Geophysical Research Abstracts
Vol. 13, EGU2011-10239-1, 2011
EGU General Assembly 2011

Reduction-exsolution of magnetite in ilmenite: Phase interfaces and exchange coupling

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Naturally occurring magnetites with oxidation-exsolution lamellae of ilmenite are common in many terrestrial rock types, and are typical carriers of a paleomagnetic signal. The ilmenite lamellae act to break up the magnetite and create smaller magnetic domains within the original host, enhancing magnetic stability and coercivity. Far more rarely reported, are examples of magnetite lamellae in ilmenite. Formation of such lamellae usually requires a more reduced environment as compared to the more typical oxidation-exsolution of ilmenite lamellae in magnetite.

Here, in a natural sample of the Black Hill Norite (BHN) from South Australia, we explore the nature of interfaces of magnetite lamellae in ilmenite. A transmission electron microscope study of the ilmenite host demonstrates that the fine lamellae with bright reflectance are magnetite rather than hematite. The interface is parallel to (001) of the host and to (111) of the magnetite lamellae. This norite has a striking remanence-dominated magnetic anomaly, and very stable paleomagnetic directions. The BHN is unusual because it contains discrete grains both of magnetite with oxy-exsolution of ilmenite, and of ilmenite with magnetite exsolution produced by reduction. These conflicting trends may possibly be explained by coupled equilibrium tie-line shifts within the cooling rock.

In parallel with the BHN, but at submicrscopic scale, a synthetic sample of ilm40 hematite-ilmenite disordered solid solution, contains very fine magnetite lamellae, < 30 nm thick, on (001) of the host, which is parallel to (111) of the magnetite. Magnetite comprises less than 0.1% of the total sample. Changes in magnetic saturation (Ms) and remanence (Mrs) were measure with increasing temperature. Although these magnetite lamellae are superparamagnetic (SPM) in size, they display a stable magnetization (Mrs) up to the 350C Néel temperature of the host, due to the effects of exchange coupling across the interfaces. Above the Tn of the ilm40, the sample continues to carry an Ms signal of the SPM magnetite to 560C, however there is no Mrs component above 350C.