The effect of hydrostatic pressure up to 1.61 GPa on the Morin transition of hematite-bearing rock: Implications for planetary crustal magnetization

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Résumé

Hematite (alfa-Fe2O3) is a common mineral in paleomagnetic and rock magnetic studies. It occurs in both igneous and sedimentary rocks as well as in meteorites, and it is one of several magnetic phases suggested to help to explain the Martian magnetic anomalies. Hematite is essentially antiferromagnetic with a superimposed weak ferromagnetism; it is characterized by a so-called Morin transition [1]. This is a 1st order magnetic phase transition from a weakly ferromagnetic to antiferromagnetic state, which occurs on cooling below the Morin transition temperature Tm _˜ -23°C [1].
The Morin transition was shown to be sensitive to the effects of static pressure. Pressure dependence of Morin transition has been previously investigated theoretically as well as through a wide range of experimental techniques such as nuclear magnetic resonance experiments, neutron scattering (e.g., [2-3] and refs wherein) as well as M´ossbauer studies. It was established theoretically and experimentally that Tm increases with increasing pressure.

However, previous experimental studies were limited to low-pressure range, non-hydrostatic conditions, or indirect (i.e., nonmagnetic) measurements [2-3] and synthetic samples. Moreover, there is still no consensus in literature about the pressure at which the Morin transition should reach room temperature (T0). The behavior of hematite under pressure is rather different in different pressure media. Klotz et al. [2013] argue that the conclusions drawn from non-hydrostatic measurements of the Morin transition under pressure are most likely unreliable. In addition, hydrostatic experiments may represent a better analog for natural in situ conditions [4].

Here we present new magnetic data on hydrostatic pressure dependence of the Morin transition up to 1.61 GPa obtained on a well-characterized multi-domain hematite-bearing rock sample from banded iron formation, which is likely responsible for Bangui magnetic anomaly

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[5]. We used a non-magnetic high-pressure cell of piston-cylinder type [6-7] for hydrostatic pressure application and a SQUID magnetometer for isothermal remanent magnetization (IRM) measurements under pressure in the course of zero-field warming of the cell with sample from -30°C to T0. IRM imparted at T0 under pressure in 270 mT magnetic field (IRM270mT) was never recovered after a cooling-warming cycle. Thermal hysteresis effect under pressure was quantified as a loss in IRM of 49%/GPa (with regard to IRM270mT). Tm reaches T0 under hydrostatic pressure 1.2÷1.61 GPa, which is roughly consistent with [3].

Pressure dependence of Tm up to 1.61 GPa has a linear trend with a warming rate of 32°C/GPa. Our confirmation of the linear behavior of Tm with pressure and estimated pressure-induced Tm warming rate in 0 to 1.61 GPa range are more robust and accurate with regard to previous works [2-3] as we used direct magnetic measurements and a much larger dataset. This work has a potential of having implications for further modeling of magnetic anomalies in geosciences. Acknowledgements: The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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