PhD thesis, Gertje ter Maar

Abstract

The interpretation of magnetic anomalies at all scales relies on the understanding of the petrophysical and rock magnetic properties. The stability of magnetic minerals in the crust depends on the composition and thermo-barometric conditions. In this thesis the nature and origin of crustal magnetization are investigated, particularly with respect to ultramafic and mafic rocks.

The first part of this thesis explores whether there may be a primary source of magnetization in deep-seated ultramafic rocks, and under what pressure and temperature conditions these sources could be stable. Rocks from the Reinfjord Ultramafic Complex (RUC) in northern Norway provide a unique opportunity to access ultramafic rocks that originate deep in the crust. This thesis presents an extensive study of the petrophysical and rock magnetic properties of the ultramafic rocks of the RUC. These properties are combined with microscopy observations from optical and scanning electron microscopy, chemical characterization by electron microprobe, and scanning magnetic microscopy. This synthesis provides a thorough characterization of the magnetic carriers and their magnetic behavior.

The main primary magnetic carriers in the ultramafic rocks were identified as Al-chromite with exsolution blebs of Cr-magnetite, (Al-)Cr-spinel with an exsolved Fe-rich phase, exsolution lamellae of magnetite from clinopyroxene and, in some lithologies, discrete magnetite grains. In a localized area of pervasive serpentinization, secondary magnetite is found in veins and discrete grains. The primary magnetic carriers are stable at temperatures up to the Curie temperature of magnetite and therefore identified as potential sources of magnetization in the lower crust. The secondary magnetic carriers have formed by serpentinization and acquired their magnetization over a long period of time.

Rock magnetic measurements, FORC diagrams and coercivity unmixing, show a high-coercivity component is present in the pristine ultramafic rocks, which contain Al-chromite with Cr-magnetite exsolution blebs. It is inferred that this phase may contain single-domain particles. In addition, exsolved magnetite lamellae from clinopyroxene are inferred to have a range in sizes, and therefore diverse domain states. Marginal Zone and Pyroxenite Dike samples display a clear MD signal that can be correlated to discrete magnetite grains. Scanning magnetic microscopy reveals magnetic anomalies over the identified magnetic carriers.

The second section of the thesis examines basalts from the Stardalur volcano in Iceland, which yield a ground-magnetic anomaly of 27 μT above background. This study uses micromagnetic modeling of microstructures in magnetite to show their effect on the magnetic properties of magnetite with and without oxidation-exsolution lamellae. While the microstructures do enhance the remanence, we suggest internal stress due to the formation of lamellae dominates the acquisition and retention properties of the NRM in the basalt rocks from the Stardalur magnetic anomaly.