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Evolution of the plate-mantle system since the late Paleozoic Period

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Detailed global plate motion models that provide a continuous description of plate boundaries through time are an effective tool for exploring processes both above and below Earth's surface. A new generation of numerical models of mantle dynamics pre- and post-Pangea timeframes requires global kinematic descriptions with full plate reconstructions extending into the Paleozoic Period. Current plate models that cover Paleozoic times assume that lowermost mantle structures are rigid and fixed through time, and anchor past plate motions to the present-day mantle structure. These reconstructions result in large plate speeds and trench migration rates, and when used as a surface boundary of geodynamic models, they do not accurately reproduce the present-day structure of the lowermost mantle. Building upon previous work, we developed a global plate motion model with continuously closing plate boundaries from 410 Ma to present day, using a Paleozoic paleomagnetic reference frame independent of any geodynamic assumptions.

We analysed our reconstruction in terms of surface kinematics and predicted lower mantle structure. The magnitude of global plate speeds and subduction zone kinematics were improved by modifying the evolution of the synthetic Panthalassa oceanic plates, the reference frame, and implementing revised models for the closure of the Rheic Ocean and the Paleozoic evolution of North and South China.

Paleozoic RMS plate speeds are on average ∼8 cm/yr, which is comparable to Mesozoic-Cenozoic average rates of ∼6 cm/yr. Paleozoic global median values of trench migration rates trend from higher speeds (∼2.5 cm/yr) in late Devonian times to closer to 0 cm/yr at the end of the Permian (∼250 Ma), and generally cluster tightly around ∼1.1 cm/yr during the Mesozoic-Cenozoic (250-0 Ma). Plate motions are best constrained over the past 130 Myr and calculations of global trench convergence rates over this period indicate median rates range between 3.2-12.4 cm/yr with a present day median rate estimated at ∼5 cm/yr. For Paleozoic times our model results in median convergence rates largely ∼5 cm/yr.

We use this new tectonic reconstruction as boundary condition of simulations of mantle flow, and find that the eastern margin of the African LLSVP margin has moved by as much as ∼1450 km since late Permian times (260 Ma), which challenges the proposed fixity of lower mantle structures. In addition, our new model for the evolution of the plate-mantle system since 410 Ma suggests that South China was proximal to the eastern margin of the African LLSVP during the Permian Period, and not the western margin of the Pacific LLSVP as previously proposed.