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The effect of shear deformation on reaction kinetics: A coupled thermodynamical and mechanical model

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Common petrologic grids in pelitic system derived either by experimental or theoretical investigations do not consider the role of deformation during metamorphism. Natural rocks, however, generally experience phase changes simultaneously with tectonic stress. Our experimental studies in quartz-muscovite system show that imposed conditions are effective and during shear deformation melting rate is 1.7 times faster than at hydrostatic conditions.

Five explanations for the increase of reaction kinetics are: shear heating, strain energy, surface energy, local pressure drops and effective viscosity. We observe that the melting reaction generates a dilatational strain of roughly 3%; in the elastic limit this strain would generate high pressures that would hinder reaction progress. Thus, a component of irreversible dilatational deformation is necessary to permit reaction progress. Our estimations showed that during shearing the observed dilatational deformation can occur with negligible melt overpressures (1x10-6 MPa), which is function of effective viscosity. This result suggests that the reduction in effective viscosity induced by macroscopic shear can have a profound effect on reactions that have a non-zero isobaric volume change. In contrast, all other explanations of increased melting as shear heating, strain and surface energies and local pressure drops effects are eliminated by our first order considerations.

To verify the significance of effective viscosity effect we performed a model of the spherical liquid inclusion growth within an inert solid matrix. In this model thermodynamics of melting reaction and mechanical response of solid phase are coupled. The normal and tangential stresses are calculated along the radius of the sphere continuously with time (the increase of liquid amount). The temperature at the each point of the model is controlled by both, the enthalpy of the melting reaction and the heat flow from the surrounding material. The rate of reaction is calculated taking in the account the melting reaction kinetics and mechanical response of the solid phase.