Diffusion creep and grain growth in forsterite + 15vol% enstatite aggregate

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In this study, we conducted grain growth and creep experiments on the same fine-grained forsterite + 15vol% enstatite aggregate under high temperature. We rapidly changed load applying to the sample for "stepped test", which was aimed to infer creep mechanisms at a wide range of stress. We gradually changed temperature under application of a constant load for "gradual temperature change test" to collect vast numbers of stress/strain rate/grain-size/temperature data which allow their statistical analyses to obtain precise flow parameters such as pre-exponential factors and activation energies for given flow laws. Grain growth experiment with a long duration (= 500 h) at different temperatures was aimed to obtain a precise temperature dependency of grain growth. Dependency of *n* on stress was investigated from the results of stepped tests conducted at temperatures from 1150°C to 1370°C at stress ranging from 5 MPa to 300 MPa. We found monotonic decrease of stress exponent from 2 to 1 with increasing stress and its rapid increase to > 3 at high stress regime. We inferred that interface-reaction control diffusional creep and grain boundary (GB) diffusion creep worked sequentially at low stress, while GB diffusion creep and dislocation creep worked parallel at high stress condition. Activation energy of 432 kJ/mol for GB creep and pre-exponential factor of 6.15×10^{11} $um^3K/MPa/sec$ were obtained from MCMC analyses mainly of the results of gradual temperature change tests. Grain growth experiment showed a monotonic increase in grains size of both forsterite and enstatite phases with increasing temperature at > 1300°C.
Diffusivities estimated from creep and grain growth rates using classic GB diffusion creep and grain growth laws well coincide at all experimental ranges indicating that governing diffusional processes for creep and grain growth are identical. We compare our obtained diffusivities with the results of previous direct measurements on grain boundary self-diffusivities of MgO (*Gardes and Heinrich*, 2011) and Si (*Fei et al.*, 2016) finding that MgO GB diffusion rather than Si explains our observations.

Keywords: upper mantle rheology, grain growth, diffusion creep, olivine, diffusivity, rate-controlling element