# **Forum** Comment

https://doi.org/10.1130/G49940C.1

## Could the Réunion plume have thinned the Indian craton?

**Gaoxue Yang***
School of Earth Science and Resources, Chang'an University, Xi'an 710054, China
*E-mail: ygx@chd.edu.cn

Paul and Ghosh (2022) construct time-dependent forward mantle convection models from 65 Ma to the present day, in order to test whether the Réunion plume activity could have reduced the Indian craton thickness, with potential implications on the higher velocity of the Indian plate since 65 Ma. However, the details of the evidence and interpretation are imprecise, so this Comment (and the associated Reply) will provide some clarity on the theme of plume-induced lithosphere thinning beneath the Indian craton.

Thick cratonic lithosphere is generally considered to be stable and dynamically inactive since it was formed. However, some cratons have had unique tectonic evolution, which has resulted in the removal of their lithospheric root (e.g., Wu et al., 2019; Singh et al., 2021). For example, Paul and Ghosh argued that the Indian craton have a thinner lithosphere, which is confirmed by geological observations and numerical models (Kumar et al., 2007; Maurya et al., 2016; Mandal, 2017). The thinning of the Indian craton is a geological fact, but when the thinning began is a key issue for mechanisms of the craton thinning. This point is confused in the paper by Paul and Ghosh.

Although lots of references are cited to show the Indian craton thinning, Paul and Ghosh did not provide and discuss the time of craton thinning. A magnetotelluric investigation found the Indian craton thickness to be at least 200 km, and also suggested that the lithosphere has not been eroded since the Precambrian (Naganjaneyulu and Santosh, 2012). In another study, Mandal (2017) reported a thin lithosphere of 78 km by P-wave receiver function, which could be attributed to the 1.6 Ga plume activity. Recently, using an integrated approach, Singh et al. (2021) illustrated a missing lithospheric root beneath the eastern Indian craton, also shown that the thinning of lithosphere (~135 km) is likely to be associated with the thermochemical erosion after the late Archean. Above results indicate that the Indian craton thinning took place since at least late Archean, but not started at the time of the Réunion plume eruption at ca. 67 Ma (Cande and Stegman, 2011).

A key prediction of Paul and Ghosh's model is that a total of ~130 km of the Indian craton root has been reduced only by Réunion plume. Why not are other plumes, which are shown in Paul and Ghosh's figure 1? Actually, the Indian plate, since breakup from Gondwanaland at ca. 130 (Gaina et al., 2007), was influenced by four major plumes; namely, the Marion, Crozet, Kerguelen and Réunion (Torsvik et al., 2008), although their role in thinning of the lithosphere cannot be ascertained. Petrology and geochemistry studies indicate that basalts and mafic dikes in the Rajmahal trap are suggestive of their linkage to the Kerguelen plume activity (Ingle et al., 2004).

Additionally, because Paul and Ghosh's model does not produce melt generated from the Réunion plume, it may be inconsistent with the geological facts. Many studies already confirmed that the generation of large quantities of melt by decompression of the Réunion plume (e.g., Haase et al., 2019; Sharma et al., 2021). Most of the large igneous provinces worldwide predict that melt generation will occur almost entirely within the plume head, beneath the lithosphere (e.g., Koppers et al., 2021). So the plume material shown in Paul and Ghosh's model probably contains a large amount of melt.

A final note should be made concerning geodynamic mechanism of the rapid drift of the Indian plate. Paul and Ghosh proposed that a lubricated lithosphere-asthenosphere boundary caused by the Réunion plume is a potential reason for the rapid movement of the Indian plate until ca. 50 Ma (Cande and Stegman, 2011). Numerical models suggested that the effect of the Réunion plume could indeed accelerate the Indian plate drift. However, it is difficult for the plate speed to exceed 10 cm/yr (van Hinsbergen et al., 2011). Moreover, applying the $^{40}K$–$^{40}Ar$ technique to the Deccan lava, Chenet et al. (2007) considered that the plume activities have only a short-term effect, of less than ~3 m.y. It is also difficult to explain the high velocities of the Indian plate lasting for ~15 m.y. Alternatively, we could discuss the rapid drift of the Indian plate through integrating plume activities and plate tectonics (such as slab pull and ridge push), but one of them cannot play both roles.

### REFERENCES CITED

Cande, S.C., and Stegman, D.R., 2011, Indian and African plate motions driven by the push force of the Reunion plume head: Nature, v. 475, p. 47–52, https://doi.org/10.1038/nature10174.

