Pérez-Díaz, Eagles and Sigloch (in review) | DrPerezDiaz

Indo-Atlantic plate accelerations and tectonic reorganisations in the Late Cretaceous: no need for plume-push forces

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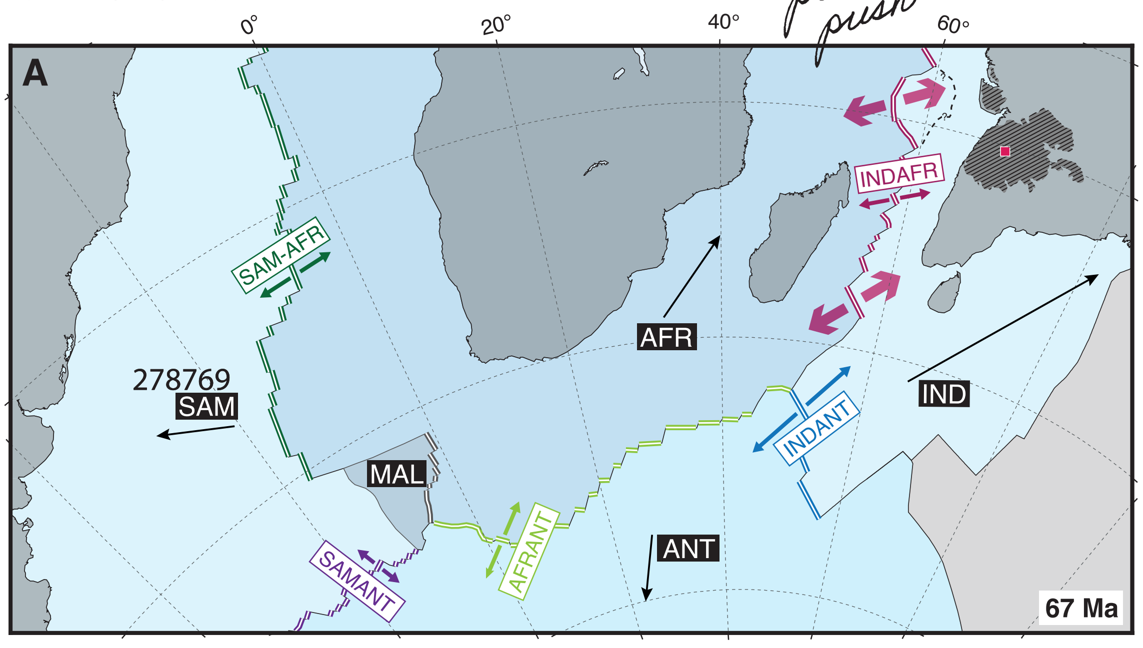
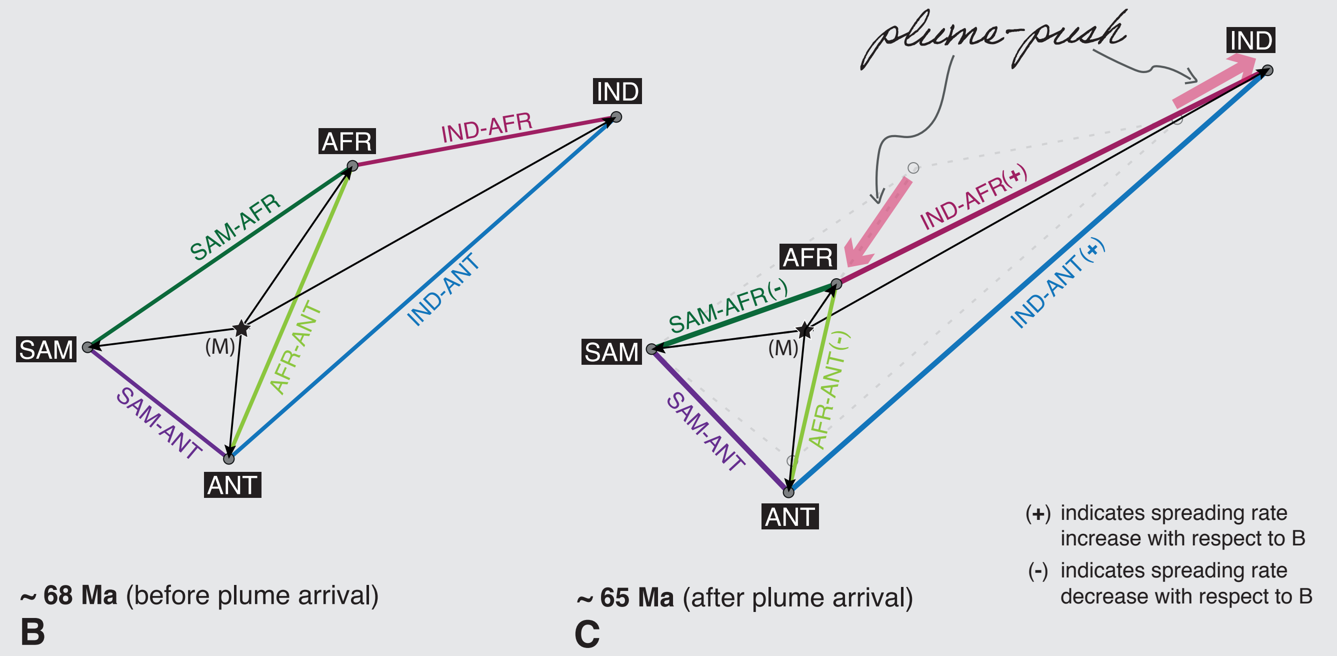
It has been suggested that the arrival of plumes at the base of the lithosphere introduces a 'plume-push force' capable of overwhelming the balance of torques driving entire plate circuits and leading to plate tectonic reorganisations (A-C).

