Plagioclase hosted magnetite micro-inclusions from oceanic gabbro: shape orientation and implication for bulk magnetic properties

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In gabbro, fine-grained magnetite (MT) micro-inclusions hosted by rock-forming silicates contribute to bulk-rock magnetism. Specific crystal orientations of micro-inclusions relative to the silicate host may dramatically affect the direction and/or intensity of natural remanent magnetization (NRM) of the rock. Understanding the influence of oriented silicate-hosted magnetite micro-inclusions on rock-magnetism is important for obtaining reliable paleomagnetic data and for revealing rock magnetic fabrics, which may shed light on the mechanisms of rock formation or the tectonic evolution. We studied needle- and lath-shaped magnetite micro-inclusions in plagioclase of oceanic gabbro from the slow-spreading Mid Atlantic Ridge (11-17°N), aiming to reveal the genesis and ferromagnetic contribution of the MT inclusions to the magnetic properties of grains of host plagioclase. To this end, we combined a detailed petrographic study on magnetite-bearing plagioclase with crystal orientation analysis by electron backscatter diffraction (EBSD), measurements of the anisotropy of magnetic remanence (AMR) and alternating field (AF) demagnetization. The results show that:

(i) Needle and lath shaped MT inclusions have systematic shape orientations following eight specific crystallographic directions that coincide with the poles of low-index crystal planes/directions of the plagioclase host.

(ii) Statistically, the MT inclusions show two types of shape orientation distribution (Ageeva et al., 2022): One type is characterized by a predominantly oblate shape orientation distribution, due to a high fraction of needle-shaped inclusions oriented sub-parallel to the (010) plane of plagioclase and forming an about 30º wide “(010)-girdle”. These inclusions are considered to be of primary magmatic origin (Bian et al. 2023a). The other type of shape distribution features a high fraction of inclusions oriented parallel to the c-axis of the plagioclase-host. These inclusions are interpreted as secondary (Bian et al. 2023b), replacing primary inclusions in domains where high-temperature hydrothermal alteration of plagioclase was effective.

(iii) Twinning of plagioclase following the Albite, Pericline, Carlsbad and Manebach twin laws increases the dispersion of inclusion orientations within the (010)-girdle, and strengthens the lineation caused by the presence of inclusions oriented parallel to [001] of plagioclase.

(iv) The anisotropic shape orientation distribution of the MT-inclusions causes anisotropy of magnetic remanence (AMR) in the plagioclase grains (Ageeva et al., 2022). A good correspondence between the shape orientation distribution of the MT-inclusions and AMR is established in the majority of the studied plagioclase grains: The direction of minimum magnetic remanence R_{min} is sub-perpendicular to the (010)-girdle. The direction of maximum magnetic remanence R_{max} lies in the (010)-girdle and often is close to parallel to the PL [001] direction, which often corresponds to a maximum in the shape orientation distribution of MT-inclusions in twinned plagioclase.

(v) The vector of natural remanent magnetism (NRM) tends to lay in the (010)-girdle, often parallel to the maximum in the elongation orientation distribution of inclusions or/and parallel to the direction of maximum magnetic remanence.

The results indicate that oriented needle- and lath-shaped MT micro-inclusions in plagioclase endow the grains of host plagioclase with anisotropic ferromagnetism. Consequently, in case of preferred orientation of grains of magnetite-bearing plagioclase, which is typical for many geological settings including mid-ocean ridges and layered intrusions, a magnetic fabric may form. The identified characteristics of the plagioclase magnetic anisotropy are highly relevant for petrological and paleomagnetic studies of oceanic gabbro.

Ageeva O, Habler G, Gilder SA, Schuster R, Pertsev A, Pilipenko O, Bian G, Abart R (2022): Oriented magnetite inclusions in plagioclase: Implications for the anisotropy of magnetic remanence. – Geochem Geophys Geosystems 23, e2021GC010272

Bian G, Ageeva O, Roddatis V, Li C, Pennycook TJ, Habler G, Abart R (2023a): Crystal structure controls on oriented primary magnetite micro-inclusions in plagioclase from oceanic gabbro. - J Petrol 64, egad008

Bian G, Ageeva O, Roddatis V, Habler G, Schreiber A, Abart R (2023b): Oriented secondary magnetite micro-inclusions in plagioclase from oceanic gabbro. - Amer Miner, doi: 10.2138/am-2022-8784