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Plate-mantle coupling from post-Pangea plate kinematics

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Convection in the Earth's mantle that involves plates at the surfaces gives rise to plate velocities that vary through time and depend on the balance of plate boundary forces, with the present-day providing a snapshot of this ongoing process. However, present-day plate velocities do not capture plate behaviour over geologically representative time-frames and thus cannot be used to evaluate factors limiting plate velocities. Previous studies investigated the effects of continental keels on plate speeds by either using the present-day snapshot or a limited number of reconstructed plate configurations, often leading to conflicting results. For example, an early assumption was that continental keels (especially cratons) were unlikely to impede fast plate motions because India's velocity approached ∼20 cm/yr in the Eocene prior to the collision with Eurasia. We employ a modern plate reconstruction approach with evolving global topological plate boundaries for the post-Pangea timeframe (since 200 Ma) to evaluate factors controlling plate velocities. Plate boundary configurations and plate velocities are extracted from the open-source and cross-platform plate reconstruction package GPlates (www.gplates.org) at 1 Myr intervals. For each plate, at each timestep, the area of continental and cratonic lithosphere is calculated to evaluate the effect on plate velocities. Our results support that oceanic plates tend to be 2-3 times faster than plates with large portion of continental plate area, consistent with predictions of numerical models of mantle convection. The fastest plates (∼8.5 cm/yr RMS) are dominated by oceanic plate area and high subducting portion of plate perimeter, while the slowest plates (∼2.6-2.8 cm/yr RMS) are dominated by continental plate area and bounded by transforms and mid-oceanic ridge segments. Importantly, increasing cratonic fractions (both Proterozoic and Archean lithosphere) significantly impede plate velocities, suggesting that deep continental keels impinge on asthenospheric flow to increase shear traction, thus anchoring the plate in the more viscous mantle transition zone. However, plates with significant cratonic fragments exhibit short-lived (∼10 Myr) accelerations, such as the rapid motion of the Indian plate that is correlated with plume head arrivals as recorded by large igneous province (LIPs) emplacement, highlighting the necessity to analyse plate velocities over long geological timeframes. By evaluating factors controlling plate velocities in the post-Pangea timeframe, simple principles can be applied to highlight potential plate velocity artefacts for Paleozoic and earlier times for which no hotspot tracks, nor in-situ seafloor spreading histories, are preserved. Based on the post-Pangea timeframe, a principle that can be applied to pre-Pangea times is that plates with less than ∼50% continental area can reach RMS velocities of ∼20 cm/yr, while plates with more than 50% continental fraction do not exceed RMS velocities of ∼10 cm/yr. Similarly, plates with large portions of continental or cratonic area with RMS velocities exceeding ∼15 cm/yr for more than ∼10 Myr should be flagged as potential artefacts requiring further justification of plate driving forces in such scenarios.