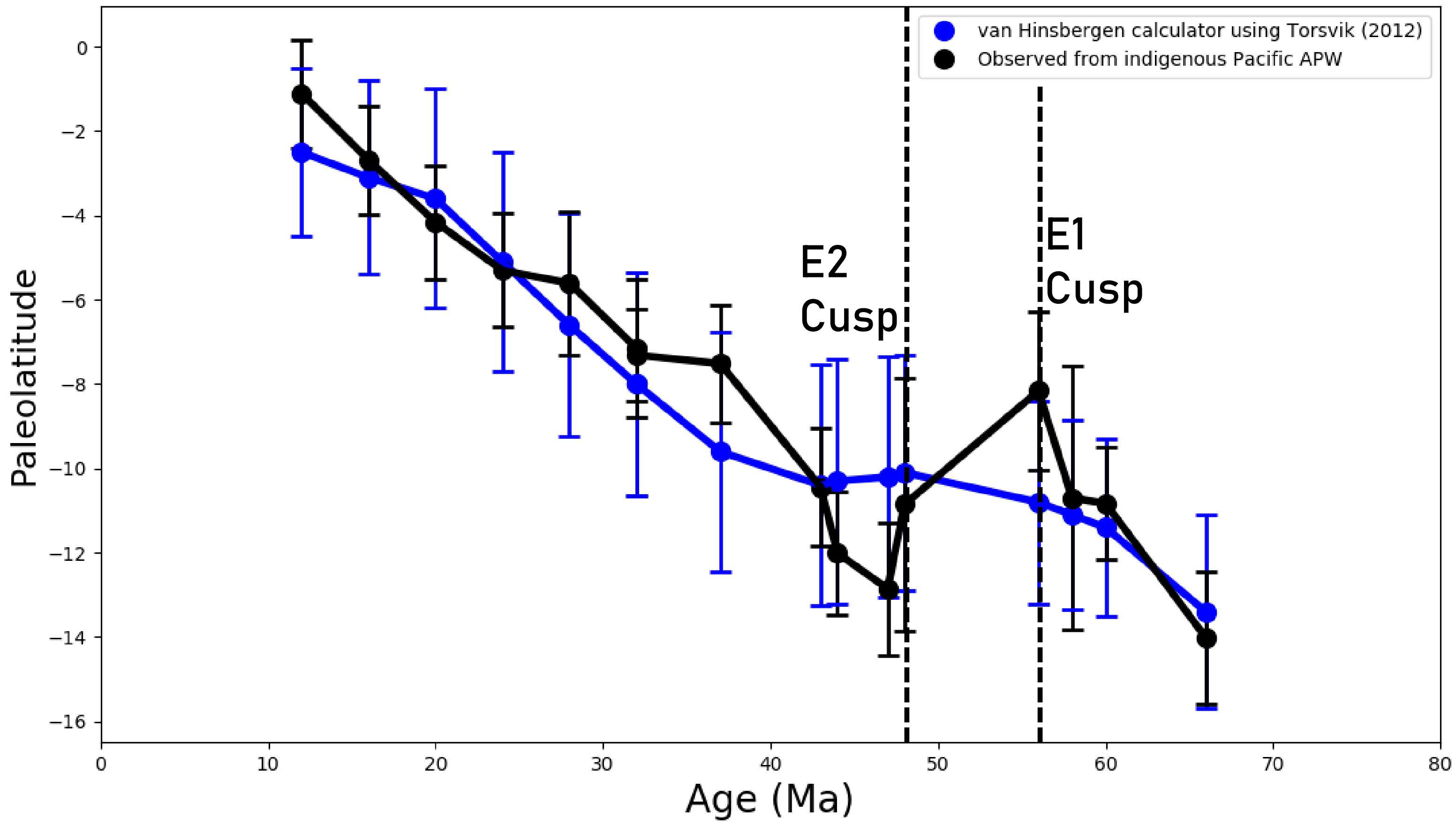


- Great-circle distance between continental APWP and PA APWP
- Error bars are 2D 95% confidence limits.
- Exclude nominal APWPs at 95% confidence
- Difference between APWPs increases with time until ≈47 Ma
  - 2.0±1.6° (5 Ma)
  - 7.7±2.8° (47 Ma)
- No significant change from 47 to 66 Ma.

