

**Supplementary Figure 1 | Strain partitioning at the edge of mylonitic complexes.** From the protolith to the mylonitic complexes, the strain partitioning between the protomylonite layers (dark) and the mylonite layers (bright) progressively strengthens.



**Supplementary Figure 2 | Element maps across ultramylonite layers. A)** Thin section (polarized light) of a mylonitic peridotite, including ultramylonites. **B)** Distribution of magnesium (microprobe) across (ultra)mylonitic layers. Location in supplementary figure 2A. The colour coding refers to point counting. The step size is 0.8  $\mu$ m and the analytical conditions are 15 kV and 10 nA on polished thin section (diamond paste of 1 µm). Ol = olivine; Amph = amphibole; CPx = clinopyroxene; Spl = Spinel. **C)** Distribution of calcium across the same area. This map highlights an enrichment in amphibole nearby ultramylonite layers.  $OPx = orthopyroxene$ .



**Supplementary Figure 3 | Equilibrium phase diagrams (pseudosections) for ultramylonites. A)**  Pseudosection with 300 ppm  $H_2O$ . **B)** Pseudosection with 400 ppm  $H_2O$ . The pseudosections were produced using Perple X calculations in the NCFMASH (Na<sub>2</sub>O-CaO-FeO-MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O) chemical system, and based on the modal proportions that include olivine (65.9%), orthopyroxene (28.8%), amphibole (3.0%), clinopyroxene (1.5%) and spinel (0.8%). For comparison, we show the calculated conditions of deformation for the ultramylonites (dotted white rectangle). Based on the absence of plagioclase in the Ronda shear zones, our Perple X calculations indicate a minimum of ~400 ppm H<sub>2</sub>O in the ultramylonite layers. Amph = amphibole;  $OPx = orthopyroxene$ ;  $Ol = Olivine$ ;  $CPx = clinopyroxene$ .



**Supplementary Figure 4 | Phase distribution and olivine fabric between ultramylonites. A)** EBSD map (phases) of the mylonitic layer shown in figure 5A of the paper. The step size is 1 µm and the analytical conditions are described in the methods section of the paper. While grain boundaries (black lines) are defined by correlated misorientation angles of more than 10°, the lattice tilt boundaries (white lines) are defined by correlated misorientation angles between  $2^{\circ}$  and  $10^{\circ}$ . X = shear direction; Z = pole to the shear plane. The black points within grains are non-indexed points. **B)** Sketch of the different areas highlighted in figure 5A of the paper and based on the olivine LPO distribution, including ultramylonites (B1), connected bands of strong LPO in the mylonite (B2), and isolated areas of moderate LPO between the ultramylonites (B3). **From C to F)** Olivine LPOs for each area, including the whole map (C), B1 area (D), B2 area (E) and B3 area (F). The three orthorhombic axes for olivine ([100], [010] and [001]) are shown in lowerhemisphere pole figures with respect to the shear plane (horizontal line) and shear direction (white dot). The iso-contours and grey shading (linear scale) are multiples of a uniform distribution. They were constructed using a Gaussian half-width angle of 10 $^{\circ}$  and based on one point per grain. N = number of grains; OPx = orthopyroxene; CPx = clinopyroxene.



**Supplementary Table 1** | Major-element compositions (in weight percent) and grain size of olivine (Ol) grains in the mylonites and ultramylonites. Por = porphyroclasts.



**Supplementary Table 2** | Major-element compositions (oxides in weight percent) and grain size of enstatite

(En) grains in the mylonites and ultramylonites. Por = porphyroclasts.



