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Seifertite, a dense orthorhombic polymorph of silica from the Martian meteorites Shergotty and Zagami

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Abstract: Seifertite is a dense orthorhombic polymorph of silica with the scrutinyite (α-PbO_2) type structure that was found as lamellae occurring together with dense silica glass lamellae in composite silica grains in the heavily shocked Martian meteorite Shergotty. The mineral is also intergrown in some grains with minor stishovite and a new unnamed monoclinic dense silica polymorph with a ZrO_2-type structure. Seifertite has also been found in the Martian shergottite Zagami and is a minor constituent in other Martian shergottites. Chemical analyses of seifertite in Shergotty indicate major SiO_2 with minor concentrations of Al_2O_3 and Na_2O. Selected-area electron diffraction (SAED) and X-ray diffraction can be interpreted in terms of an orthorhombic pattern from a scrutinyite (α-PbO_2) structure. The cell parameters are a = 4.097(1) Å, b = 5.0462(9) Å, c = 4.4946(8) Å, V = 92.92 Å^3, Z = 4, and the space group is *Pbcn* or *Pb*2*n*. Density is (calc.) = 4.294 g/cm^3 (with pure SiO_2), 4.309 g/cm^3 (with empirical formula). It is inferred that seifertite was formed by shock-induced solid-state transformation of either tridymite or cristobalite on Mars at an estimated minimum equilibrium shock pressure in excess of 35 GPa. The new mineral is named after Friedrich A. Seifert (b. 1941), founding Director of the Bayerisches Geoinstitut, Universität Bayreuth, Germany, for his seminal contributions to high-pressure geoscience.

Key-words: seifertite, new mineral, silica, high-pressure phases, α-PbO_2 structure type, shock metamorphism, Shergotty meteorite.

Introduction

Since the discovery of coesite and stishovite in Meteor Crater in Arizona (Chao *et al.*, 1960, 1962) and in the Ries Crater in Germany (Shoemaker & Chao, 1961; Chao & Littler, 1962), and the finding of coesite in exhumed ultrahigh pressure metamorphic rocks (Chopin, 1984; Gillet *et al.*, 1984), there has been significant interest in the existence of denser silica polymorphs. There are two closely-related themes in the exploration of these higher density phases. First, whether very dense silica polymorphs exist either in the deep mantle (*e.g*. Hemley *et al.*, 1994) or at even higher pressures (Kuwayama *et al.*, 2005). Second, whether the phase transitions from low-pressure polymorphs of silica induced by dynamic compression can constrain the conditions of impact events on planetary surfaces.

Silica polymorphs denser than coesite have never been encountered in any exhumed rocks on Earth. Planetary material that has been subjected to dynamic pressures in excess of $\geq$ 35 GPa remains the best candidate for searching for stishovite and other denser natural polymorphs. It has been known for many years that the basaltic shergottites, a category of SNC meteorites (Shergotty, Nakhla, Chassigny), widely considered to be of Martian origin, contain an accessory silica mineral (Tschermak, 1872, 1883; Duke, 1968). The nature of this mineral, however, has been controversial for more than four decades. It was once described as cristobalite (Duke, 1968) or as α-quartz with shock-induced planar defects (Stöffler *et al.*, 1986). Shergottites also display other deformation features suggesting that they have been subjected to high-pressure conditions in a dynamic event on their parent body (Stöffler *et al.*, 1986; Müller, 1993; Chen & El Goresy, 2000; Langenhorst & Poirier, 2000a, b, c; Beck *et al.*, 2004; Malavergne *et al.*, 2001; Chennaoui-Aoudjehane *et al.*, 2005; Chennaoui-Aoudjehane & Jambon, 2006).

An orthorhombic silica polymorph denser than stishovite was found in Shergotty and characterized by Sharp *et al.* (1999), Dera *et al.* (2002) and El Goresy *et al*. (2004). Its description as a new mineral was submitted to the

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