Paleolatitudes for Pacific plate reference point (0°N, 150°W)

- Red 50-Ma isochron shows easternmost extent of paleo-Pacific plate.
- Largest paleolatitude change from E1 to E2 cusps occurs at 50-Ma isochron (e.g., near 0°N, 150°W).

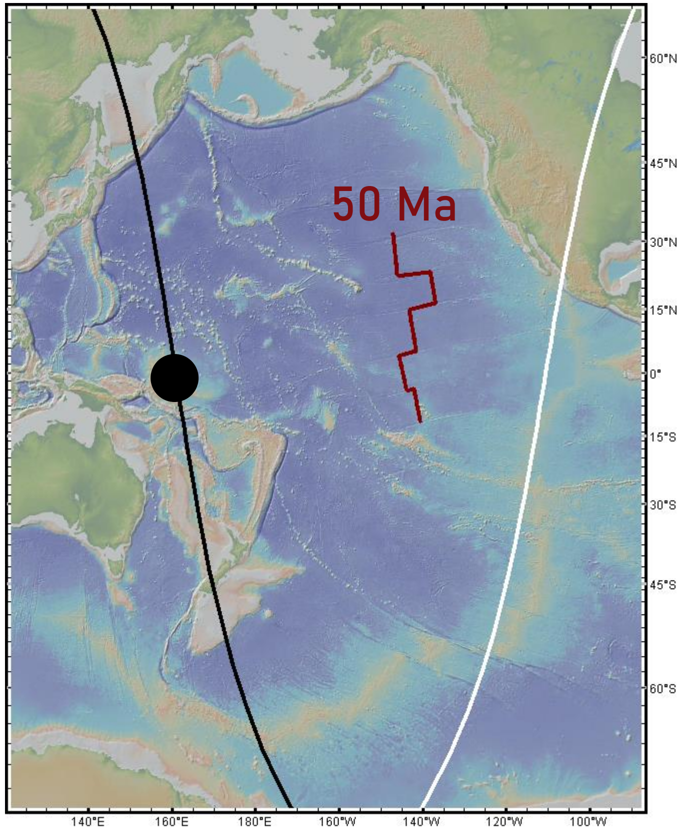


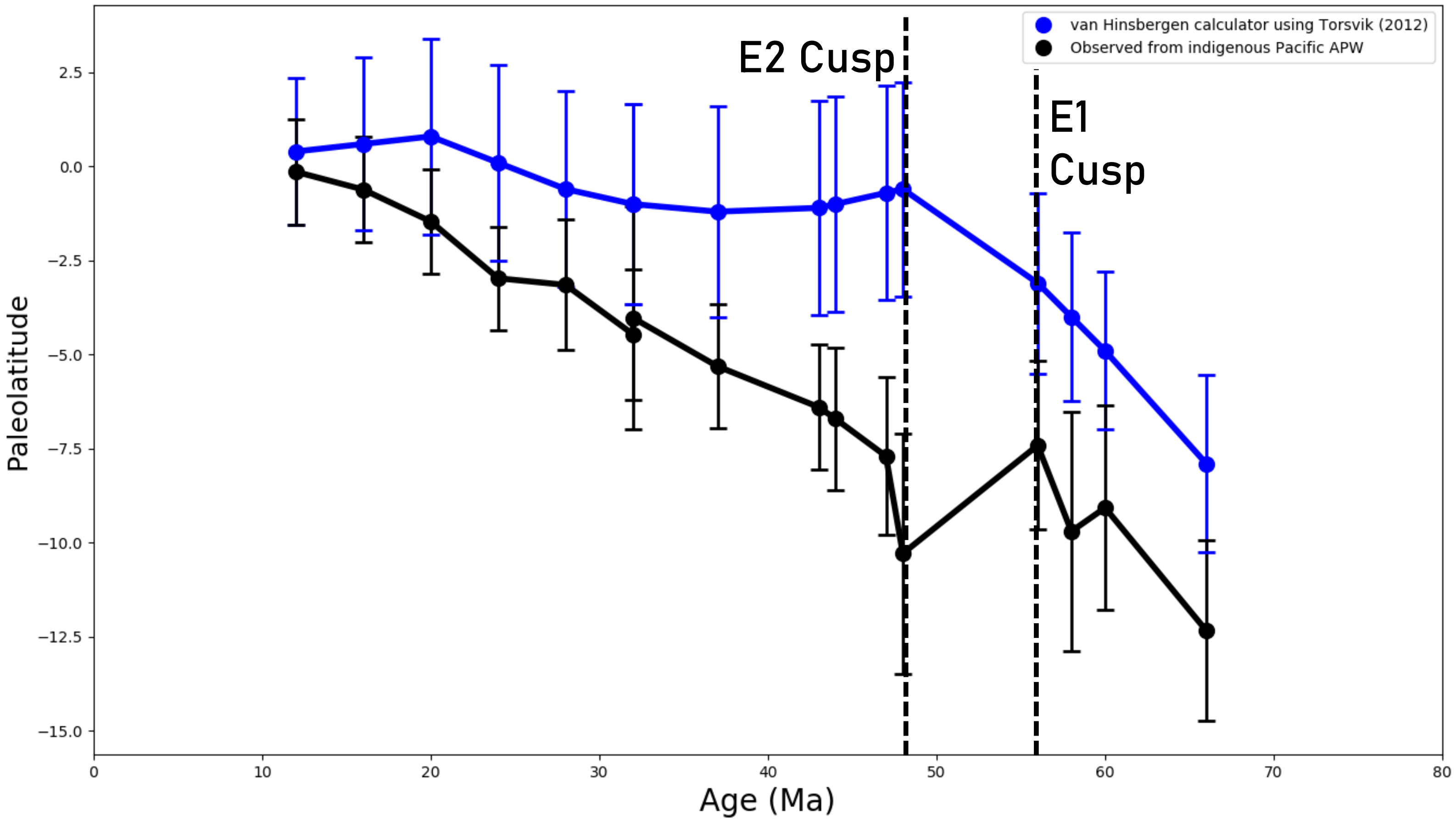


- Predicted paleolatitude from van Hinsbergen et al. (2015) calculator (blue) using continental APWP of Torsvik et al. (2012).
- Paleolatitude from Pacific APW (black) is similar to predicted
- Largest difference: 3.3°±3.1° (56 Ma)

Paleolatitudes for Pacific plate reference point (0°N, 160°E)

- The smallest paleolatitude change from E1 to E2 cusps is expected in the western Pacific plate (e.g., 0°N, 150°E)

