Magnetic properties and microstructures of ferrimagnetic minerals from impact structures and shock experiments

Agnes Kontny[1] and Boris Reznik[1]

[1] KIT, Germany

Corresponding author: agnes.kontny@kit.edu

Abstract: Pyrrhotite and Magnetite are the most important magnetic minerals in impacted terrestrial rocks. Pressure experiments have consistently documented that all samples substantially demagnetize at pressures of a few GPa and that the degree of demagnetization depends strongly on magnetic mineralogy and on coercivity (e.g. Louzada et al. 2011). Shock experiments conducted by Mang et al. (2013) on natural pyrrhotite ore revealed two shock pressure regimes (0-8 GPa and 20-30 GPa) with different characteristics. Up to 8 GPa, microstructures in shocked pyrrhotite are characterized by mechanical deformation producing a damage of the crystal structure. At pressures of 20 GPa and upward, amorphization and mechanical twinning are the dominant shock-induced features. Increasing coercivity, coercivity of remanence and saturation isothermal remanent magnetization with increasing pressure in the regime up to 8 GPa are in agreement with a more single-domain behaviour, which is linked with the breakup of larger grains into smaller ones and the formation of amorphous PDFs, which additionally divide the existing grains into smaller structural and magnetic domains. Although under hydrostatic pressure, a ferrimagnetic to paramagnetic transition of monoclinic Fe_7S_8 is reported to take place at about 2.8 GPa (Rochette et al. 2003), respectively ~6.8 GPa (Kobayashi et al. 1997) a high-pressure phase was up to now not identified in our shocked samples. But synchrotron X-ray powder diffraction revealed a clear decrease in crystallite sizes and a peak shift of the (102) reflexion of pyrrhotite in direction of lower d-values over the shock regime up to 30 GPa. Such a shift of reflexion might indicate a strain memory of the pyrrhotite phase. Interestingly, the λ-peak of NC pyrrhotite decreases and the 34 K transition of 4C pyrrhotite, broadens and is depressed for these samples suggesting that magnetic transition temperatures are strain sensitive.

Magnetite also exhibits a high-pressure transition, which is reported to occur >25 GPa, above which the Fe_3O_4 sluggishly transforms into an insulating perovskite-like phase (Rozenberg et al. 2006). From extrapolations >25 GPa a total loss of ferromagnetic moments is suggested to occur around 70 GPa (Baudelet et al. 2010) indicating that the magnetic structure of magnetite is more stable under pressure than pyrrhotite. However, the Verwey transition temperature (T_V) is described to be pressure

dependent and decreases significantly with increasing pressure until it disappears above 8 GPa (e.g. Todo et al. 2001). This behaviour indicates that at pressures >8 GPa no Verwey transition occurs any more. Decompressed samples, which were previously compressed to 5 GPa, show a shift of T_V toward higher temperatures (Carporzen and Gilder 2010), which is in principal agreement with our first results and seems to indicate a strain memory. We have produced a set of four shocked magnetite samples (5, 10, 20 and 30 GPa) for which we made first magnetic susceptibility measurements.

Keywords: (magnetic properties of shocked pyrrhotite and magnetite)

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