

Clinopyroxene-hosted Fe-Ti-oxide micro-inclusions in oceanic gabbro: inferences from phase content, shape and lattice orientation relations

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Clinopyroxene-hosted Fe-Ti-oxide micro-inclusions found in lower-crust oceanic gabbro from the Vema lithospheric section (Mid-Atlantic Ridge, 10°42.95'N, 41°34.60'W, 5195-4620 mbsl) were studied using electron backscatter diffraction and electron probe microanalyses. A first generation of Fe-Ti-oxide micro-inclusions forms needles or elongated plates lying in the (010) plane of the clinopyroxene host. The inclusions show two distinct elongation directions either nearly parallel to the *c*-axis (Z-type inclusions) or the *a*-axis (X-type inclusions) of the clinopyroxene host. The inclusion-host interfaces defining the inclusion elongation direction correspond to planes, where densely packed oxygen layers of the inclusion and the host phase are coherent across the interface. Both inclusion types have distinct crystallographic orientation relationships to the host, which are determined by the nearly parallel alignment of densely packed oxygen layers in the inclusions and the host. One of the densely packed {111} planes of magnetite is nearly parallel to the (100) plane of clinopyroxene in the more abundant Z-type inclusions and one of the {111} planes of magnetite is nearly parallel to the (-101) plane of clinopyroxene in the less abundant X-type inclusions. Based on the temperature dependence of the angle between the two elongation directions as calibrated by Feinberg et al. (2004) the temperature of primary magnetite precipitation was estimated to have taken place at 800° to 900°C. Initially, the precipitates were homogeneous Ti-bearing magnetite, which was formed together with titanian pargasite lamellae due to reaction of the pre-existing, early magmatic clinopyroxene with late magmatic fluid or melt. After cooling below 600°C the Ti-magnetite decomposed to an oriented magnetite+ulvospinel intergrowth. Late stage hydrothermal alteration lead to corrosion of the magnetite-ulvospinel inclusions and partial replacement by ilmenite. A separate product of hydrothermal activity is represented by newly precipitated homogeneous ilmenite plates that are closely associated with actinolite lamellae extending parallel to the (100) plane of the clinopyroxene host. Despite of the fact that the Fe-Ti oxide micro-inclusions only occupy a negligible fraction of the rock volume, they serve as sensitive monitors of the gabbro petrogenetic history. As the Fe-Ti oxides are the main carriers of the rock remanent magnetization, understanding the formation conditions and later modifications of the Fe-Ti oxide micro-inclusions is of pivotal importance in the context of paleomagnetic reconstructions.

Feinberg, J. M., Wenk, H. R., Renne, P. R., & Scott, G. R. (2004). Epitaxial relationships of clinopyroxene-hosted magnetite determined using electron backscatter diffraction (EBSD) technique. *American Mineralogist*, 89(2-3), 462-466.