The **Deccan-Réunion plume**, which ascended beneath the southwestern part of the northwards-moving Indian plate at 67-63 Ma, is a much-studied example:



(A) The Indo-Atlantic plate circuit at 67 Ma (according to Eagles and Hoang, 2013; Eagles and Wibisono, 2013; Pérez-Díaz and Eagles, 2014; Tuck-Martin et al., 2018, this study), reconstructed in the hotspot reference frame of O'Neill et al. (2005). Red square and black hashing: location of the Réunion plume head and extent of Deccan volcanism (O'Neil et al. 2005). Black arrows: vectors describing instantaneous plate motion with respect to the mantle. Arrow lengh is indicative of plate speed. Coloured arrows: spreading direction across plate boundaries. Arrow lengh is indicative of spreading rate.

can plume-related forces overwhelm entire plate circuits???



(B), (C) Velocity triangles describing plate motions with respect to the mantle (M) immediately before and inmediatly after plume arrival, respectively. Black arrows (plate speeds and azimuths) and colored lines (spreading rates and azimuths) are also shown in panel A. (C) shows the effects on the entire plate circuit of the shortening of the AFR-M and lenghening of the IND-M vectors as a result of the introduction of a plume push force (as suggested by Cande and Stegman, 2011). Plates are African (AFR), Antarctic (ANT), Indian (IND), and South American (SAM).

Reunion **plume arrival** at ~67 Ma

observed to coincide with...

speed-up of India
&
slowdown of Africa

(Cande and Stegman, 2011; van Hinsbergen et al., 2011)

has led to...

changes across the entire Indo-Atlantic circuit being interpreted in terms of the introduction of "plume-push" forces

(increasing spreading rates between IND-ANT, IND-AFR; decreasing between SAM-AFR, AFR-ANT)

