Hysteretic ferro-paramagnetic phase transition in finitely-strained viscoelastic media

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The *thermodynamic model of visco-elastic deformable magnetic materials* at finite strains is formulated in a *fully Eulerian* way in rates. The *Landau theory* applies for ferro-to-para-magnetic phase transition as devised mathematically rigorously for rigid magnets in [3]. *Hysteresis* in magnetization evolution by Landau-Lifshitz-Gilbert equation involving objective corotational time derivative of magnetization and demagnetizing field are considered in the model.

The basic model involves the dissipative stress in the *Kelvin-Voigt viscoelastic rheology*. For rigorous mathematical analysis, a gradient theory both for magnetization (leading *exchange energy*) and for the dissipative stress (exploiting the concept of 2nd-grade *multipolar materials* with a higher-order viscosity) is used. The model complies with energy conservation and Clausius-Duhem entropy inequality. Global-in-time existence and a certain regularity of weak solutions is proved by a Faedo-Galerkin semi-discretization in time and a suitable regularization, cf. [1].

A noteworthy enhancement is the fluidic-type *Jeffreys viscoelastic rheology* in the deviatoric part to model effects of isocharic plasticity or creep, and melting/solidification by making the additional temperature-dependent viscosity. This might be used for modelling of magnetic rocks and their various transformations as depicted in Figure 1, as occurs within so-called thermoremanent magnetization which is the main phenomena behind *paleomagnetism* in Earth's crust, cf. [2] for a linearized convective variant. The *hysteresis* occurs in cold rocks under the so-called blocking temperature and is responsible for recording magnetic information in oceanic or continental rocks over millions of years. Magnetic minerals in cooling rocks typically undergo antiferro-to-ferrimagnetic phase transition at so-called Neél temperature, analogously to the mentioned para-to-ferromagnetic phase transition at Curie temperature.

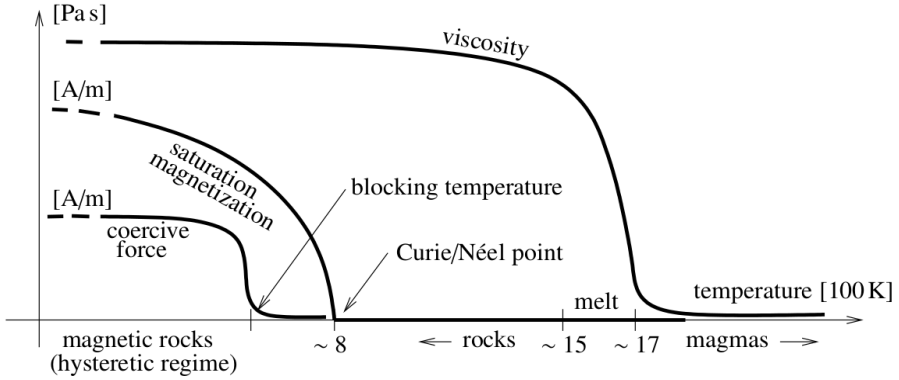

Fig.1: *Schematic temperature dependence of some magnetic properties behind antiferro-to-ferrimagnetic phase transition in solid rocks together with a mechanical viscosity behind solidification of melting of magma towards rocks.*

References

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[3] P.Podio Guidugli, T.Roubíček, G.Tomassetti: A thermodynamically-consistent theory of the ferro/paramagnetic transition. Archive Rat. Mech. Anal. 198 (2010), 1057-1094.