American Mineralogist, Volume 100, pages 1940–1951, 2015

Magnetic anisotropy in natural amphibole crystals

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Abstract

Anisotropy of magnetic susceptibility (AMS) is often used as a proxy for mineral fabric in deformed rocks. To do so quantitatively, it is necessary to quantify the intrinsic magnetic anisotropy of single crystals of rock-forming minerals. Amphiboles are common in mafic igneous and metamorphic rocks and often define rock texture due to their general prismatic crystal habits. Amphiboles may dominate the magnetic anisotropy in intermediate to felsic igneous rocks and in some metamorphic rock types, because they have a high Fe concentration and they can develop a strong crystallographic preferred orientation. In this study, the AMS is characterized in 28 single crystals and 1 crystal aggregate of compositionally diverse clino- and ortho-amphiboles. High-field methods were used to isolate the paramagnetic component of the anisotropy, which is unaffected by ferromagnetic inclusions that often occur in amphibole crystals. Laue imaging, laser ablation-inductively coupled plasma-mass spectrometry, and Mössbauer spectroscopy were performed to relate the magnetic anisotropy to crystal structure and Fe concentration. The minimum susceptibility is parallel to the crystallographic *a**-axis and the maximum susceptibility is generally parallel to the crystallographic *b*-axis in tremolite, actinolite, and hornblende. Gedrite has its minimum susceptibility along the *a*-axis, and maximum susceptibility aligned with *c*. In richterite, however, the intermediate susceptibility is parallel to the *b*-axis and the minimum and maximum susceptibility directions are distributed in the *a*-*c* plane. The degree of anisotropy, k', increases generally with Fe concentration, following a linear trend: $k' = 1.61 \times 10^{-9}$ Fe – 1.17×10^{-9} m^3/kg. Additionally, it may depend on the Fe^{2+}/Fe^{3+} ratio. For most samples, the degree of anisotropy increases by a factor of approximately 8 upon cooling from room temperature to 77 K. Ferroactinolite, one pargasite crystal and riebeckite show a larger increase, which is related to the onset of local ferromagnetic (s.l.) interactions below about 100 K. This comprehensive data set increases our understanding of the magnetic structure of amphiboles, and it is central to interpreting magnetic fabrics of rocks whose AMS is controlled by amphibole minerals.

Keywords: Anisotropy of magnetic susceptibility (AMS), magnetic properties, single crystal, amphibole, hornblende, actinolite, richterite, tremolite