

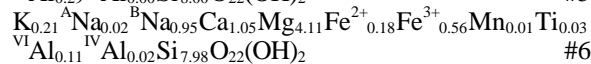
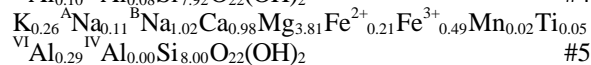
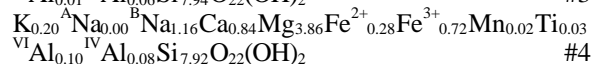
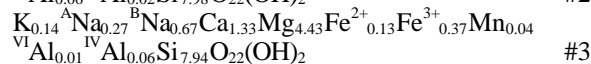
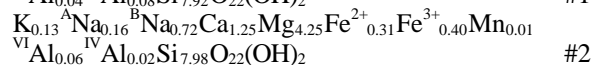
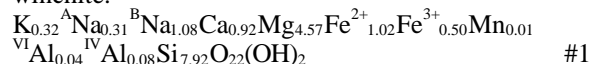
## AMPHIBOLE-ASBESTOS, VERMICULITE MINING AND LIBBY, MONTANA: WHAT'S IN A NAME?

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**Introduction:** Over the past year, tremolite-asbestos and vermiculite mining in Libby, Montana have gone from obscurity to the forefront of the national media. The Seattle Post-Intelligencer “broke” the story in November 1999 about the world’s largest vermiculite mine and the problems associated with its asbestos exposure. As the stories point out, several hundred miners, their families, and non-mining residents of Libby were affected, as were thousands of workers in the exfoliation plants where the vermiculite was heated (i.e., exfoliated) into the commercial product Zonolite. Millions of homeowners who have Zonolite in their attics as insulation were also exposed. It now appears that this form of asbestos is one of the most hazardous to date. Why?

**Geology and mineralogy:** The former mine, which was in operation from 1923 to 1990, is located in an altered ultramafic body associated with a Cretaceous age syenite intrusion [1]. The intrusion consists of a ring dike with biotite in its center surrounded by a biotite pyroxenite, and a pyroxenite with a width of 5-6 km. Some of the biotite is altered to vermiculite and the pyroxenes to amphiboles [2].

**Amphibole-asbestos:** There have been several studies of the composition of the vermiculite and pyroxenes at the mine [2], but only one analysis of an amphibole [3]. Even though the analysis showed that the amphibole is richterite (formula #1), most workers dealing with these samples still incorrectly refer to them as tremolite. Recently, two more analyses were performed [4] (#2, #3) on samples that turned out to be winchite.



We have analyzed three more samples (#4-#6) and also found them to be winchite. Fe<sup>2+</sup>/Fe<sup>3+</sup> values in #1 are from wet chemistry, and in #2-#6 are by Mössbauer spectroscopy. These analyses assume that all the Fe in the samples is in the amphibole; however preliminary low temperature data suggest the possible presence of a very fine-grained (100 Å scale) ferric oxide impurity.

Winchite and richterite are not among the six regu-

lated asbestos minerals. Clearly they should be, and ALL amphibole-asbestos should be regulated (i.e., we should regulate based on group and not species names).

**Amphibole-asbestos:** But what is asbestos? Surprisingly, this question still does not have a good answer. Based on current OSHA regulations, any of the five regulated amphiboles (crocidolite, amosite, tremolite, actinolite and anthophyllite) are considered asbestos if they have an aspect ratio (i.e., length to width) of >3 and are >5 μm in length. In 1992, OSHA deregulated cleavage fragments regardless of their aspect ratio, based on health effects studies showing differences between fibers and fragments [5]. The table below gives particle counts for samples #4-#6 for approximately 900 particles using a polarized light microscope. We found that the samples were about 1/3 fibers (i.e., asbestos), 1/3 fragments and 1/3 undetermined.

	#4	#5	#6	NIST
asp rat	fib,frg,un	fib,frg,un	fib,frg,un	fib,frg,un
<5	-,5,-	1,30,8	-,41,12	1,20,8
5-10	7,26,4	6,30,24	8,18,34	3,12,9
11-20	23,34,19	17,15,32	18,21,32	9,14,10
21-50	49,40,34	35,20,25	36,6,30	4,6,1
51-100	20,11,10	17,5,2	20,1,2	2,-,1
>100	9,6,4	31,1,1	20,2,-	-,,-
totals	108,121,71	107,101,92	102,89,110	19,52,29

The last column in the table is the NIST tremolite-asbestos standard, for which we counted 100 particles. Compared to the NIST samples, the Libby samples have higher fiber counts and greater aspect ratios; both may lead to greater health risks upon inhalation.

**Epidemiology studies:** Prompted by concerns in the early 1980s, two independent studies were performed on the miners in Libby [6,7]. Both studies showed high levels of asbestos-related diseases. The Libby studies led to the assumption that “tremolite-asbestos is the worst form of asbestos” [8]. Interestingly, a 1981 review stated “Epidemiological evidence does not exist to assess the health effects of tremolite” [9]. To date no tremolite has been found at Libby!

**References:** [1] Boettcher, A.L. (1967) *J Geol.*, 75, 526-553. [2] Boettcher, A.L. (1966) *Clay Mins.*, 6, 283-296. [3] Larsen, E.S. (1942) *USGS Prof. Paper*, 197A. [4] Wylie, A.G. & Verkouteren, J.R. (2000) *Am. Min.*, 85, 1540-1524. [5] Davis J.M.G. et al. (1991) *Ann. NY Acad. Sci.*, 643, 473-490. [6] Amandus, H.E. et al. (1987a) *Am. J Ind. Med.*, 11, 15-26. [7] McDonald J.C. et al. (1988) *Brit. J Ind. Med.*, 45, 630-634. [8] Weill, H. et al. (1990) *Am. Rev. Resp. Dis.*, 142, 1453-1458. [9] Ross. M. (1981) *Rev. Mins.*, 9A.