Evolving viscous anisotropy in the upper mantle and its geodynamic implications – Supplementary Materials, Data, and Code

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The materials listed below are linked to the paper: Evolving viscous anisotropy in the upper mantle and its geodynamic implications by Király et al., submitted to Geochemistry Geophysics, Geosystems in May, 2020, and updated in August, 2020.

List of Materials:

- Supplementary tables (in this document)
    - Table S1: Containing information about each model and filenames related to the models
    - Table S2: Parameters in the data files
- Supplementary figures (in this document)
    - S1: Correlation matrixß
    - S2: Plot of texture orientation vs. β vs. plate velocity

Animations (Texture_evolution folder in repository 10.11582/2020.00039)
- Texture evolution for each model in fixed shear and fixed mantle reference frames

Data files (Model_evolution_parameters_Data folder in repository 10.11582/2020.00039)
- Model results containing all parameters calculated for each model. See list of parameters in Table S2.

Code (Code folder in repository 10.11582/2020.00039)

MATLAB functions and an example for a model run. Models were run using MATLAB2019b and the MTEX toolbox (version 4.5.2)

- Rate_Aggregate_Placticity_CRATE: function for the mechanical model described in Hansen et al., (2016)
- director_quat_ode: function for rotating grains based on a deformation tensor.
- director_quat: function calling director_quat_ode for each grain.
- Model example: an example for simple shear model with unchanged shear direction, as described in the Mathematical Formulation (2.1) section, including plots as shown on Figure 2 of the article. With 500 grains and 150 timesteps (until a strain of ~8) the model runs for 2.5 minutes (including creating a plot) on a MacBook Pro (2017) with macOS Mojave.

Supplementary tables:

Model Name	**Shear force (as in Fig.4)**	**Switch strain**	**Rotation axes**	**Rotation angle**	**Rotation time**	**Figures showing the model results**
Norotation_model1	F1	-		-	-	2,3,5,6,7,8,9,10
Norotation_model2	F1	-	-	-	-	2,9
strain8_rotZ_ccw90_in0Myr	F1-F2	8	Z	90	0 Myr	5,9,10
strain8_rotX_ccw90_in0Myr	F1-F4	8	X	90	0 Myr	5,10
strain8_rotY_ccw90_in0Myr	F1-F3	8	Y	90	0 Myr	5,10
strain8_rotXY_ccw90_in0Myr	F1-F6	8	X-Y	90	0 Myr	5,10
strain8_rotXZ_ccw90_in0Myr	F1-F5	8	X-Z	90	0 Myr	5,10
strain8_rotZ_ccw90_in1Myr	F1-F2	8	Z	90	1 Myr	6,7,8,9
strain8_rotZ_ccw90_in3Myr	F1-F2	8	Z	90	3 Myr	6,9
strain8_rotZ_ccw90_in5Myr	F1-F2	8	Z	90	5 Myr	6,9
strain8_rotZ_ccw90_in7Myr	F1-F2	8	Z	90	7 Myr	6,9
strain8_rotZ_ccw90_in10Myr	F1-F2	8	Z	90	10 Myr	6,7,8,9
strain8_rotZ_ccw90_in13Myr	F1-F2	8	Z	90	13 Myr	6,9
strain2_rotZ_ccw90_in1Myr	F1-F2	2	Z	90	1 Myr	7,9
strain2_rotZ_ccw90_in10Myr	F1-F2	2	Z	90	10 Myr	7,9

strain5_rotZ_ccw90_in1Myr	F1-F2	5	Z	90	1 Myr	7,9
strain5_rotZ_ccw90_in10Myr	F1-F2	5	Z	90	10 Myr	7,9
strain11_rotZ_ccw90_in1Myr	F1-F2	11	Z	90	1 Myr	7,9
strain11_rotZ_ccw90_in10Myr	F1-F2	11	Z	90	10 Myr	7,9
strain14_rotZ_ccw90_in1Myr	F1-F2	14	Z	90	1 Myr	7,9
strain14_rotZ_ccw90_in10Myr	F1-F2	14	Z	90	10 Myr	7,9
strain8_rotZ_ccw22_in1Myr	F1-F2	8	Z	22	1 Myr	8,9
strain8_rotZ_ccw22_in10Myr	F1-F2	8	Z	22	10 Myr	8,9
strain8_rotZ_ccw45_in1Myr	F1-F2	8	Z	45	1 Myr	8,9
strain8_rotZ_ccw45_in10Myr	F1-F2	8	Z	45	10 Myr	8,9
strain8_rotZ_ccw67_in1Myr	F1-F2	8	Z	67	1 Myr	8,9
strain8_rotZ_ccw67_in10Myr	F1-F2	8	Z	67	10 Myr	8,9

Table S1. Model names refer to the switch strain, the rotation axes, the rotation angle and direction, and the time of rotation. All data that experienced rotation were started from Model 1 at a point 1 strain unit prior to the imposed rotation.

