Geophysical Research Abstracts
Vol. 15, EGU2013-2072, 2013
EGU General Assembly 2013

The effect of deformation on the TitaniQ geothermobarometer – an experimental study

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In order to investigate the effects of deformation on the TitaniQ geothermobarometer, and to study the relationships between different deformation mechanisms and incorporation of Ti into recrystallized quartz grains, we performed high strain (up to 40%) axial compression experiments on natural quartz single crystals with the addition of rutile powder (TiO_2) and ~0.2 wt% (H_2O). Experiments were performed in a Griggs-type solid medium deformation apparatus at confining pressures between 1.0 to 1.5 GPa and at temperatures of 800-1000°C, at constant strain rate of 1x10 -6 to 1 x 10-7 s-1.

Mobility of Ti in the fluid phase and saturation of rutile at grain boundaries during the deformation experiments are suggested by precipitation of secondary rutile in cracks and along grain-boundaries of newly recrystallized quartz grains. Microstructural analysis by light and scanning electron microscopy (the latter including EBSD mapping of grain misorientations) indicates that the strongly deformed quartz single crystals contain a wide variety of deformation microstructures including undulatory extinction, subgrain rotation (SGR), and grain boundary migration recrystallization (GBMR). In addition, substantial grain growth has taken place in annealing experiments after deformation. The GBMR and grain growth are clear evidence of moving grain boundaries, a microstructure favored by high temperatures.

Electron Microprobe Analysis (EMPA) shows no significant increase in Ti content in recrystallized quartz grains formed by SGR or by GBMR, nor in grains grown by annealing. This result indicates that neither SGR nor moving grain boundaries during GBMR and grain growth are adequate processes to facilitate the re-equilibration of the Ti content of experimentally deformed quartz crystals at the conditions investigated here. More generally, our results suggest that exchange of Ti in quartz at low H_2O contents (which may be realistic for natural deformation conditions) are not fully understood yet. Thus, the application of the TitaniQ geothermobarometer to deformed metamorphic rocks at low fluid-contents may not be as straightforward as previously thought and requires further research.