## **Supplementary Table 2 (continued)**



**Supplementary Table 3** | Major-element compositions (oxides in weight percent) and grain size of diopside

Oxides $(\% )$	Di <sub>1</sub>	$\mathbf{Di}_2$	$\mathbf{Di}_3$	Di <sub>4</sub>	$\mathbf{Di}_5$	$\mathbf{Di}_6$	$\mathbf{Di}_7$	Di <sub>8</sub>	Di <sub>9</sub>	$Di_{10}$	$Di_{11}$	$Di_{12}$
SiO <sub>2</sub>	54.24	53.95	53.95	54.26	53.70	54.24	53.87	53.57	53.30	53.95	54.12	53.44
TiO <sub>2</sub>	0.03	0.03	0.02	0.02	0.05	0.01	0.01	0.04	0.06	0.07	0.04	0.05
Al <sub>2</sub> O <sub>3</sub>	1.57	1.94	1.90	1.20	2.23	1.55	1.60	1.97	2.21	1.78	1.28	1.55
FeO	2.11	2.26	2.22	2.13	2.27	2.15	2.19	2.15	2.31	2.22	2.03	2.19
MnO	0.06	0.08	0.06	0.08	0.09	0.07	0.06	0.08	0.07	0.07	0.05	0.07
MgO	17.32	17.34	17.38	17.66	16.86	17.45	17.16	17.35	17.39	17.07	17.45	17.16
CaO	23.14	22.85	23.07	23.38	23.21	23.32	23.33	22.72	22.53	23.18	23.44	23.47
Na <sub>2</sub> O	0.59	0.59	0.63	0.53	0.67	0.60	0.58	0.71	0.65	0.58	0.52	0.47
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.55	0.72	0.65	0.39	0.81	0.55	0.55	0.89	0.99	0.70	0.33	0.44
<b>Total</b>	99.59	99.75	99.88	99.66	99.88	99.95	99.35	99.48	99.52	99.61	99.27	98.85
<b>Grain size</b> $(\mu m)$	15	30	50	8	15	5	10	200	100	25	15	25

(Di) grains in the mylonites and ultramylonites. Por = porphyroclasts.





**Supplementary table 4** | Major-element compositions (oxides in weight percent) and grain size of spinel (Spl) grains in the mylonites and ultramylonites. Por = porphyroclasts.



**Supplementary Table 5** | Major-element compositions (oxides in weight percent) of amphibole grains (Amp) in the mylonites and ultramylonites. Por = porphyroclasts.



**Supplementary Table 6** | Pressure (P in kbar) and temperature (T in  $\degree$ C) data estimated in the mylonites and ultramylonites based on the major-elements compositions and geothermobarometers. Each number refers to the phase number shown in previous tables (from tables S1 to S5). The temperature data are summarized in the figure 3D of the paper. (1) = Ca in OPx at 5 kbar<sup>1</sup>; (2) = Ca in OPx at 8 kbar<sup>1</sup>; (3) = Al and Cr in OPx<sup>2</sup>;  $(4)$  = Two-pyroxene thermometer at 5 kbar<sup>1</sup> (TBKN); (5) = two-pyroxene thermometer at 8 kbar<sup>1</sup>. (6) = Olivine-spinel thermometer<sup>3</sup>. (7) = Two-pyroxene barometer<sup>4</sup>.



Di<sub>o</sub>

 $En_{41}$ 

11.8

 $\frac{Di_{10}}{En_{40}}$ 

 $9.0$ 

 $10.8\,$ 

 $7.7$ 

 $Di_{14}$ 

 $En<sub>10</sub>$ 

 $9.2$ 

9.6

 $\frac{\text{Di}_{15}}{\text{En}_6}$ 

4.9

 $\mathbf{Di}_{16}$ 

 $En<sub>18</sub>$ 

 $8.9\,$ 

 $\frac{\mathbf{Di}_{17}}{\mathbf{En}_{20}}$ 

 $6.1\,$ 

 $5.1$ 

Di<sub>2</sub>

 $\widetilde{\mathbf{En_{27}}}$ 

9.0

 $4.8$ 

Phase(s)

 $P(7)$ 

Di<sub>4</sub>

 $En<sub>34</sub>$ 

8.8

 $En<sub>32</sub>$ 

6.9

Dis/

 $\overline{\text{En}_{35}}$ 

10.6

 $En_{36}$ 

10.7

 $En_{37}$ 

6.5

 $En<sub>42</sub>$ 

5.9

## **Supplementary References**

- 1. Brey, G. P., & Köhler, T. Geothermobarometry in four-phase lherzolites II. New thermobarometers, and practical assessment of existing thermobarometers. *J. Petrol.* **31,** 1353-1378 (1990).
- 2. Witt-Eickschen, G. & Seck, H. A. Solubility of Ca and Al in orthopyroxene from spinel peridotite: an improved version of an empirical geothermometer. *Contrib. Min. Petrol*. **106,** 431-439 (1991).
- 3. Jianping, L., Kornprobst, J., Vielzeuf, D. & Fabriès, J. An improved experimental calibration of the olivine-spinel geothermometer. *Chinese J. Geochem.* **14,** 68-77 (1995).
- 4. Putirka, K. D. Thermometers and barometers for volcanic systems. *Rev. Min. Geochem*. **69,** 61-120 (2008).