Unit	Symbol	Parameter	Column
Myr	t	Time	1
-	ε	Strain	2
s^{-1}	$\dot{\varepsilon}_{13}$	Strain rate (13)	3
s^{-1}	$\dot{\varepsilon}_{23}$	Strain rate (23)	4
s^{-1}	$\dot{\varepsilon}_{12}$	Strain rate (12)	5
s^{-1}	$\lvert\dot{\varepsilon}\rvert$	Shear strain rate (norm)	6
º	α	Shear direction (from	7
Pa·s	η_{2313}	Viscosity (2313)	8
Pa·s	η_{1313}	Viscosity (2313)	9
Pa·s	η_{1213}	Viscosity (2313)	10
Pa·s	η_{eff}	Effective Viscosity	11
º	α-β	Plate motion direction	12
cm/yr	v_{plate}	Plate velocity	13
$Pa^{-n}\cdot s^{-1}$	A_{2323}	Fluidity parameter (2323)	14
$Pa^{-n}\cdot s^{-1}$	A_{1323}	Fluidity parameter (1323)	15
$Pa^{-n}\cdot s^{-1}$	A_{1223}	Fluidity parameter (1223)	16
$Pa^{-n}\cdot s^{-1}$	A_{2313}	Fluidity parameter (2313)	17
$Pa^{-n}\cdot s^{-1}$	A_{1313}	Fluidity parameter (1313)	18

Unit	Symbol	Parameter	Column
$Pa^{-n}\cdot s^{-1}$	A_{1213}	Fluidity parameter (1213)	19
$Pa^{-n}\cdot s^{-1}$	A_{3212}	Fluidity parameter (2312)	20
$Pa^{-n}\cdot s^{-1}$	A_{1312}	Fluidity parameter (1312)	21
$Pa^{-n}\cdot s^{-1}$	A_{1212}	Fluidity parameter (1212)	22
º	*ori-a*	*Mean orientation (a-axes)*	*23*
º	*ori-b*	*Mean orientation (b-axes)*	*24*
º	*ori-c*	*Mean orientation (c-axes)*	*25*
-	*P-a*	*Point-distribution (a-axes)*	*26*
-	*P-b*	*Point-distribution (b-axes)*	*27*
-	*P-c*	*Point-distribution (b-axes)*	*28*
-	*G-a*	*Girdle-distribution (a-axes)*	*29*
-	*G-b*	*Girdle-distribution (b-axes)*	*30*
-	*G-c*	*Girdle-distribution (c-axes)*	*31*
-	*R-a*	*Random-distribution (a-axes)*	*32*
-	*R-b*	*Random-distribution (a-axes)*	*33*
-	*R-c*	*Random-distribution (a-axes)*	*34*
-	*M-index*	*M-index*	*35*
-	*J-index*	*J-index*	*36*

Table S2. List of parameters in the data files. Parameters from columns 1-22 are saved for every time step (~ 0.1 strain unit) while columns 23-36 are texture parameters that are only calculated for every 0.5 strain units. These parameters (together with the down-sampled version of all the other parameters from columns 1-22) are saved in the text files ending with _texture.txt (after the model names listed in Table S1). Note: $|\dot{\varepsilon}| = 2 * \sqrt{\dot{\varepsilon}_{12}{}^2 + \dot{\varepsilon}_{13}{}^2 + \dot{\varepsilon}_{23}{}^2}$, and $V_{plate} = 2 * \sqrt{\dot{\varepsilon}_{13}{}^2 + \dot{\varepsilon}_{23}{}^2} * H_{asthenosphere}$

Supplementary figures:

