Supplementary material – A tectonic-rules based mantle reference frame since 1Ga – implications for supercontinent cycles and plate-mantle system evolution

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Supplementary figures

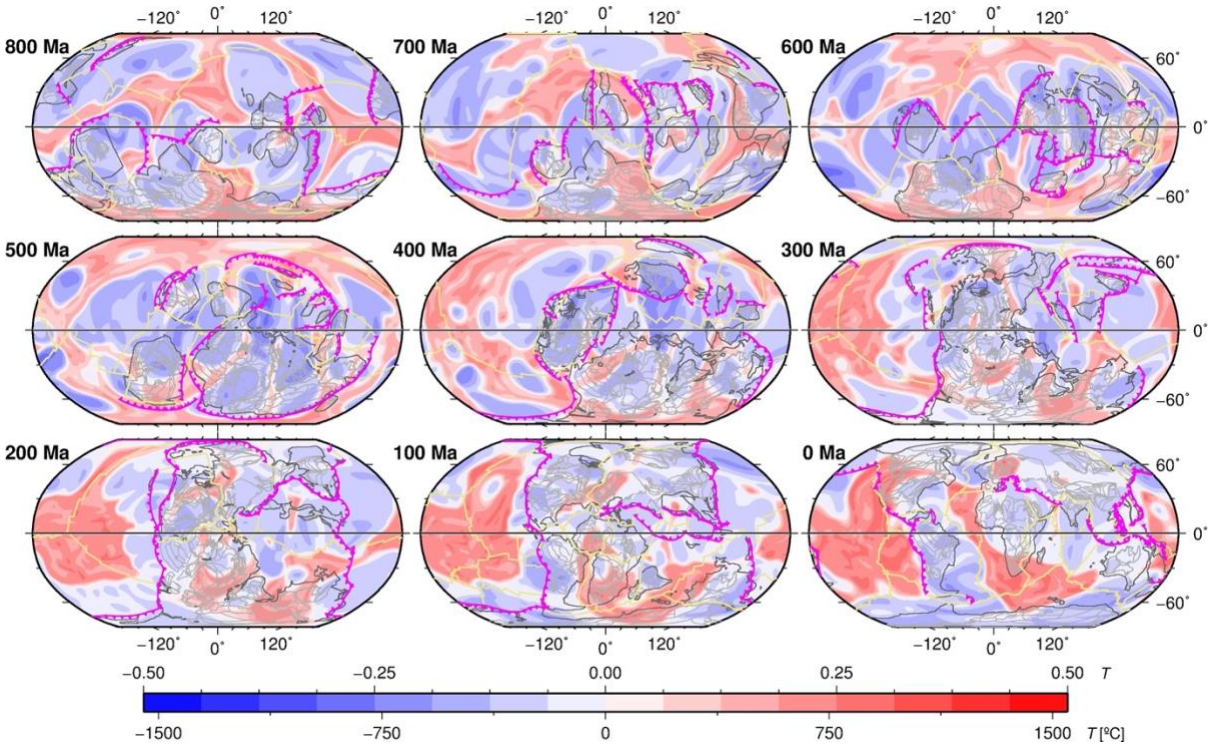

Figure S1. Map view of mantle temperature anomalies relative to the mean temperature at 2677 km depth for model the no-net-rotation (NNR) model in 100 Myr increments since 800 Ma (see Table 1 for model parameters). Present-day coastlines and continental sutures are shown as thin grey lines, while outlines of continents are displayed as bold grey lines. Subduction zones are bold magenta lines with triangles pointing towards overriding plates while mid-ocean ridges are shown as yellow lines.