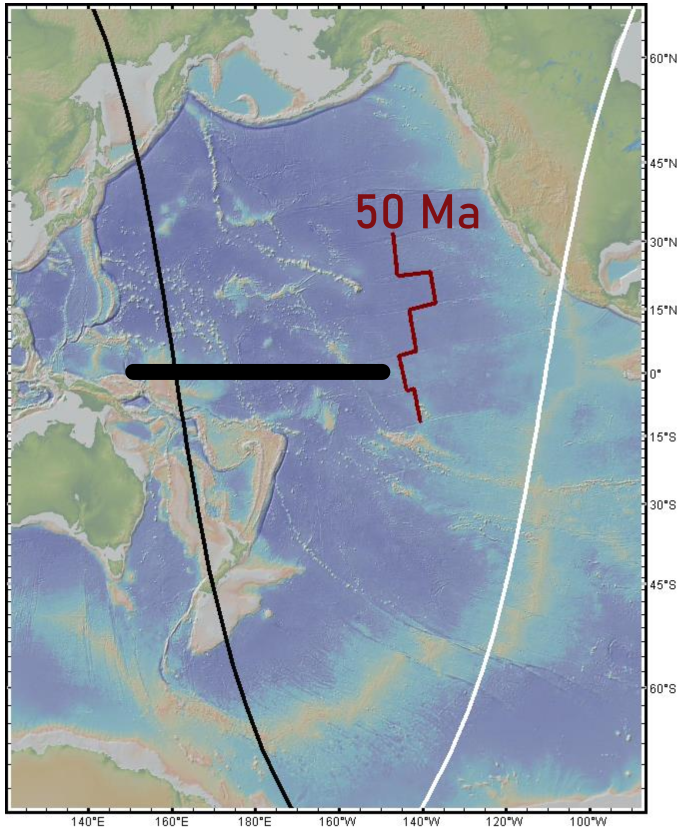


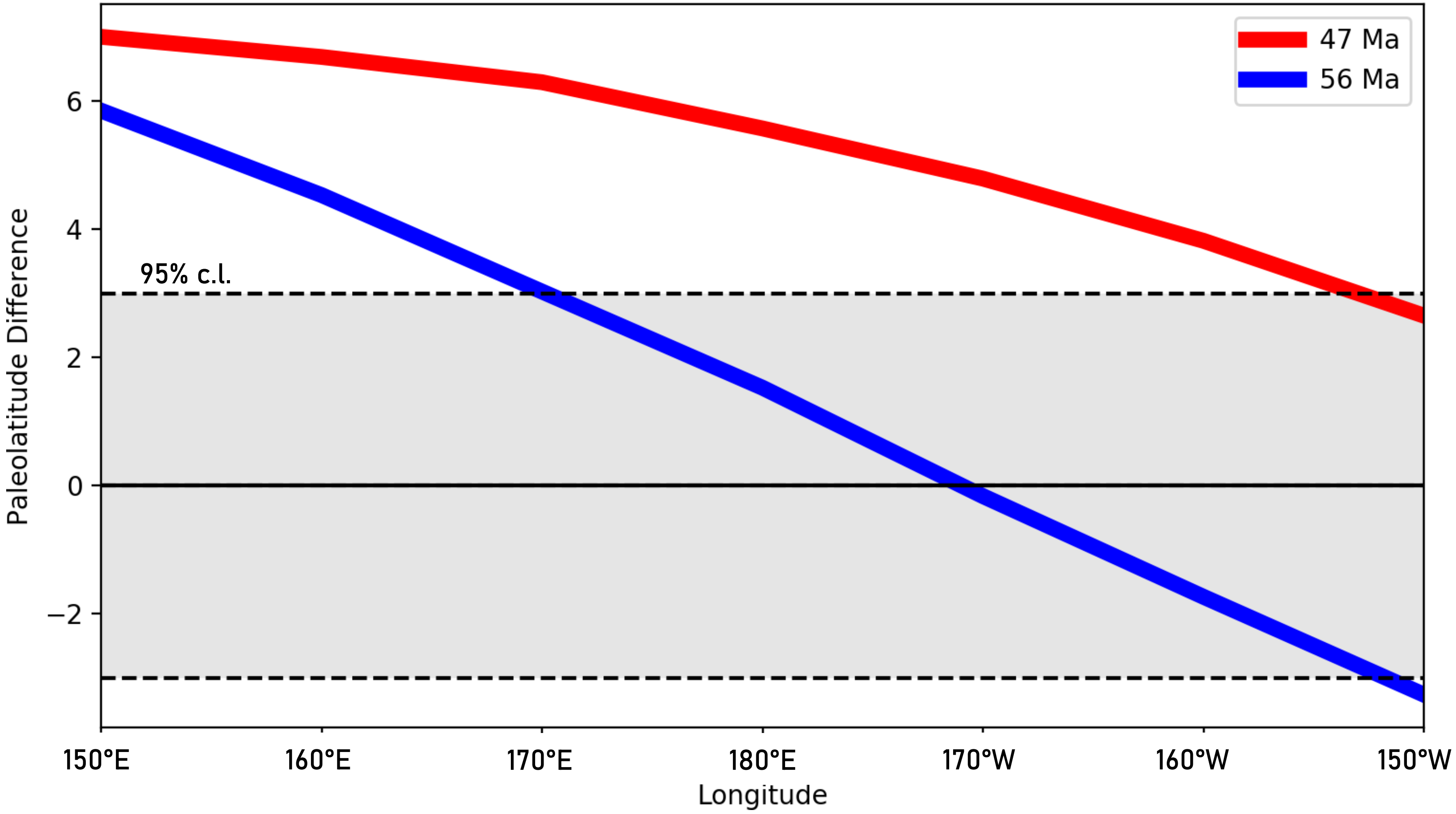


- Paleolatitude determined from indigenous Pacific plate APW differs from van Hinsbergen calculator (up to ≈10°).
- Differs at 95% c.l. from 37 to 66 Ma.