we test this hypothesis

METHOD

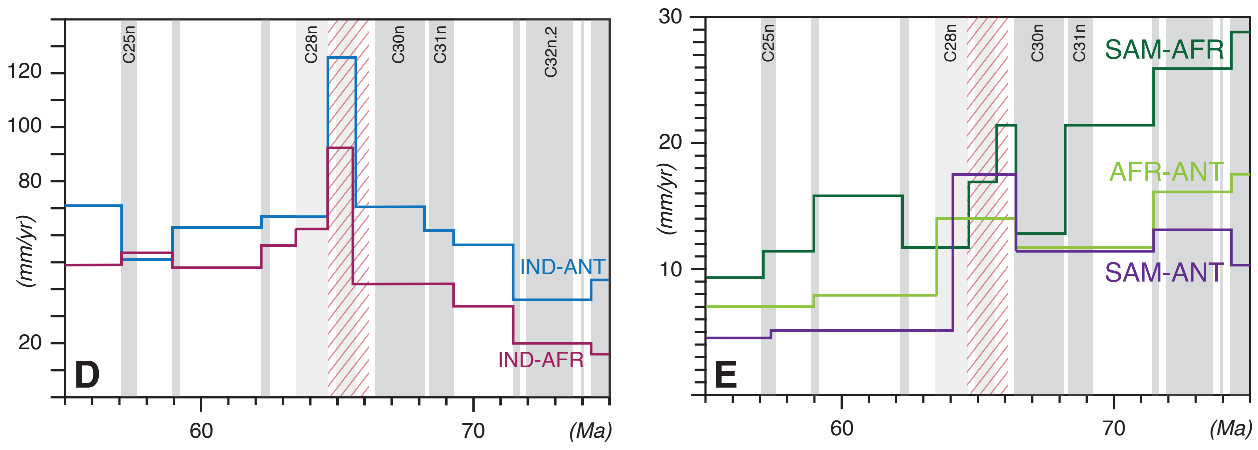
Using existing and newly-calculated plate kinematic models, each of considerably higher resolution over the K-Pg boundary than those considered by previous studies, we calculate spreading rates for the five plate pairs in the Indo-Atlantic circuit, and we test the presence or absence of a short-lived changes in spreading rates during the latest Cretaceous-earliest Tertiary previously interpreted as evidence that plumes arriving at the base of the lithosphere can have large periodic effects on lithospheric plate motions .

RESULTS

Q: Do spreading rates reflect an increase in Indian and decrease in African plate motions at the time of plume arrival (as previously suggested, and as it would be expected from the introduction of a plume-push force)?

A: No! Our higher resolution results in fact show that short-lived divergence rate peaks exist for every spreading ridge across the entire circuit.

If the increase in spreading rates across all five plate pairs at C29 (65-67 Ma) is disregarded, spreading rates along ridges either side of the African plate anticorrelate over a long period starting ~84-74 Ma and continuing into the early Paleocene.



(D, E) Half-spreading rate changes for the five plate pairs in the Indo-Atlantic circuit, according to the models of Eagles and Hoang, 2013 (IND-AFR); Eagles, 2019 (IND-ANT); Eagles, 2016 (IND-ANT); Tuck-Martin et al., 2018 (AFR-ANT), and this study (SAM-AFR). Light gray bars: magnetic reversal timescale of Gradstein F.M. et al. (2012). Red hashing: Deccan-Reunion volcanism. AFR: Africa; ANT: Antarctica; IND: India; SAM: South America.

INTERPRETATION

A magnetic reversal timescale error

The primary evidence supporting the plume-push hypothesis is a sharp short-lived IND-AFR and IND-AFR divergence rate increase and simultaneous AFR-ANT and SAM-AFR divergence rate decrease at around 67 Ma. For the first time, we instead show that a short-lived spike in divergence rates exists for **all plate pairs** in the Indo-Atlantic circuit (D,E). This is impossible to reconcile with the introduction of a plume-push force and is best explained in terms of an error in the geochronological timescale affecting C29-C28.

Long-term African torque balance

If the divergence rate increases at C29-C28 are disregarded as artefacts of a timescale error, the long-term trends (IND-AFR and IND-ANT accelerating, SAM-AFR and AFR-ANT decelerating) are easily explained in terms of the changes in the contribution of the IND-AFR maturing ridge (which initiated at ~89 Ma) to the balance of torques on the African plate.

IN A NUTSHELL...

- **We find no evidence that plume-push forces play a significant role in driving plate motions**
- **We identify a possible error in the magnetic reversal timescale affecting the period around the much-studied K-Pg boundary**

We reach these conclusions after testing plume-push hypothesis by revisiting the principal evidence supporting it, finding that...

a) Pulse in IND-AFR and IND-ANT divergence rates at the time of Reunion plume arrival ✗

Our higher resolution results show ubiquitous spikes in divergence rates across the entire circuit: incompatible with the effects of plume-related forces and best explained in terms of a timescale error

b) Anticorrelating divergence rates (IND-AFR and IND-ANT accelerating & SAM-AFR and AFR-ANT decelerating) ✗

Divergence rates either side of Africa do anticorrelate, but over a much longer period than previously suggested (84-63 Ma) - best explained in terms of gradual changes to the African torque balance by the maturing IND-AFR ridge.