Mechanisms of ductile deformation in the lithospheric mantle

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Up to recently, ductile deformation of mantle rocks has been described using experimentally-obtained semi-empirical equations involving the motion of only two types of defects in minerals (dislocations and cation vacancies) and using almost solely very fine-grained polycrystalline San Carlos olivine. It resulted in a bimodal conception of ductile deformation in Earth upper mantle: the so-called dislocation creep and diffusion creep. Nevertheless, the Earth mantle is not a giant single crystal, but a polymineralic rock with millimetric grain size, deforming permanently at slow strain rates. Lately, the role of grain boundaries started to be taken into account to properly estimate the strength of lithospheric rocks and the mechanisms of their ductile deformation behind plate tectonics.

To achieve these aims, we must first identify and quantify all agents of ductile deformation (e.g., vacancies, dislocations, grain boundary defects: disclinations and disconnections) in naturally deformed and in experimentally deformed olivine-rich rocks at high pressures and high temperatures. We must also identify their interactions and the implications for the bulk ductile deformation of mantle rocks. These challenging tasks required the use of new experimental tools, associated with microstructural characterization involving a combination of microscopy techniques (SEM-EBSD, TEM and data treatment).

These updated working strategies highlight the role of grain boundaries activity and its contribution to the ductile deformation of upper mantle rocks and re-assess the physics at play behind mantle convection, formation of the lithosphere-asthenosphere vertical and horizontal boundaries, and thus plate tectonics.

This keynote will briefly compile the most recent advances in the field of ductile deformation of mantle rocks.