PLAYTHINGS VERSUS THE KILLER ROCK?

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What could be stranger than a rock you can weave into cloth and liquid metal you can hold in your hand? Both of these useful materials were common playthings for children (and adults) not long ago, but we know more about their health effects now. Mercury chemistry is complex and methyl-mercury can do more than make you "mad as a hatter." It can kill you. Likewise, "asbestos" refers to a range of minerals, some forms of which are more harmful than others and can be lethal if inhaled in sufficient quantities.

The regulatory response is mixed. Mercury use has declined, but the metal continues to pour into the environment, principally from burning coal. Other significant sources include small-scale gold production and, bizarrely, the cremation of bodies with mercury-amalgam tooth fillings. In contrast, six asbestos minerals are tightly regulated in the U.S. and billions are spent in asbestos removal of questionable value. Arguably, mercury is underregulated and one form of asbestos (chrysotile) is probably overregulated. Basic mineralogical facts about asbestos are commonly confused. Few in the general public can distinguish one fibrous mineral from another. This was demonstrated in 2010 by the misinformed attempt to brand serpentinite "the killer rock" and dethrone it as the state rock of California. Geoscientists have an important role in this debate. These materials have been discussed before in *Elements*, most recently in the Serpentinites issue (Guillot and Hattori 2013), as have other natural materials occurring in the environment. Also, *American Mineralogist* has published a virtual special issue on asbestos, and the Mineralogical Society of America has crafted an "asbestos" policy statement (www.minsocam.org/msa/policy.html?policy=Asbestos).

Chrysotile is widely recognized by its silky, asbestiform fibers, which lend themselves to weaving fire-resistant cloth, but as most readers of *Elements* are aware, it is only one of the minerals in the serpentine group, and many other minerals can also occur with an asbestiform habit, including amphiboles. The regulatory definition of asbestos is confused and based only on shape, often ignoring chemistry (see Gunter 2009, 2010). One accepted regulatory definition is based on the so-called aspect ratio and considers a mineral to be a fiber if it is more than 3 times longer than it is wide. Thus a small, brick-shaped mineral grain would be considered a fiber. This lapse is serious. Numerous epidemiological studies have strongly linked amosite and crocidolite (fibrous grunerite and riebeckite, respectively) to asbestosis, lung cancer, and mesothelioma (see Ross and Nolan 2003; Plumlee et al. 2006), while erionite (fibrous zeolite, currently unregulated) has been related to mesothelioma in Turkey. However, studies where chrysotile occurs in the absence of amphiboles have shown a less well-established link. Ross and Nolan conclude that chrysotile health risks are low and "indistinguishable from risks associated with substitute materials such as fiberglass, rock wool and various composites."

Mineralogists can also help guide safe mineral extraction. Harmful amphibole asbestos is only sometimes found in serpentinites, where it occurs especially at intrusive contacts with other rock types and can be avoided during mining, if identified. Likewise, fibrous serpentine and amphibole typically form due to shearing or dilation, and areas of concern are predicted by geological setting.

Tailings from the Vermont Asbestos Group chrysotile mines at Belvidere Mountain, Vermont. Photo by André Lalonde, provided by M. E. Gunter

This issue of *Elements* is dedicated to ophiolites, the most common source of chrysotile asbestos. How do these rocks form and where do we find them? What tectonic secrets do they reveal? Much has been learned since the first Penrose definition of an ophiolite. Multiple tectonic settings are now recognized and are summarized in this issue, and a geochemical basis is presented for their identification. The classic localities of Oman and the Izu-Bonin-Mariana arc are described in detail. This issue also reports on the discovery of diamonds and an amazing array of reduced and exotic minerals in chromitites from several ophiolites. The alteration of basaltic glass in ophiolites may even lead to the recognition of primitive lifeforms on the seafloor of the early Earth. The study of ophiolites and their mineralogy, petrology, and geochemistry, has never been more fascinating or relevant to mankind.

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