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## Supplementary information

# Dynamics of the abrupt change in Pacific Plate motion around 50 million years ago

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Supplementary Table 1: Summary of models.

| Models | Geological reconstruction | Age (Ma) | IBM slab? | Tonga-Kermedec Slab? | Plume? | Weak zone factor deviation |
|---|---|---|---|---|---|---|
| **MT60** | IZG-PAC-ridge-SUB(ref. [9]) | 60 | N | N | N | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0) |
| **MT50** | IZG-PAC-ridge-SUB(ref. [9]) | 50 | N | N | N | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0) |
| **MT50pl** | IZG-PAC-ridge-SUB(ref. [9]) | 50 | N | N | Y | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0) |
| **MT50asth** | IZG-PAC-ridge-SUB(ref. [9]) | 50 | N | N | Y, with 200 km-thick low-viscosity (hot) asthenosphere beneath Pacific | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0) |
| **MT47** | IZG-PAC-ridge-SUB(ref. [9]) | 47 | Y, 52-47 | Y, 50-47 | N | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0) |
| **MN60** | Kronotsky-SUB | 60 | N | N | N | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0) |
| **MN50** | Kronotsky-SUB | 50 | N | N | N | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0), KAM(10000.) |
| **MN50IBM** | Kronotsky-SUB | 50 | Y, 52-50 | N | N | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0), KAM(10000.) |
| **MN47** | Kronotsky-SUB | 47 | N | Y, 50-47 | N | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0) |
| **MN47IBM** | Kronotsky-SUB | 47 | Y, 52-47 | Y, 50-47 | N | SAM(50.0), CAM(50.0), NAM(0.1), IND(5.0) |

"Y" means the model has incorporated the corresponding feature, while "N" means the opposite. Those numbers following "Y" represent the time interval when the plate convergence is computed to construct the slab. The last column shows the subduction zones where the weak zone viscosity reduction deviates from the nominal value, with the numbers in the brackets representing the multiplier. In the model of Kronotsky-SUB, the Kamchatka subduction zone has a strong weak zone at 50 Ma, because this is the time the Olyutorsky arc collided with the Kamchata. These adjustments do not have an impact on Pacific Plate motion, but they help in the fit of the motion of other plates. SAM, South America; CAM, Central America; NAM, North America; IND, Indian; KAM, Kamchatka.

Supplementary Table 2: Parameters for the non-dimensional viscosity law.

| Parameter | Variable | Upper mantle dislocation creep | Lower mantle diffusion creep |
|---|---|---|---|
| Yield stress | $\sigma_y$ | 130 MPa | 130 MPa |
| Prefactor | $A(r)$ | $2.705 \times 10^4$ | $1.356 \times 10^4$ |
| stress exponent | $n$ | 3.2 | 1 |
| Activate Energy | $E_a$ | 55.04<br>640 kJ/mol | 8.6<br>100 kJ/mol |
| Weak zone factor | $w$ | $10^{-5}$ | – |
| Weak zone width | $\sigma$ | 5 km | – |

Numbers with units are dimensionalized values, while those without units are non-dimensionalized values. The formula yields an upper mantle viscosity of $3\times10^{20}$ Pa·s at $T = 1.0$ and $\dot{\varepsilon}_{II} = 10^{-15}$ s$^{-1}$, a lower mantle viscosity of $2\times10^{22}$ Pa·s at $T = 1.0$.

Supplementary Table 3: Basic model parameters.

| Parameter | Symbol | Non-dimensional value | Dimensional value | Units |
|---|---|---|---|---|
| Earth radius | $R_0$ | 1.0 | $6.371\times10^6$ | $m$ |
| reference density | $\rho_0$ | 1.0 | 3300 | $kg \cdot m^{-3}$ |
| thermal diffusivity | $\kappa$ | - | $10^{-6}$ | $m^2 s^{-1}$ |
| gravitational acceleration | $g$ | - | 9.81 | $m \cdot s^{-1}$ |
| thermal expansivity | $\alpha_0$ | - | $2.0\times10^{-5}$ | $K^{-1}$ |
| reference viscosity | $\eta_0$ | 1.0 | $10^{20}$ | $P_a \cdot s$ |
| mantle temperature | $T_m$ | 1.0 | 1400 | $^\circ C$ |
| Rayleigh number | $R_a = \frac{\rho_0 g \alpha_0 T_m R_0^3}{\kappa \eta_0}$ | - | $2.344\times10^9$ | - |