Origin of vesuvianite-garnet veins in calc-silicate rocks from part of the Chotanagpur Granite Gneiss Complex, East Indian Shield: The quantitative P-T-X_{CO2} topology in parts of the system CaO-MgO-Al_{2}O_{3}-SiO_{2}-H_{2}O-CO_{2} (+Fe_{2}O_{3}, F)

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Abstract

A calc-silicate rock from part of the Chotanagpur Granite Gneiss Complex, East India, develops veins and patches of vesuvianite (F: 2.3–3.9 apfu, Fe^{3+}: 1.7–2.1 apfu) and garnet (Gr_{71.46}Al_{2.15}Ad_{1.89}) proximal to amphibole-bearing quartzo-feldspathic pegmatic veins. The host calc-silicate rock exhibits a prominent gneissic banding that is defined by alternate clinopyroxene- and plagioclase-rich layers. The vesuvianite-garnet veins are both parallel and cross-cutting the gneissic banding of the host calc-silicate rock. Two contrasting mineralogical domains that are rich in garnet and vesuvianite, respectively, develop within the vesuvianite-garnet veins. Textural studies support the view that the garnet- and vesuvianite-rich domains preferentially develop in the clinopyroxene- and plagioclase-rich layers of the host calc-silicate rocks, respectively. Some of the vesuvianite-rich domains of the veins develop the assemblage vesuvianite + quartz + calcite + anorthite (as a result of the reaction diopside + quartz + calcite + anorthite = vesuvianite) that was deemed metastable in the commonly used qualitative isobaric P-X_{CO2} topology in the system CaO-MgO-Al_{2}O_{3}-SiO_{2}-H_{2}O-CO_{2} (CMASV).

Using an internally consistent thermodynamic database, quantitative petrogenetic grids in the P-T and isobaric P-X_{CO2} spaces have been computed in the CMASV system. The influence of the non-CMASV components (e.g., Na, Fe^{3+}, F) on the CMASV topologies have been discussed using the published a-X relations of the minerals. Our study shows topological inversion in the isobaric P-X_{CO2} space that primarily depends upon the composition of the vesuvianite. The quantitative CMASV topologies presented in this study successfully explain the stabilities of the natural vesuvianite-bearing assemblages including the paradoxical assemblage vesuvianite + quartz + calcite + anorthite.

Application of the activity-corrected CMASV topology suggests that infiltration of F-bearing oxidizing aqueous fluids into the calc-silicate rocks develop the vesuvianite-garnet veins in the studied area. A genetic link between quartzo-feldspathic pegmatites and the vesuvianite-garnet veins seems plausible.

This study demonstrates controls of topological inversion in the complex natural system, owing to which certain mineral assemblages develop in nature that are otherwise deemed metastable in one set of reaction geometry.

Keywords: Calc-silicate rocks, vesuvianite, CMASV petrogenetic grid, fluorine infiltration, topological inversion

Introduction

Vesuvianite (previously known as “idoocrase”) is a rare mineral that is found in contact metamorphic aureoles, regionally metamorphosed calcareous rocks, rodingites, and altered nepheline syenites (Arem 1973; Hochella et al. 1982; Rice 1983; Valley et al. 1985; Ahmed-Said and Leake 1996; Bogoch et al. 1997; Galuskine et al. 2003; Zanoni et al. 2016). Studies have shown that in terms of ordering and symmetry, the high-temperature (>400 °C) vesuvianites that are found at contact metamorphic aureoles can be distinguished from the vesuvianites that formed in low-temperature (<300 °C) metasomatic processes (Allen and Burnham 1992; Elmi et al. 2011). Although the majority of the workers reported vesuvianite from low pressure (<2 kbar) assemblages (Labotka et al. 1988; Cartwright and Oliver 1994; Ahmed-Said and Leake 1996; Johnson et al. 2000; Nabelek and Morgan 2012; Nabelek et al. 2013, among others), its occurrence in higher pressure rocks has also been encountered by many workers (Palache 1935; Tracy et al. 1978; Valley and Essene 1979; Valley et al. 1985; Bogoch et al. 1997; Halama et al. 2013 among others). The structural formula, the site distribution of cations and anions, and, most importantly, the stability of vesuvianite have been a subject of considerable debate (Hochella et al. 1982; Valley et al. 1985; Hoisch 1985; Groat et al. 1992a, 1992b, 1994; Armbruster and Edwin 2000b, 2000a; Balassone et al. 2011; Elmi et al. 2011; Ogorodova et al. 2011; Panikorovskii et al. 2017). Studies have shown that vesuvianite-bearing rocks may be a monitor of the metamorphic fluid flow over a range of pressure and temperature (Valley et al. 1985 among others). However, the reaction topologies of the vesuvianite-bearing assemblages are not properly understood. Contrasting topologies (majorly qualitative) have been proposed in the isobaric P-X_{CO2} space in the system CaO-MgO-Al_{2}O_{3}-SiO_{2}-mixed volatile/H_{2}O-CO_{2} (CMASV; Kerrick et al. 1973; Valley et al. 1985). The main discrepancy of the previous studies seems to be related to the lack...