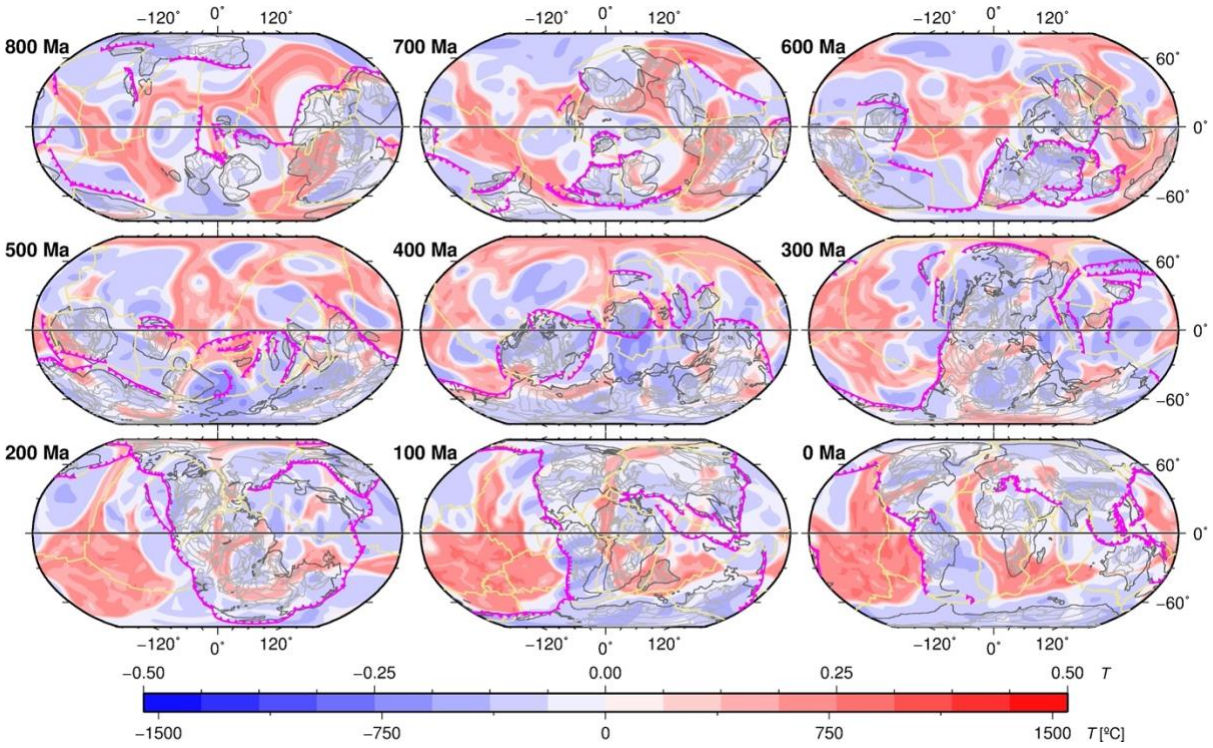

Figure S2. Map view of mantle temperature anomalies relative to the mean temperature at 2677 km depth for model the paleomagnetic (PMAG) model in 100 Myr increments since 800 Ma (see Table 1 for model parameters). Present-day coastlines and continental sutures are shown as thin grey lines, while outlines of continents are displayed as bold grey lines. Subduction zones are bold magenta lines with triangles pointing towards overriding plates while mid-ocean ridges are shown as yellow lines.

