Epidote spherulites and radial euhedral epidote aggregates in a greenschist facies metavolcanic breccia hosting an UHP eclogite in Dabieshan (China): Implication for dynamic metamorphism

AN-PING CHEN1,2, JIAN-JUN YANG1,2,*, DA-LAI ZHONG1,2, YONG-HONG SHI3, and JING-BO LIU1,2

1State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beifu Xilu 19, P.O. Box 9825, Beijing 100029, China
2University of Chinese Academy of Sciences, Yuquan Lu 19(A), Beijing 100049, China
3School of Resources and Environment Engineering, Hefei University of Technology, Tunxi Lu 193, Hefei 230009, China

ABSTRACT

Epidote spherulites are identified in a greenschist facies metavolcanic breccia enclosing a body of coesite-bearing eclogite at Ganghe in the Dabie ultrahigh-pressure metamorphic belt, east-central China. The epidote spherulites are formed by fibrous, radially arranged, and rare earth element (REE)-rich epidote crystals (ΣREE = 0.13–0.36) and REE-poor epidote (ΣREE ≤ 0.10). Some of the epidote spherulites are overgrown by radially arranged euhedral epidote crystals, which also form aggregates around preexisting quartz, plagioclase, and/or epidote. The epidote grains in such aggregates display oscillatory zoning with REE content varying from a negligible amount to about 0.44. Epidote also occurs as REE-poor individual euhedral crystals about the radial epidote aggregates or form loose clusters of randomly oriented crystals. Thermodynamic modeling of the mineral assemblages in the plagioclase pseudomorphs and in the matrix shows that they formed at greenschist facies metamorphic conditions (435–515 °C and 5–7 kbar). The epidote spherulites and radial euhedral epidote aggregates, however, do not belong to these assemblages and are non-equilibrium textures. They imply crystal growth under large degrees of supersaturation, with relatively low ratios of the diffusion rate (D) to the crystal growth rate (G). At low D/G ratios, spiky interfaces are favorable for diffusion-controlled growth and the resultant texture is a collection of spikes around a growth center, forming a spherulite. The change of epidote texture from spherulite to radial euhedral crystal aggregate implies a decrease of supersaturation and an increase of D/G, such that the crystal morphology was controlled by its crystallographic structure. The crystallization of the individual epidote grains corresponds to a further drop of supersaturation and a further increase of the D/G ratio, approaching to the equilibrium conditions. Transiently higher P-T conditions are inferred from the spherulite-forming reactions, relative to the P-T estimates for the equilibrium assemblages. The fibrous crystals in the epidote spherulites having relatively large interfacial energies would inevitably adjust their shapes to equilibrium ones with low interfacial energies if the P-T-H2O conditions were maintained for a sufficiently long period of time. The non-equilibrium epidote aggregates likely formed in response to P-T and fluid pulses, possibly related to seismicity.

Keywords: Dabieshan, epidote, non-equilibrium, radial euhedral crystal aggregates, spherulite, supersaturation

INTRODUCTION

Spherulite are radial aggregates of fibrous crystals (Vernon 2004). They can be formed by silicates, metal alloys, elements, organic molecules, and synthetic polymers, crystallized from melts, solids, solutions, or gels (Shukenberg et al. 2011). The driving force of crystallization, which measures the distance from equilibrium, is an important factor in controlling the crystal morphology. It is well known that crystal shape changes from polyhedral, skeletal, and dendritic to spherulitic with an increasing driving force (e.g., Lofgren 1974; Oaki and Imai 2003; Jones 2017). Such a relationship is also supported by theoretical modeling (Saito and Ueta 1989; Sunagawa 1999; Wilbur and Ague 2006; Gránásy et al. 2014). It is therefore established that no matter what materials and physical states are involved, the conditions required by the crystallization of spherulites are highly non-equilibrium.

In crystalline rocks, spherulites can be formed by the same or different minerals and are known to crystallize from supercooled volcanic or frictional melts, devitrifying glasses, or supercooled fluids (e.g., Lofgren 1971a, 1971b; Vernon 2004; Xu and Scott 2005; Lin 2008; Watkins et al. 2009; Gardner et al. 2012; Melinger-Cohen et al. 2015; Jones 2017). Spherulitic epidote aggregates have been described in pseudomorphs after plagioclase in altered rhyolites (Hudson 1937), quartz–feldspar porphyry clasts in conglomerates (McCann and Kennedy 1974),...