Genesis of chromium-rich kyanite in eclogite-facies Cr-spinel-bearing gabbroic cumulates, Pohorje Massif, Eastern Alps

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ABSTRACT

Natural kyanites with Cr2O3 contents >1 wt% are very rare and known only from high-P environments, for example, eclogite-facies gabbroic cumulates containing Cr-spinel from the Pohorje Massif, Eastern Alps, Slovenia. In these rocks, turquoise-colored Cr-rich kyanites are present in two different textural types. A first type has formed as blocky crystals of several hundred micrometers in size around clusters of small drop-like Cr-spinels. This kyanite shows a highly irregular Cr distribution and may contain up to 15.6 wt% Cr2O3, which is one of the highest Cr2O3 contents reported so far. A second type is present as part of reaction coronas around large red-brownish Cr-spinel and forms deep-blue needle-like crystals that rarely exceed 100 μm in size. This kyanite contains up to 8.2 wt% Cr2O3 and is associated with Cr-rich corundum (±9.1 wt% Cr2O3) and Cr-Al-rich pargasite (±3.9 wt% Cr2O3). The formation of kyanite around Cr-spinel droplets is interpreted to be the result of increasing P-T conditions during prograde metamorphism where Cr-spinel and plagioclase or quartz react to Cr-kyanite, ± garnet, ± zoisphacite. In contrast, the formation of kyanite associated with Cr-rich corundum and Cr-rich pargasite within coronas around Cr-spinel occurred in an early stage of the retrogressive evolution of the gabbroic cumulates at eclogite-facies conditions of ~2.5 GPa and 750–800 °C triggered by the influx of H2O-rich fluids. The driving force for developing these coronas was an increase in the chemical potential of silica caused by the infiltrating hydrous fluid phase. P-T estimates using matrix mineral assemblage place the peak metamorphic conditions close to the quartz/coesite transition with temperatures in the range of 750–810 °C and pressures of ~2.9 GPa.

Keywords: Cr-rich kyanite, Cr-rich corundum, eclogite facies cumulates, Pohorje Massif, Eastern Alps

INTRODUCTION

Kyanite is a common metamorphic mineral in metapelites and Al-rich metabasites at medium to high pressures and can accommodate substantial amounts of manganese, iron (e.g., Chinner et al. 1969; Gramblíng and Williams 1984), and especially chromium in its crystal structure. Cr–Al substitution results in a spectacular turquoise-blue color and strong pleochroism as reported by Sobolev et al. (1968), Cooper (1980), and Gil-Ibarguchi et al. (1991). Cr–Al substitution in synthetic kyanite, on the other hand, produces a deep emerald green color (Langer and Seifert 1974). This suggests that the blue color of natural Cr-bearing kyanite results from a combination of Cr and additional minor substituents such as Fe and/or Ti (White and White 1967; Rost and Simon 1972). Natural kyanite with Cr2O3 contents >1 wt% have been known so far only from high-P environments. The highest Cr2O3 content documented in the literature so far is 15.7 wt%, which corresponds to ~18 mol% Cr2SiO5 component and was reported by Negulescu and Sabau (2012) from chromite-bearing meta-gabbroic eclogites. Kyanite with up to 12.7 and 11.8 wt% Cr2O3 were reported by Sobolev et al. (1968) and Pivin et al. (2011) from kimberlite-derived grosspydite and clinopyroxenite nodules. Kyanite with up to 25 mol% Cr2SiO3 was synthesized by Langer and Seifert (1974) at 3 GPa and 1300–1500 °C. These authors suggested that significant amounts of Cr can enter the kyanite structure only at P ≥ 1.8 GPa and T ≥ 900 °C and that the amount of Cr incorporated is positively correlated with both P and T. A comparison with P-T conditions of equilibration estimated for Cr-kyanite-bearing eclogite from the Carpathians by Negulescu and Sabau 2012 shows that whereas high pressures are indeed essential, temperatures as low as 600 °C are sufficient to allow substantial Al–Cr substitution. Hence, high pressures in excess of ~2 GPa and a suitable source of Cr that is usually Cr-spinel are essential prerequisites for the formation of Cr-rich kyanite.

Eclogites within the Eastern alpine crystalline basement typically appear as lenses and small bodies of up to several hundred meters in size within a narrow E-W trending zone, ~400 km in length, immediately north of the Periadriatic Lineament, which is termed the Eo-alpine high pressure belt (EHB) (Hoinkes et al. 1991; Thöni and Jagoutz 1993; Exner et al. 2001; Šolka et al. 2005a, 2005b). The south-easternmost part of the EHB is represented by eclogites of the Pohorje massif (e.g., Ippen 1892; Hinterlechner-Ravnik and Moine 1977; Hinterlechner-Ravnik et al. 1991a, 1991b; Janák et al. 2004; Miller et al. 2002a, 2005a; Vrabec et al. 2012) and of the Koralpe and Sualpe basement complexes (Miller 2001b).