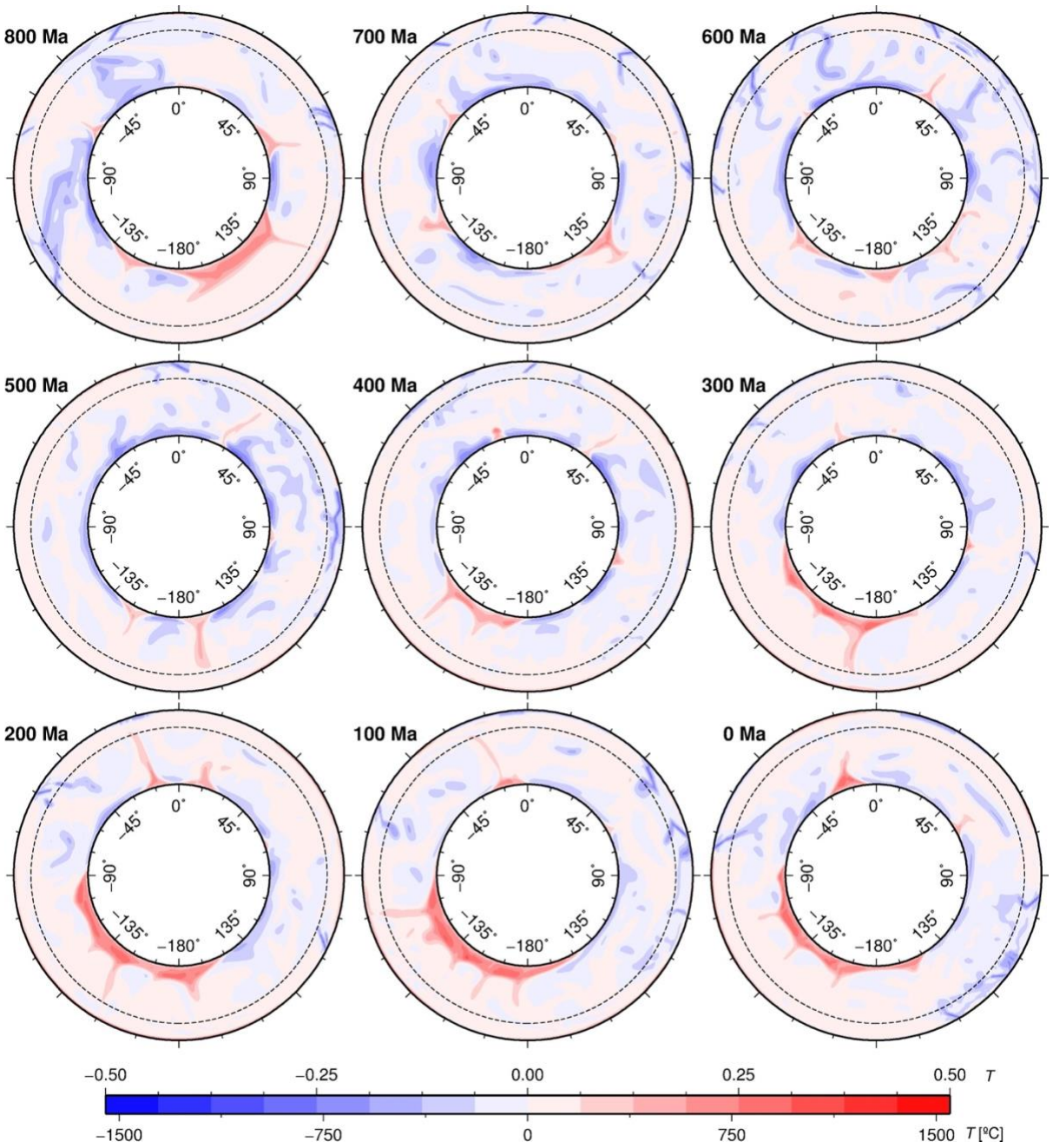

Figure S3. Global equatorial mantle cross-sections for the NNR model in 100 Myr increments since 800 Ma. The dotted grey line is the boundary between the upper and lower mantle. Numbers above the colour palette represent non-dimensional temperature anomalies, while numbers below the colour palette are dimensional temperature anomalies.