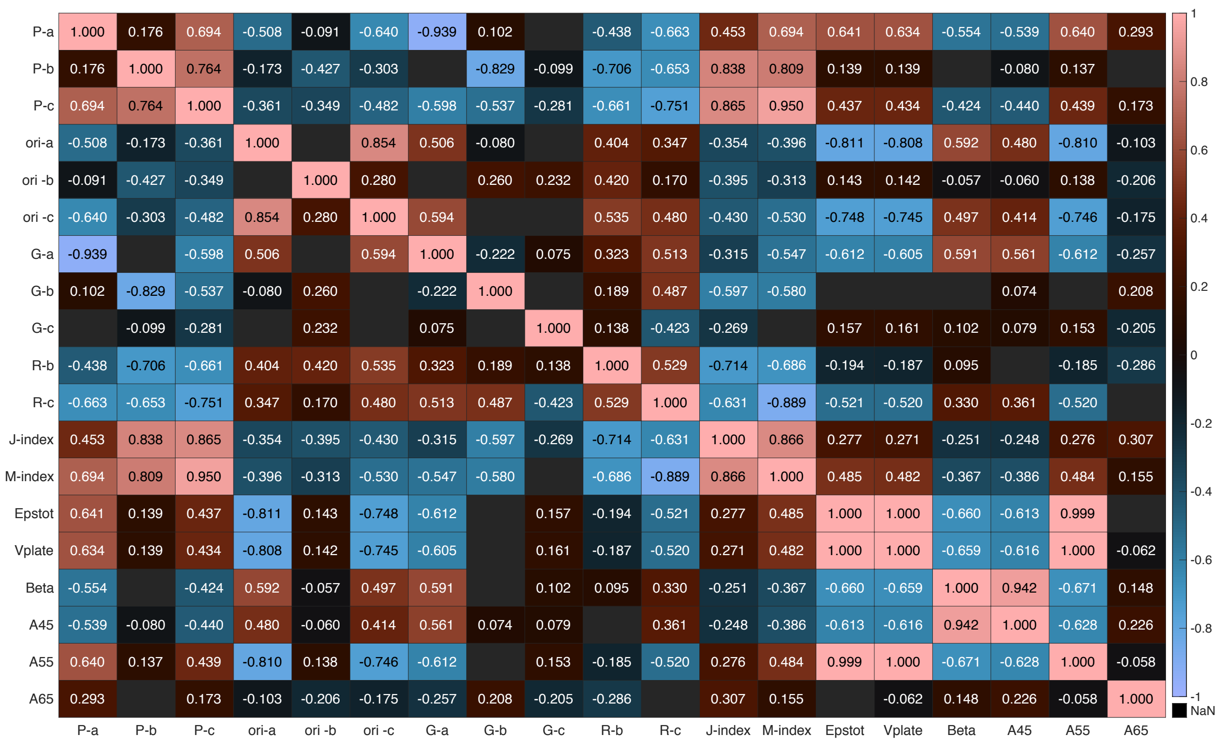

Figure S1: Full correlation matrix between all texture indicators and a selection of mechanical parameters for all the models representing changes in plate motion directions (i.e. models that experience texture rotation (0-90º) around the z-axis). All of the model results (functions of accumulated strain, which contribute to Fig. 9, see table S1) are saved into a single (large) matrix to calculate the overall correlations between the parameters.

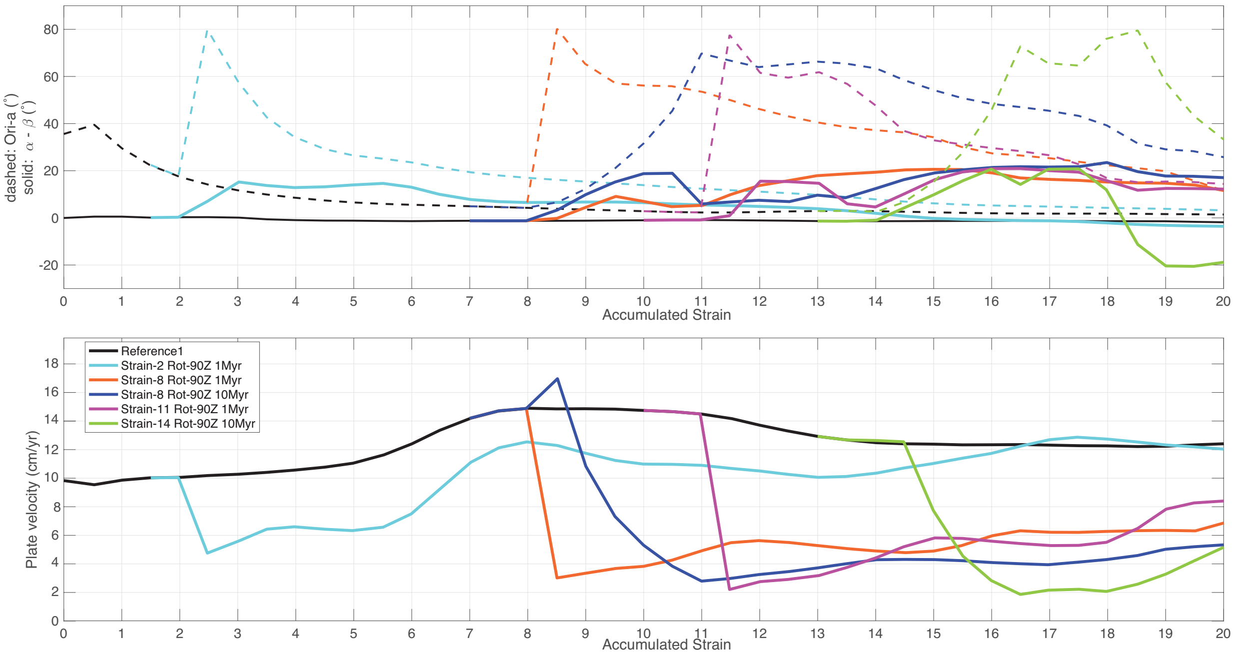

Figure S2: Top: the mean orientation of the olivine a-axes (ori-a; dashed lines) and α-β (i.e. the orientation of the plate movement with respect to the shear direction; solid lines; for a selection of models calculated at every 0.5 strain intervals. Bottom panel shows the plate velocity for the same models.

References:

Hansen, L.N., Conrad, C.P., Boneh, Y., Skemer, P., Warren, J.M., and Kohlstedt, D.L., 2016, Viscous anisotropy of textured olivine aggregates: 2. Micromechanical model: Journal of Geophysical Research: Solid Earth, v. 121, p. 7137–7160, doi:10.1002/2016JB013304.