Chenet, A., Quidelleur, X., Fluteau, F., Courtillot, V., and Bajpai, S., 2007, 40K-40Ar dating of the Main Deccan large igneous province: Further evidence of KTB age and short duration: Earth and Planetary Science Letters, v. 263, p. 1–15, https://doi.org/10.1016/j.epsl.2007.07.011.

Gaina, C., Müller, R.D., Brown, B., and Ishihara, T., 2007 Breakup and early seafloor spreading between India and Antarctica: Geophysical Journal International, v. 170, p. 151–169, https://doi.org/10.1111/j.1365-246X.2007.03450.x.

Haase, K.M., Regelous, M., Schöbel, S., Günther, T., and de Wall, H., 2019, Variation of melting processes and magma sources of the early Deccan flood basalts, Malwa Plateau, India: Earth and Planetary Science Letters, v. 524, 115711, https://doi.org/10.1016/j.epsl.2019.115711.

Ingle, S., Scoates, J.S., Weis, D., Brügmann, G., and Kent, R.W., 2004, Origin of Cretaceous continental tholeiites in southwestern Australia and eastern India: Insights from Hf and Os isotopes: Chemical Geology, v. 209, p. 83–106, https://doi.org/10.1016/j.chemgeo.2004.04.023.

Koppers, A.A.P., Becker, T.W., Jackson, M.G., Konrad, K., Müller, R.D., Romanowicz, B., Steinberger, B., and Whittaker, J.M., 2021, Mantle plumes and their role in Earth processes: Nature Reviews Earth & Environment, v. 2, p. 382–401, https://doi.org/10.1038/s43017-021-00168-6.

Kumar, P., Yuan, X., Kumar, M.R., Kind, R., Li, X., and Chadha, R.K., 2007, The rapid drift of the Indian tectonic plate: Nature, v. 449, p. 894–897, https://doi.org/10.1038/nature06214.

Mandal, P., 2017, Lithospheric thinning in the Eastern Indian Craton: Evidence for lithospheric delamination below the Archean Singhbhum Craton?: Tectonophysics, v. 698, p. 91–108, https://doi.org/10.1016/j.tecto.2017.01.009.

Maurya, S., Montagner, J.-P., Kumar, M.R., Stutzmann, E., Kiselev, S., Burgos, G., Rao, N.P., and Srinagesh, D., 2016, Imaging the lithospheric structure beneath the Indian continent: Journal of Geophysical Research: Solid Earth, v. 121, p. 7450–7468, https://doi.org/10.1002/2016JB012948.

Naganjaneyulu, K., and Santosh, M., 2012, The nature and thickness of lithosphere beneath the Archean Dharwar Craton, southern India: A magnetotelluric model: Journal of Asian Earth Sciences, v. 49, p. 349–361, https://doi.org/10.1016/j.jseaes.2011.07.002.

Paul, J., and Ghosh, A., 2022, Could the Réunion plume have thinned the Indian craton?: Geology, v. 50, p. 346–350, https://doi.org/10.1130/G49492.1.

Sharma, J., Kumar, M.R., Roy, K.S., Pal, S.K., and Roy, P.N.S., 2021, Low-velocity zones and negative radial anisotropy beneath the plume perturbed northwestern Deccan volcanic province: Journal of Geophysical Research: Solid Earth, v. 126, p. e2020JB020295, https://doi.org/10.1029/2020JB020295.

Singh, A.P., Kumar, N., Rao, B.N., and Tiwari, V.M., 2021, Geopotential evidence of a missing lithospheric root beneath the eastern Indian shield: An integrated approach: Precambrian Research, v. 356, 106116, https://doi.org/10.1016/j.precamres.2021.106116.

Torsvik, T.H., Steinberger, B., Cocks, L.R.M., and Burke, K., 2008, Longitude: Linking Earth's ancient surface to its deep interior: Earth and Planetary Science Letters, v. 276, p. 273–282, https://doi.org/10.1016/j.epsl.2008.09.026.

van Hinsbergen, D.J.J., Steinberger, B., Doubrovine, P.V., and Gassmöller, R., 2011, Acceleration and deceleration of India-Asia convergence since the Cretaceous: Roles of mantle plumes and continental collision: Journal of Geophysical Research, v. 116, B06101, https://doi.org/10.1029/2010JB008051.

Wu, F.-Y., Yang, J.-H., Xu, Y.-G., Wilde, S.A., and Walker, R.J., 2019, Destruction of the North China craton in the Mesozoic: Annual Review of Earth and Planetary Sciences, v. 47, p. 173–195, https://doi.org/10.1146/annurev-earth-053018-060342.