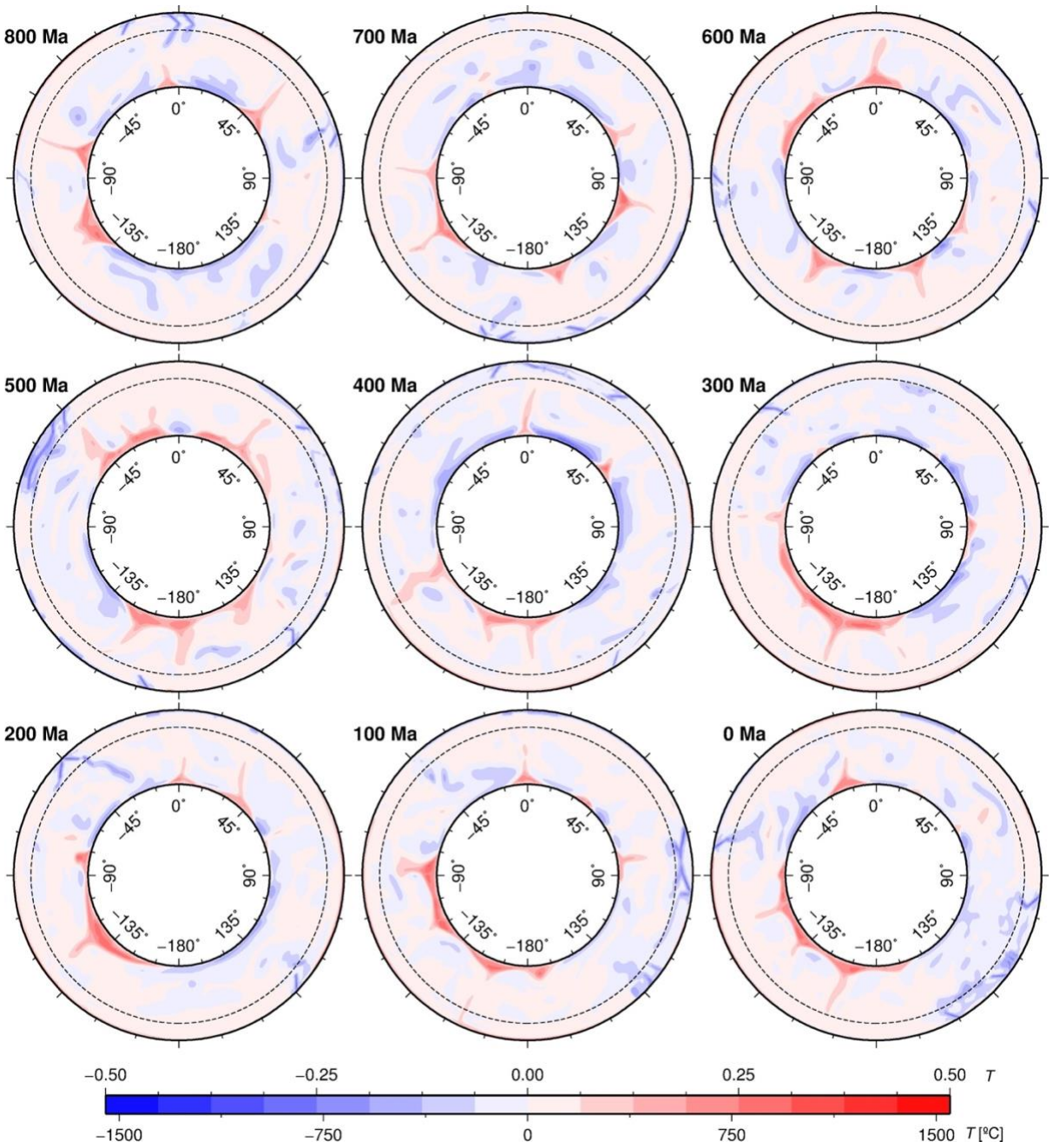

Figure S4. Global equatorial mantle cross-sections for the PMAG model in 100 Myr increments since 800 Ma. The dotted grey line is the boundary between the upper and lower mantle. Numbers above the colour palette represent non-dimensional temperature anomalies, while numbers below the colour palette are dimensional temperature anomalies. Note that the large lithospheric net rotations through time implicit in this model induce pronounced lateral depth-dependent motion in the mantle, which is geodynamically unreasonable.

