Mineralogy of mine waste at the Vermont Asbestos Group mine, Belvidere Mountain, Vermont

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ABSTRACT

Samples from the surfaces of waste piles at the Vermont Asbestos Group mine in northern Vermont were studied to determine their mineralogy, particularly the presence and morphology of amphiboles. Analyses included powder X-ray diffraction (XRD), optical microscopy, scanning electron microscopy (SEM), electron probe microanalysis (EPMA), and Raman spectroscopy. Minerals identified by XRD were serpentine-group minerals, magnetite, chloride, quartz, olivine, pyroxene, and brucite; locally, mica and carbonates were also present. Raman spectroscopy distinguished antigorite and chrysotile, which could not be differentiated using XRD. Long-count, short-range XRD scans of the (110) amphibole peak showed trace amounts of amphibole in most samples. Examination of amphiboles in tailings by optical microscopy, SEM, and EPMA revealed non-fibrous amphiboles compositionally classified as edenite, magnesiohornblende, magnesiokatophorite, and pargasite. No fibrous amphibole was found in the tailings, although fibrous tremolite was identified in a sample of host rock. Knowledge of the mineralogy at the site may lead to better understanding of potential implications for human health and aid in designing a remediation plan.

Keywords: Asbestos, chrysotile, amphibole, mine waste, Raman spectroscopy

INTRODUCTION

The mineralogy of asbestos is an essential, yet controversial, aspect of the assessment of human-health risks associated with asbestos, especially for asbestos mine sites. Asbestos has been linked to several primarily pulmonary health problems in humans including asbestosis, lung cancer, and mesothelioma (Skinner et al. 1988; ATSDR 2001; Roggli and Coin 2004). Asbestos is an industrial term used to describe several silicate minerals that form long, thin, durable mineral fibers that have high tensile strength, flexibility, and resistance to heat (Skinner et al. 1988; Virta 2005; Van Gosen 2007). Commercially produced asbestos includes the serpentine mineral chrysotile and the amphibole minerals crocidolite (riebeckite), amosite (cummingtonite-grunerite), tremolite, actinolite, and anthophyllite, when the latter three are asbestiform. Greater than 95% of global asbestos production has been chrysotile (Virta 2005).

Controversy surrounds the relationship of specific asbestos minerals to specific pulmonary diseases. Asbestosis has been tied to all asbestos mineral species, and the U.S. Department of Health and Human Services, U.S. Environmental Protection Agency, and International Agency for Research on Cancer consider asbestos a carcinogen (ATSDR 2001). The link between mesothelioma and amphibole asbestos is indisputable, but a link with chrysotile is debated (McDonald et al. 1997; Fattman et al. 2004; Sporn and Roggli 2004; Gunter et al. 2007). One complicating factor in the chrysotile debate is that many chrysotile deposits may have asbestiform amphiboles as minor constituents of the ores (Williams-Jones et al. 2001; Van Gosen 2007). Therefore, it is difficult to discern unequivocally the effects of chrysotile from those of asbestiform amphibole. Additional controversy surrounds the relative toxicity of long vs. short fibers. Numerous studies demonstrate that short fibers are cleared more effectively from the lungs than longer fibers; however, other studies suggest that shorter fibers can travel deeper into respiratory systems, making them more problematic (ATSDR 2003; Fattman et al. 2004; Plumlee et al. 2006). Thus, knowledge of the mineralogical character of asbestos minerals at specific sites is important.

The Vermont Asbestos Group (VAG) mine on Belvidere Mountain in northern Vermont was the second largest asbestos mine in the United States. Chrysotile was mined from serpentined ultramafic rocks that are believed to be portions of ophiolites emplaced during the Taconic orogeny (Van Baalen et al. 1999). These rocks are part of a belt of serpentinites that extends northeastward into Quebec and also contains the well-known asbestos deposits at Thetford Mines (Chidester et al. 1978). The mine operated from around 1900 until 1993 (Van Baalen et al. 1999). During its peak, the mine was the source of as much as 96 to 98% of the chrysotile mined in the United States (Burmeister and Matthews 1962). Chrysotile asbestos was mined from three main areas: the Eden, the Lowell, and the C-area quarries (Fig. 1). Tailings from the mills at the site formed three areas of waste piles currently estimated to contain over 26 Mt of material. Due to the location of milling operations throughout the site’s history, it is presumed that the waste in the Eden quarry and nearby tailings pile is predominantly from the Eden quarry, whereas waste in the Lowell and C areas is from throughout the site.

In 2004, the Vermont Agency of Natural Resources began studying the VAG site following a complaint about the erosion of waste material into nearby wetlands. The site has become a growing concern, particularly from the perspective of human-