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Amphiboles between the sheets: observations of interesting morphologies by TEM and FESEM

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Abstract: We observed interesting amphibole morphologies by transmission electron microscopy (TEM) in air samples collected by the United States Environmental Protection Agency (USEPA) in Libby, Montana. Individual amphibole particles were identified and photographed on approximately 200 randomly selected air samples. Transfer of the TEM grids and relocation of these amphiboles in the field emission scanning electron microscope (FESEM) produced high-resolution secondary electron images that allowed a closer examination of these particles. Some of the amphiboles were perfect euhedral single crystals (several micrometers long and 200–500 nanometers wide) showing the classic {110} forms, while other single crystals appeared to be attached to sheet silicates and yet others appeared to have "wings" or "fins," often less than one micrometer in width, attached to their edges. Energy Dispersive X-Ray Spectroscopy (EDS) and selected area electron diffraction (SAED) from the TEM confirmed that these particles were intergrown amphiboles and sheet silicates. Soil samples collected by the USEPA in Libby, Montana were also analyzed. FESEM investigation revealed that the soil samples contained amphiboles with the same morphologies as observed in the air samples, and were also intergrown with sheet silicates. Thus, these amphiboles occur as single crystals between the layers of vermiculite and hydrobiotite.

Key-words: amphiboles, sheet silicates, asbestos, airborne particles, Libby, Montana.

1. Introduction

In the fall of 1999 attention was turned to the small town of Libby, Montana, because of health concerns based on asbestos exposure that occurred in the now-closed vermiculite mine. Since that time efforts have been put forth in the geological community to better characterize the amphiboles and amphibole asbestos that occurred as an accessory mineral in the vermiculite deposit. Chemical, morphological, diffraction, and optical data are provided by Bandli *et al.* (2003), morphological data by Brown & Gunter (2003) and Bellamy & Gunter (2008), chemical and structural data by Gunter *et al.* (2003), chemical and morphological data by Meeker *et al.* (2003), and compositional data on historical samples by Sanchez *et al.* (2008). Characterization efforts were also conducted on the commercial vermiculite produced from the mine. The United States Environmental Protection Agency (USEPA) tested the asbestos content of the product (USEPA, 2000, 2004), Gunter *et al.* (2005) developed a method to potentially determine the source of commercial vermiculites, and Sanchez & Gunter (2006) developed and tested a method to determine the total amphibole content of commercially available vermiculite products. For an overview of the mining history, geology, mineralogy, and amphibole asbestos health effects at Libby see Bandli & Gunter (2006).

During this same time period, the USEPA collected air samples in and around Libby. As part of an on-going effort to characterize the materials from the mine, air samples obtained from the USEPA were examined by TEM and FESEM. As this work progressed, many of the particles appeared to have unusual morphology, different from that of the more common, and in-turn well-characterized amphiboles present in the deposit, namely those that formed from the alteration of pyroxenes, ranging from fibrous to acicular to prismatic (Brown & Gunter, 2003; Meeker *et al.*, 2003; Bandli & Gunter, 2006; Gunter *et al.*, 2007). In addition to gaining a better understanding of the morphology of these particles, one of the goals of this investigation was to determine where they occurred in the deposit (*i.e.*, what other minerals or rock types they were associated with). Recalling that the major component of the ore produced from the Libby mine was a mixture of sheet silicates, mainly intergrown vermiculite and hydrobiotite, and that these sheet silicates formed as an alteration of biotite (Boettcher, 1966), it seemed possible that the amphiboles may have occurred associated with the sheet silicates. To further investigate this hypothesis, flakes of sheet silicates from the deposit were obtained and examined for amphiboles with similar morphologies as those found in the air samples.

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