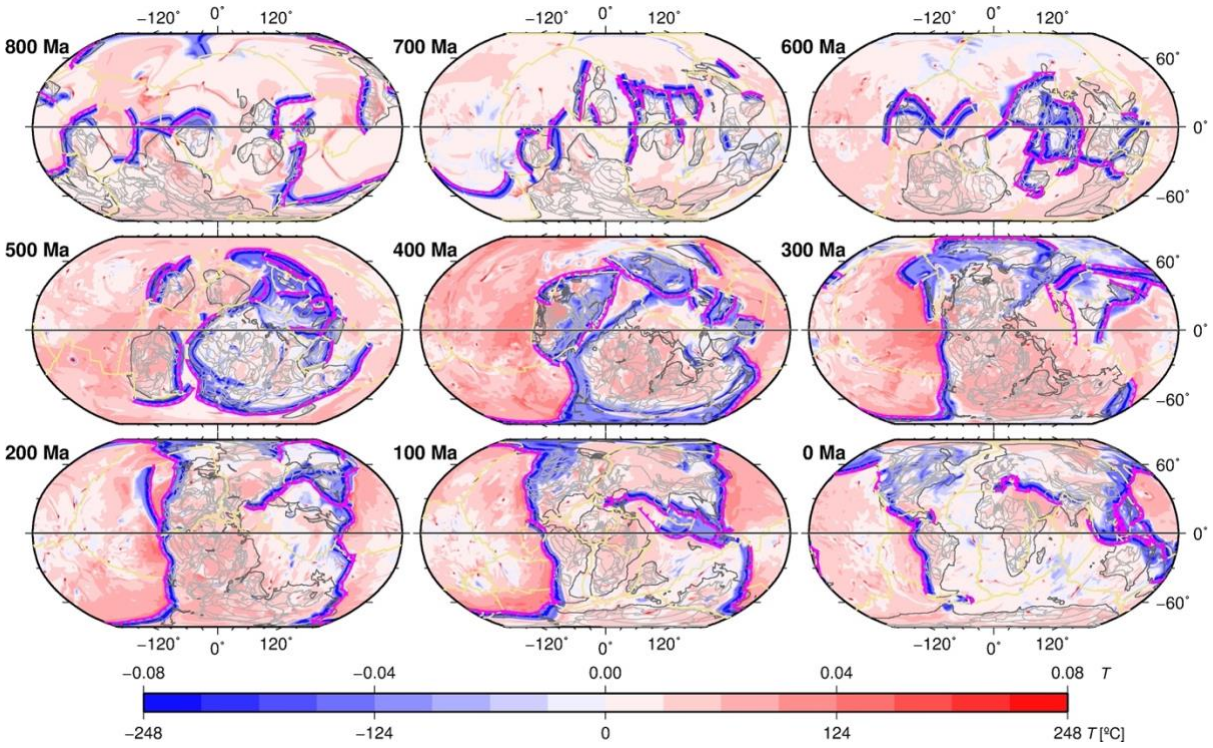

Figure S5. Map view of mantle temperature anomalies relative to the mean temperature at 396 km depth for model OPT2 in 100 Myr increments since 800 Ma. Present-day coastlines and continental sutures are shown as thin grey lines, while outlines of continents are displayed as bold grey lines. Subduction zones are bold magenta lines with triangles pointing towards overriding plates while mid-ocean ridges are shown as yellow lines.

