**Table S1.** Physical parameters and variables.

|  |  |  |  |
| --- | --- | --- | --- |
| **Symbol** | **Explanation** | **Value** | **Unit** |
| *A* | Pre-exponential factor in constitutive laws |  | Pa-n s-1 |
| *A*diff | for diffusion creep (*z* > 300 km) | 4.3733 × 10-12 | Pa-n s-1 |
| *A*disl | for dislocation creep (*z* < 300 km) | 4.6546 × 10-11 | Pa-n s-1 |
| *C*Y | Friction coefficient of intact material | 0.3 | - |
| *C*YF | Friction coefficient of fractured material | 0.004 | - |
| *C*p | Specific heat at constant pressure | 1.2 × 103 | JK-1kg-1 |
| *d*410 | Half thickness of the 410-km boundary | 20 | km |
| *d*660 | Half thickness of the 660-km boundary | 2 | km |
| *E*\* | Activation energy |  |  |
| *E\**diff | for diffusion creep (*z* > 300 km) | 240 | kJ mol-1 |
| *E\**disl | for dislocation creep (*z* < 300 km) | 430 | kJ mol-1 |
| *g* | Gravity acceleration | 10 | m s-2 |
| *h* | Thickness of mantle | 2,900 | km |
| *H* | Internal heating |  | W kg-1 |
| *k* | Thermal conductivity | 4.68 | W m-1 |
| *n* | Stress exponent for dislocation creep | 3.0 | - |
| *p* | Pressure |  | Pa |
| *R* | Gas constant | 8.3145 | J mol-1 K-1 |
| *t* | Time |  | s |
| *T* | Absolute temperature of mantle |  | K |
| *T*0 | Temperature at the surface (*z* = 0) | 273 | K |
| *T*440 | Temperature at the 410-km boundary | 1,691 | K |
| *T*660 | Temperature at the 660-km boundary | 1,818 | K |
| *v*=(*u*,*w*) | Velocity field of mantle |  | m s-2 |
| *V*\* | Activation volume |  |  |
| *V*\*diff | for diffusion creep (*z* > 300 km) | Eq. (9) | cm3 mol-1 |
| *V*\*disl | for dislocation creep (*z* < 300 km) | 15 | cm3 mol-1 |
| *V*0 | at *z* = 0 km to calculate LM viscosity | 5 | cm3 mol-1 |
| *V*L | at *z* = 2000 km to calculate LM viscosity | 4 | cm3 mol-1 |
| *x* | Lateral coordinate | 0-10000 | km |
| *z* | Vertical coordinate | 0-2900 | km |
| *z*410 | Depth of the 410-km boundary (*T* = *T*410) | 410 | km |
| z660 | Depth of the 660-km boundary (*T* = *T*660) | 660 | km |
| *α* | Thermal expansivity | 2.5 × 10-5 | K-1 |
| Γ410 | Function for smooth 410-km boundary |  | - |
| Γ660 | Function for smooth 660-km boundary |  | - |
| ΓC | Function for smooth crust/mantle boundary |  | - |
| γ410 | Clapeyron slope of the 410-km boundary | +3 | MPa K-1 |
| γ660 | Clapeyron slope of the 660-km boundary | -3 | MPa K-1 |
| ∆*ρ*c | Density contrast between granite and mantle | 600 | kg m-3 |
| ∆*ρ*410 | Density contrast at the 410-km boundary | 182.5 | kg m-3 |
| ∆*ρ*660 | Density contrast at the 660-km boundary | 194.2 | kg m-3 |
| , | Strain rate |  | s-1 |
|  | Second invariant of strain rate |  | s-1 |
| *η* | Effective viscosity of mantle |  | Pa s |
| *η*ref | Reference viscosity at 410-km depth | 5 × 1020 | Pa s |
| σ, σ*ij* | Stress |  | Pa |
| *σ*II | Second invariant of stress |  | Pa |
| *σ*Y | Yield strength |  | Pa |
| *σ*Y0 | Cohesive strength | 50 | MPa |
| *σ*Ymax | Maximum yield strength | 200 | MPa |
| *ψ* | Stream function |  | m2 s-1 |
| *ρ* | Density of mantle |  | kg m-3 |
| *ρ*0 | Reference density | 3,900 | kg m-3 |
| *ρ*s | Density at the surface to calculate σY | 3,300 | kg m-3 |