Hydrothermal mineralization of celadonite: Hybridized fluid–basalt interaction in Janggi, Korea

JONGKYU PARK1,2†, HOSEONG LIM3, BORA MYEONG4, AND YUN-DEUK JANG1,2,*

1Department of Geology, Kyungpook National University, Daegu 41566, Republic of Korea
2Research Institute for Dok-do and Ulleung-do Island, Daegu 41566, Republic of Korea
3School of Earth, Atmosphere and Environment, Monash University, 3800 Clayton, Victoria, Australia
4GeoZentrum Nordbayern, Friedrich-Alexander-Universität Erlangen-Nürnberg, Schlossgarten 5, 91054 Erlangen, Germany

ABSTRACT

The origin of celadonite still remains enigmatic and fragmentary. Exceptional celadonite mineralization was discovered in the Miocene lacustrine Janggi Basin in the southeastern Korean Peninsula. This Janggi celadonite is a greenish, earthy/vitreous material filling east-west trending fault zones in basaltic flows. The scale of the celadonite body is up to a meter thick and laterally extends ~10 m. These occurrences are markedly in contrast with celadonite as vesicle-filling or mineral-replacing types in the literature. The Janggi celadonite allows exploring the puzzling genesis of celadonite and comparing its characteristics with global cases for a better understanding of celadonite formation.

X-ray diffraction and microprobe analyses demonstrate that the Janggi celadonite ranges from ferroceldonadonite through celadonite to ferroaluminoceladonite and is mixed with opal at a ratio of up to ~3:7. Detailed fieldwork and whole-rock major, trace, and oxygen isotope analyses indicate that celadonite is formed in an open system at ~120 °C by the interaction of hybridized fluid (a mixture of <55% magmatic and >45% other origins) and basalts during the physicochemical fault brecciation of the host rock. The cations needed for celadonite formation were supplied from the smectitization/zeolitization of rhyolitic mesostasis (for Al and part of K) and pyroxene microlites (for Fe and Mg) in the basaltic breccias during the associated oxidation of micro-nanoparticles by circulating fluids (for most of K).

A comparison of the Janggi celadonite with global cases highlights that celadonite genesis is neither limited to the seawater alteration of basalt nor do hosts and reactive fluids control celadonite compositions. A contextualized perspective on celadonite genesis alludes that a potassic alteration of rock that is rich in ferromagnesian components in a shallow crustal environment (<~200 MPa at <~450 °C) produces celadonite. Because of the relative availability of the necessary components for celadonite precipitation, our model predicts celadonite mineralization in many volcanic environments, where magmatic fluid and particle size reduction could contribute. These insights emphasize celadonite’s potential applications for tracing geothermal history.

Keywords: Celadonites, hydrothermal mineralization, fault brecciation, fluid–rock interaction, oxygen isotope

INTRODUCTION

Celadonite is a 2:1 dioctahedral true mica with a general formula of KR⁺R³⁺Si₃O₁₀(OH)²⁻ (Rieder et al. 1998). Because of the complex homo- or heterovalent cation substitution in octahedral sites, its compositional variety has been reported to be ferroceladonite-ferroaluminoceladonite (Li et al. 1997), aluminoceladonite (Drits et al. 2010), and manganoceladonite (Lepore et al. 2017) end-members.

Celadonite commonly occurs as greenish vesicle-lining or vesicle-filling materials in highly porous basalts (e.g., Baker et al. 2012) and occasionally as replacement phases for various ferromagnesian minerals, such as olivine (Laverne et al. 2006), pyroxene (Alt et al. 2010), amphibole (Barzoi and Seclaman 2010), biotite (Keeling et al. 2018), and Fe-(OH)₃ (Schramm et al. 2005). Celadonite has long been regarded as a product of the seawater alteration of basalt in marine environments (e.g., Alt et al. 2010; Andrews 1980; Böhlke et al. 1984; Marescotti et al. 2000; Odin et al. 1988; Talbi and Honnorez 2003; Teagle et al. 1996) (Table 1). However, this genetic consensus has been challenged by recent works. For example, celadonite is observed as a product of groundwater alteration (Baker et al. 2012; Innocent et al. 1997; Renac et al. 2010), deuteric alteration of basalt (Schenato et al. 2003), and microbial activity within basalt (Reolid and Abad 2014) (Table 1). Furthermore, the host rock spectrum of celadonite is significantly broad, ranging from basaltic (Baker et al. 2012), andesitic (Cathe-lineau and Izquierdo 1988), and rhyolitic volcanic rocks (Li et al. 1997) to sedimentary (Tóth et al. 2010) and metamorphic rocks (Keeling et al. 2018) (Table 1).

Tracking the source of cations and fluids needed for celadonite precipitation would provide a plausible formation mechanism because celadonite genesis has many possible routes (not limited to one of those above) that must be carefully constrained to extract geological implications. Therefore, various aspects of approaches on celadonite and its hosts should...