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Strain localisation in the Ronda peridotites induced by grain size reduction and grain boundary sliding

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The strength of the continental mantle plays a first-order role in lithosphere deformation modes, from localised to distributed. However, the rheology of the subcontinental mantle is still poorly constrained and its ability to localise strain is not yet well understood. For example, olivine grain size reduction is a common feature of peridotite shear zones; but the relationship between dynamic recrystallisation (grain size reduction) and mantle rock weakening remains a matter of debate. If dynamic recrystallisation is only accommodated by dislocation creep and diffusion creep, no major weakening is expected. Recently, a new creep mechanism involving grain boundary sliding accommodated by dislocation creep and diffusion creep has been experimentally documented and could explain a significant weakening during dynamic recrystallisation. However, this mechanism has not yet been identified in naturally deformed peridotites. The western part of the Ronda peridotite (Sierra Bermeja, Betic cordillera, southern Spain) exposes a kilometre-scale strain gradient from low-strain spinel-bearing tectonite to strongly deformed garnet-spinel-bearing mylonite. A microstructural study reveals three main features across the ductile strain gradient: 1) a decrease in olivine recrystallised grain size with increasing strain, 2) a mixture of fine-grained olivine and pyroxene in the mylonite that is not observed in less deformed samples, and 3) a decrease of the olivine LPO intensity with increasing strain. From these features, we infer the enhancement of grain boundary sliding during progressive deformation and associated dynamic recrystallisation. Consequently, we propose a new model of the subcontinental mantle rheology involving various combinations of dislocation creep, diffusion creep and grain boundary sliding according to the temperature, the strain rate and the grain size. For temperature higher than 850°C; grain boundary sliding is inhibited and dynamic recrystallisation is only accommodated by dislocation creep

and diffusion creep with no significant weakening. In contrast, for lower temperature, grain boundary sliding accommodates dynamic recrystallisation and induces weakening which is maximum for a context of mantle rocks cooling. This new rheological model could thus explain local weakening in the uppermost continental mantle and subsequent strain localisation.