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# A coupled model between mechanical deformation and chemical diffusion: An explanation for the preservation of chemical zonation in plagioclase at high temperatures

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Compositional zoning in metamorphic minerals have been generally recognized as an important geological feature to decipher the metamorphic history of rocks. The observed chemical zoning of, e.g. garnet, is commonly interpreted as disequilibrium between the fractionated inner core and the surrounding matrix. However, chemically zoned minerals were also observed in high grade rocks (T>800 degree C) where the duration of metamorphic processes was independently dated to take several Ma. This implies that temperature may not be the only factor that controls diffusion timescales, and grain scale pressure variation was proposed to be a complementary factor that may significantly contribute to the formation and preservation of chemical zoning in high temperature metamorphic minerals [Tajcmanová 2013, 2015].

Here, a coupled model is developed to simulate viscous deformation and chemical diffusion. The numerical approach considers the conservation of mass, momentum, and a constitutive relation developed from equilibrium thermodynamics. A compressible viscoelastic rheology is applied, which associates the volumetric change triggered by deformation and diffusion to a change of pressure.

The numerical model is applied to the chemically zoned plagioclase rim described by [Tajcmanová 2014]. The diffusion process operating during the plagioclase rim formation can lead to a development of a pressure gradient. Such a pressure gradient, if maintained during ongoing viscous relaxation, can lead to the preservation of the observed chemical zonation in minerals.

An important dimensionless number, the Deborah number, is defined as the ratio between the Maxwell viscoelastic relaxation time and the characteristic diffusion time. It characterizes the relative influence between the maintenance of grain scale pressure variation and chemical diffusion. Two extreme regimes are shown: the mechanically-controlled regime (high Deborah number) and diffusion-controlled regime (low Deborah number). In the mechanically-controlled regime, the grain scale pressure variation and thus the chemical zonation can be maintained due to slow viscous relaxation. Furthermore, by utilizing experimental flow laws and diffusion coefficients, the Deborah number is estimated in a variety of physical conditions.

References

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