Cathodoluminescence images and trace element compositions of fluorapatite from the Hongge layered intrusion in SW China: A record of prolonged crystallization and overprinted fluid metasomatism

CHANG-MING XING1,2,* AND CHRISTINA YAN WANG1,2

1Key Laboratory of Mineralogy and Metallogeny, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510460, China
2Guangdong Provincial Key Laboratory of Mineral Physics and Materials, Guangzhou 510640, China

ABSTRACT

Cathodoluminescence (CL) and trace element analyses were performed for fluorapatite from the gabbro and Fe-Ti oxide ores in the upper zone of the Hongge Fe-Ti oxide-bearing, mafic-ultramafic layered intrusion in SW China. The fluorapatite is closely associated with Fe-Ti oxides and interstitial to plagioclase and clinopyroxene. The fluorapatite grains in one thin section vary from ~10 to 800 μm in width and ~50 to 1200 μm in length. Coarse-grained fluorapatite crystals (>200 in width) in the same thin section show both simple and complex CL images. The coarse-grained fluorapatite crystals with simple CL images show discontinuous, thin dark rims along grain boundaries, whereas those with complex images show clearly bright veinlets across the grains. On the other hand, fine-grained fluorapatite crystals (<200 μm in width) show complex CL images and can be divided into four types, i.e., concentric, chaotic, banded, and overall dark. The concentric type shows distinctly bright core surrounded by dark mantle that is irregularly zoned, whereas the chaotic type shows disordered bright and dark sectors in the interior with a thin dark rim. The banded type shows unevenly distributed bright and dark bands. The overall dark type shows a relatively dark and uneven image. Fluorapatite grains contain 1.84–2.74 wt% F, 0.07–0.19 wt% Cl, and 0.86–1.63 wt% OH. Coarse-grained fluorapatite grains have total rare earth elements (REE) concentrations ranging from 2278 to 3008 ppm and Sr/Y of 9 to 13. Fine-grained fluorapatite grains have relatively high REE (2242–4687 ppm) and low Sr/Y of 6 to 14 in the bright cores, sectors, and bands and relatively low REE (1881–2728 ppm) and high Sr/Y of 9 to 15 in the dark mantles, sectors, and rims under CL imaging. On the thin section scale, the bright sections under CL imaging for fine-grained fluorapatite have much higher REE contents than those for similar bright CL images for coarse-grained fluorapatite. The highly variable REE concentrations among fluorapatite grains and the sections within a single fluorapatite are attributed to a prolonged crystallization process and overprint by fluid metasomatism. The coarse-grained fluorapatite may have crystallized earlier than fine-grained fluorapatite. Then variable degrees of hydrothermal metasomatism released REE from the fine-grained fluorapatite so that diverse CL images developed in the crystals. This study reveals that magmatic apatite from a layered intrusion can be intensively modified by later-stage fluid-induced metasomatism in both trace element composition and CL image texture. Reconstruction of primary melt compositions using apatite from layered intrusions should therefore be treated with caution.

Keywords: Fluorapatite, cathodoluminescence image, trace element, fluid metasomatism, mafic-ultramafic layered intrusion

INTRODUCTION

Apatite mainly occurs in the upper zone of layered intrusions, such as the Skaergaard intrusion in Greenland and the Bushveld complex in South Africa, and is considered as a cumulus phase during late-stage magma differentiation (Cawthorn 1994; Holness et al. 2007). Apatite can be substantially enriched in some layered intrusions and associated with Fe-Ti oxides, forming Fe-Ti-P-rich nelsonite with ~30 vol% apatite (Reynolds 1985; Von Gruenewaldt 1993; Tollari et al. 2008). The origin of apatite-rich rocks/Fe-Ti oxide ores in layered intrusions has been a matter of debate between fractional crystallization and silicate liquid immiscibility models (Reynolds 1985; Von Gruenewaldt 1993; Tegner et al. 2006; Tollari et al. 2008; Namur et al. 2012; VanTongeren and Mathez 2012). Nevertheless, the growth process of apatite itself has been relatively neglected.

Magmatic apatite commonly has a hexagonal habit when crystallizing under near-equilibrium condition (Webster and Piccoli 2015). Cumulus apatite from layered intrusions has been widely used to reconstruct the trace element compositions of the melt in equilibrium with the apatite (Tollari et al. 2008; VanTongeren and Mathez 2012; She et al. 2016).