Browneite, MnS, a new sphalerite-group mineral from the Zakłodzie meteorite

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ABSTRACT

Browneite (IMA 2012-008), MnS, is a new member of the sphalerite group, discovered in Zakłodzie, an ungrouped enstatite-rich achondrite. The type material occurs as one single crystal (~16 µm in size) in contact with and surrounded by plagioclase; enstatite and troilite are nearby. Low-Ni iron, martensitic iron, tridymite, quartz, cristobalite, sinoite, schreibersite, buseckite, keilite, and graphite, are also present in the type sample. Browneite is yellowish brown and translucent. The mean chemical composition, as determined by electron microprobe analysis of the type material, is (wt%) S 36.46, Mn 62.31, Fe 0.62, Ca 0.10, sum 99.49, leading to an empirical formula calculated on the basis of 2 atoms of (Mn$_{0.99}$Fe$_{0.01}$C$_{0.00}$)$_{2}$S$_{0.99}$. Electron back-scatter diffraction patterns of browneite are a good match to that of synthetic $\beta$-MnS with the $F\bar{4}3m$ structure, showing $a = 5.601$ Å, $V = 175.71$ Å$^3$, and $Z = 4$. Browneite is a low-temperature (<200 °C) phase, metastable relative to alabandite, that postdates the impact melting and subsequent crystallization of an enstatite-rich rock.

Keywords: Browneite, MnS, new mineral, sphalerite group, EBSD, Zakłodzie meteorite, enstatite achondrite

INTRODUCTION

The Zakłodzie meteorite, which is a moderately weathered find discovered near the village of Zakłodzie, Poland, in September 1998, is an ungrouped enstatite-rich achondrite with likely affinities to enstatite chondrites. Its origin has been ascribed to impact melting (e.g., Keil 2010) and to internal melting within the parent body (Przylibski et al. 2005). During a nano-mineralogical investigation of this meteorite, a new manganese monosulfide mineral, MnS, with a $F\bar{4}3m$ sphalerite structure was identified and named “browneite”. Field-emission scanning electron microscope (SEM), electron-backscatter diffraction (EBSD), electron microprobe, and micro-Raman spectroscopic analyses were used to characterize its composition and structure and those of associated minerals. Synthetic $\beta$-MnS with space group $F\bar{4}3m$ is a well-known synthetic material (Schnaase 1933; Yang et al. 2012) that has been heavily studied recently because MnS is a P-type semiconductor with a wide band gap (e.g., Yang et al. 2012), making it attractive for applications in short wave optoelectronic devices. It is readily synthesized as a metastable phase at low temperatures (in place of $\alpha$-MnS or alabandite, which is the stable MnS phase at room temperature) using molecular beam epitaxy and solvothermal reactions (e.g., Skromme et al. 1995; Lu et al. 2001). This study reports the first natural occurrence of MnS with the $F\bar{4}3m$ sphalerite structure, joining alabandite ($Fm\bar{3}m$; NaCl structure) and rambergite ($P6_{3}mc$, wurzite structure) as natural polymorphs of Mn monosulfides. We consider the properties and origin of this phase, its relationships to coexisting minerals, and implications through its formation and survival for the evolution of the Zakłodzie meteorite.

MINERAL NAME AND TYPE MATERIAL

The new mineral and its name have been approved by the Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association (IMA 2012-008) (Ma 2012). The name browneite is in honor of Patrick R.L. Browne (b. 1941), Professor at the University of Auckland, New Zealand, for his contributions to low-temperature mineralogy and petrology. The holotype material in a Caltech Zakłodzie section (ZAK-TS2) has been deposited in the Smithsonian Institution’s National Museum of Natural History, Washington, D.C., and is cataloged under USNM 7607. This section also hosts the type buseckite (IMA 2011-070; Ma et al. 2012).

APPEARANCE, PHYSICAL AND OPTICAL PROPERTIES

The type material is a fractured single crystal (as revealed by EBSD) in USNM 7607, occupying a triangular (in section) region with a maximum dimension of 20 µm. A portion of the crystal has a partially polished surface, ~8 µm across. The phase is surrounded by plagioclase. Troilite (as close as ~2 µm) and enstatite (within ~10 µm), are nearby (Fig. 1).

Browneite is yellowish brown, translucent, and brittle (observed during final phases of section polishing). Synthetic $\beta$-MnS, is red or pink (e.g., Yang et al. 2012). Luster, streak, hardness, cleavage, fracture, and details of the optical properties were not determined because of the small grain size. The density, calculated from the empirical formula, is 3.291 g/cm$^3$. The crystal is non-fluorescent under the electron beam in an SEM.

CHEMICAL COMPOSITION

Quantitative elemental microanalyses were conducted with a JEOL 8200 electron microprobe operated at 10 and 15 kV and...