On the origin of sellaite (MgF$_2$)-rich deposits in Mg-poor environments

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ABSTRACT

Sellaite (MgF$_2$) forms from melts, fluids, and gases under variable temperature, pressure, $f_{O_2}$, and fluid salinity conditions. It is typically associated with, but much rarer than fluorite (CaF$_2$). The Clara mine near Oberwolfach (Schwarzwald, Germany) is an extensive hydrothermal vein-type deposit, where sellaite occurs in huge quantities (thousands of tons) in veins of mostly Jurassic/Cretaceous age. The sellaite mineralization, occurring in gneisses altered prior to and during sellaite mineralization, represents a stockwork-like network of veins and fissures, which is overlain and sealed by sediments, preventing the inflow of and fluid-mixing with sedimentary formation waters. The occurrence of sellaite is unique among the more than 1000 hydrothermal vein-type occurrences of the Schwarzwald ore district. The favored formation of sellaite compared to fluorite requires the initial Ca/Mg-ratio of the mineralizing fluid to be unusually low. These conditions are possible if fluids equilibrate with pre-altered rocks that lost some or much of their Ca during an earlier hydrothermal alteration event. Indeed, calculations demonstrate that rock-buffered fluids of pre-altered rocks (i.e., gneiss around the Clara mine altered during prior hydrothermal events) show significantly lower Ca/Mg-ratios than fluids equilibrated with unaltered gneisses, because Ca-phases (e.g., the anorthite component of plagioclase) are more prone to hydrothermal destruction. Due to the network-like structure of the sellaite-bearing portion of the Clara fluorite vein, the fluid is shielded from sedimentary formation water, resulting in fractionation processes of the repeatedly ascending mineralizing fluid. In addition, fluid cooling and formation of water-bearing phases like illite that consume fluids, favor sellaite, and later fluorite precipitation. The rarity of this combination of prerequisites explains the limited occurrence of sellaite in hydrothermal vein-type deposits.

Keywords: Sellaite, Clara mine, Schwarzwald, hydrothermal vein-type mineralization, fluid inclusion thermometry, fluid conditions

INTRODUCTION

Sellaite (MgF$_2$) is a rare mineral that occurs in variable geological settings. It can form under various different conditions (Table 1), ranging from magmatic [Oldoinyo Lengai, Tanzania; Nkombwa Hill, Zambia (Mitchell 1997; Zambezi et al. 1997; Keller and Krafft 1990)], sedimentary [New Brunswick, Canada (Grice et al. 2005)], metamorphic (Huanzala, Peru (Imai et al. 1985)], to hydrothermal environments [Suran, Russia (Ellmies et al. 1999)] and burning coal dumps [Chelyabinsk, Russia (Sokol et al. 2002)]. A locality with an unusually rich occurrence of sellaite is the Clara hydrothermal fluorite vein system in the Schwarzwald ore district, SW Germany (Maus 1977; Maus et al. 1979; Gerler 1983). This is an ideal locality for investigating the formation conditions of this unusual mineral because: (1) the Clara vein system is exposed as part of an operating mine, and (2) the Clara vein system is part of a well-investigated ore district (Schwarzwald ore district) where the geochemistry of host and possible source rocks (Hofmann and Köhler 1973; Matter et al. 1987; Schleicher 1994; Kalt et al. 2000), the formation age (e.g., Pfaff et al. 2009 and references therein), principal formation mechanisms (Schwinn et al. 2006; Baatartsogt et al. 2007; Staud et al. 2009, 2010a), ore-forming fluid conditions (Behr and Gerler 1987; Schwinn and Markl 2005; Markl et al. 2006a, 2006b; Staud et al. 2007, 2010b, 2011, 2012; Glodny and Grauer 2009; Pfaff et al. 2010), and structural control (Franzke et al. 2003; Staud et al. 2009) are well known.

In this study, we will explore the formation conditions of sellaite and investigate why the otherwise rare mineral sellaite occurs in large quantities in the Clara vein system within an elsewhere sellaite-free ore district.

MATERIALS AND METHODS

The complex vein system of the Clara mine was subdivided into numerous stages and sub-stages (Huck 1984). Stage 1 consists of a quartz-pyrite-dominated vein assemblage accompanied by intense host rock alteration and silification. In the following stage 2, the NW-SE-striking fluorite vein containing abundant sellaite formed. Stage 3 is represented by a parallel