Longitudinal Variation of Difference Between Observed and Calculator Paleolatitude

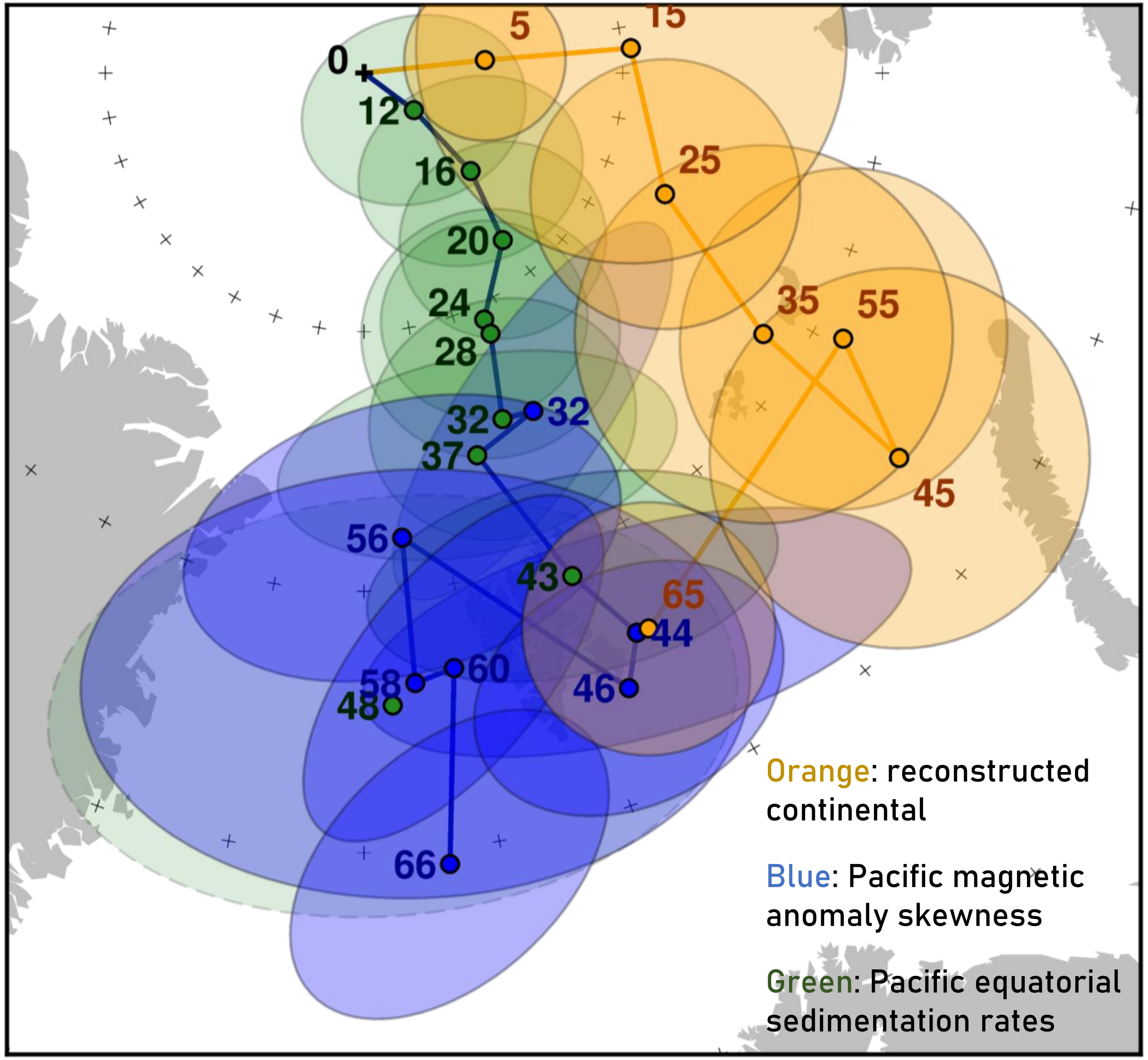
- ➢ A great-circle segment (150°E-150°W) along the equator captures longitudinal variation in paleolatitude discrepancy.





- ➢ Observed minus calculator increases westward.
- ➢ Larger difference at 47 Ma than 56 Ma for most longitudes.
- ➢ At 47 Ma nearly all calculator paleolatitudes differ significantly from observed.

Summary



- Differences in APWP are significant for reconstructed continental paleopoles 25 Ma and older
- Angular distance between APWPs increases to ≈8° by 47 Ma
- Differences in paleolatitude vary with longitude and age, but are significant across the Pacific plate at 47 Ma
- Paleolatitude frameworks must incorporate this discrepancy between Pacific and continental paleolatitude to be truly global.