Geophysical Research Abstracts
Vol. 14, EGU2012-4811, 2012
EGU General Assembly 2012

Anisotropy of magnetic susceptibility in the giant Lac Tio hemo-ilmenite ore body (Quebec Province, Canada): source and geological implications

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The Lac Tio hemo-ilmenite ore body is a magmatic ilmenite deposit that crops out in the 1.06 Ga Lac Allard anorthosite which is part of the Havre-Saint-Pierre anorthosite suite, one of many AMCG (Anorthosite-Mangerite-Charnockite-(rapakivi) Granite) suites from the Grenville province of North America. It is the world's largest hard-rock ilmenite deposit, with reserves still estimated at ca. 138 Mt after 60 years of mining exploitation (Charlier et al., 2010).

The magnetic properties of the Lac Tio ore body were first studied in the 50s and 60s (e.g. Hargraves, 1959; Carmichael, 1961), and have recently been reinvestigated by McEnroe et al. (2007). All these works focused on the high and stable natural remanent magnetization of the hemo-ilmenite ore (up to 120 A/m) that was shown to reside in the exsolution intergrowths of hematite and ilmenite, following the theory of lamellar magnetism (McEnroe et al., 2007). The present study investigates the anisotropy of magnetic susceptibility (AMS; e.g. Borradaile and Jackson, 2004) of 46 samples from the Lac Tio ore body and its anorthosite wall rocks.

The bulk magnetic susceptibility (Km) in the ore, which is essentially made up of hemo-ilmenite (commonly >75 wt.%) and plagioclase, ranges from 5.3 to 115.9 x 10-3 SI. Not surprisingly, samples with high Km values (>7 x 10-3 SI) usually contain magnetite, either as small grains or as plates replacing some hematite exsolutions. Km ranges from 0.35 to 3.8 x 10-3 SI in the host anorthosite, as well as in plagicolase-rich layers found within the hemo-ilmenite ore. Such relatively low values reflect minor to trace amounts of Fe-Ti oxides (ilmeno-hematite, hemo-ilmenite, magnetite) and pyroxenes.

The hemo-ilmenite ore displays a shape-preferred orientation of the hematite lamellae that exsolved parallel to the basal (0001) plane of the ilmenite host grains. Thus, the ore has a lattice-preferred orientation (LPO) for the hemo-ilmenite grains. Electron backscatter diffraction confirms this LPO and demonstrates that it controls AMS: there is a marked concentration of the crystallographic c axis of the hemo-ilmenite grains, sub-parallel to the AMS K3 axis. Investigation of the shape-preferred orientation of grains in some studied lithologies, through image analysis, further demonstrates that the AMS axes proxy for the orientation of the rock shape fabric.

The pattern of the magnetic foliation (AMS K1-K2 plane) in the Lac Tio ore body reveals folding of the deposit, into a synform or an elongated basin, around an axis that is gently plunging to the NE. This axis is parallel to a stretching direction of regional significance, that is materialized by the magnetic lineation (AMS K1 axis) whose orientations in the ore body and the host anorthosite are similar (average orientation of N35E/4NE and N16E/17NNE, respectively). The Lac Tio hemo-ilmenite ore body was thus strained together with its anorthosite wall rocks, during a deformational event that needs to be clearly identified.