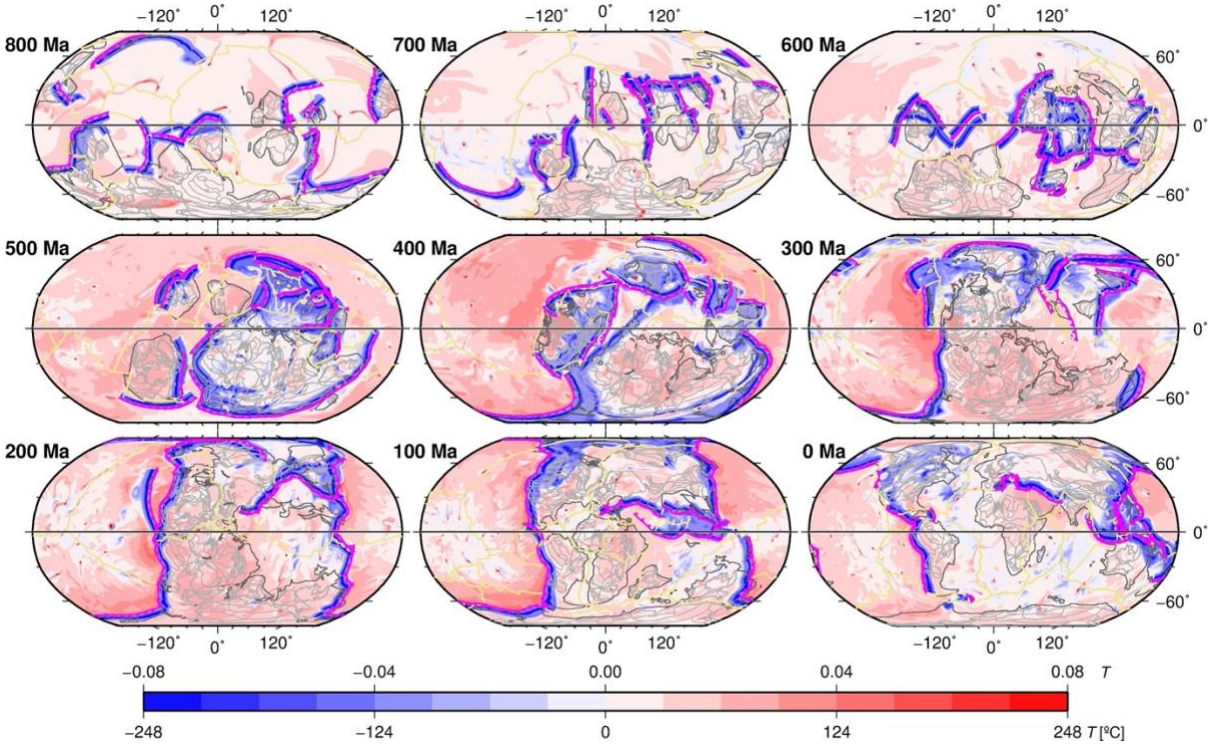

Figure S6. Map view of mantle temperature anomalies relative to the mean temperature at 396 km depth for model NNR in 100 Myr increments since 800 Ma. See Figure S5 for explanations of the colour and styles of lines.

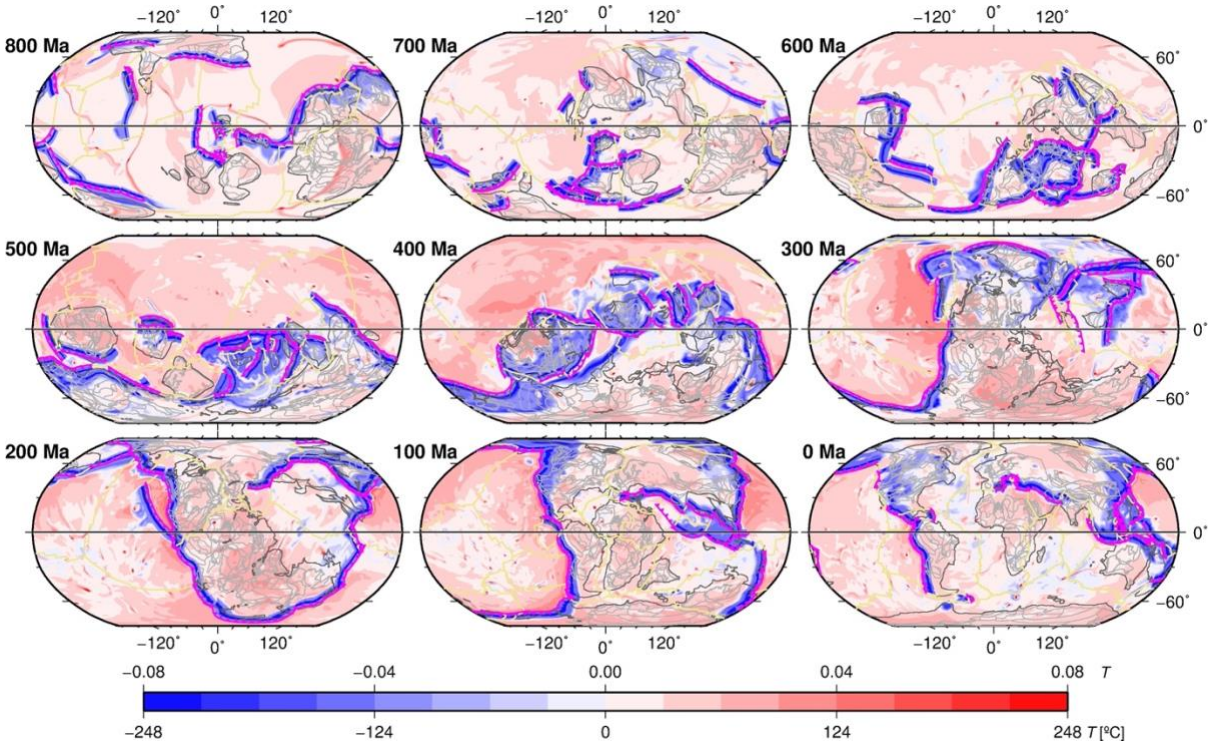

Figure S7. Map view of mantle temperature anomalies relative to the mean temperature at 396 km depth for model PMAG in 100 Myr increments since 800 Ma. See Figure S5 for explanations of the colour and styles of lines.

Supplementary Animations

Supplementary animations are available at 10.5281/zenodo.5801084.

Animation_S1. Absolute plate motions in a mantle reference frame based on our tectonic rules based optimised plate model. Mid-ocean ridges are olive lines, subduction zones are bold, toothed black lines and regions of continental crust filled with dark grey and extended continental margins with light grey. Black arrows show absolute plate motion velocities.

Animation S2. Absolute plate motions and reconstructed oceanic crustal age grids from 1 Ga to present-day based on our optimised plate model. Oceanic age grids are reconstructed using the method by Williams et al. (2021) with mid-ocean ridges shown as white lines, subduction zones as toothed black lines, and regions of continental crust filled with grey.

Animation S3. Animated map views (top) and equatorial cross sections (bottom) of mantle temperature anomalies relative to the mean temperature at 2,677 km depth for our geodynamic reference model OPT1 (see Table 1 for model parameters) from 1 Ga to the present. Present-day coastlines and continental sutures are shown as thin grey lines, while outlines of continents are displayed as bold grey lines; subduction zones are bold magenta lines with triangles pointing towards overriding plates while mid-ocean ridges are shown as yellow lines (top). On the mantle cross sections (bottom) the dotted grey line is the boundary between the upper and

lower mantle and the numbers above the colour palette represent non-dimensional temperature anomalies, while numbers below the colour palette are dimensional temperature anomalies.

Animation_S4. Animation as in Animation S3, but for model OPT2 (see Table 1 for model parameters).

Animation_S5. Animation as in Animation S3, but for model NNR (see Table 1 for model parameters).

Animation_S6. Animation as in Animation S3, but for model PMAG (see Table 1 for model parameters).

Animation S7. Animated map views (top) and equatorial cross sections (bottom) of upper mantle temperature anomalies relative to the mean temperature at 396 km depth for our geodynamic reference model OPT1 from 1 Ga to the present. Present-day coastlines and continental sutures are shown as thin grey lines, while outlines of continents are displayed as bold grey lines. Subduction zones are bold magenta lines with triangles pointing towards overriding plates while mid-ocean ridges are shown as yellow lines. The colour palette was adjusted to represent temperature variations at 396 km depth.

Animation_S8. Animation as in Animation S7, but for model OPT2.

Animation_S9. Animation as in Animation S7, but for model NNR.

Animation_S10. Animation as in Animation S7, but for model PMAG.

Animation S11. Animated Visualisation of modelled mantle structure through time centred on six central meridians from the Indian Ocean to the eastern Pacific Ocean. Mantle hotter than the layer average by non-dimensional value 0.1 (305 K) is shown in orange while mantle colder than the layer average by non-dimensional value -0.05 (153 K) is shown in blue, highlighting upwellings versus subducting slabs, respectively.