WHITE PAPER

ASBESTOS, HEALTH RISK AND TREMOLITIC TALC

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Introduction

One of our country's oldest and most interesting mineral risk issues involves an industrial grade talc commonly known as tremolitic talc. Tremolitic talc is a unique and complex blend of minerals most often used in the manufacture of paints and ceramics. Today this talc is mined exclusively in upstate New York by R. T. Vanderbilt Company, Inc. Vanderbilt has mined and milled this ore since 1948.

Vanderbilt tremolitic talc was the focus of an asbestos-linked rulemaking by the Occupational Safety and Health Administration (OSHA) in 1992 [(1)], the cause of an internal National Institute of Occupational Safety and Health (NIOSH) controversy in the 1980's [(2)], and the center of a media scare involving children's crayons in 2000 [(3)]. In December of 2000 it also perplexed a subcommittee of the National Toxicology Program (NTP) for the better part of a day [(4)]. For three decades the complex mineralogy of Vanderbilt's tremolitic talc has confused analytical laboratories and regulatory agencies.

The issues associated with Vanderbilt talc are multi-layered involving no less than the definition of asbestos, fiber risk theory and what constitutes meaningful health research. The original controversy involved an OSHA proposal to regulate nonasbestiform amphibole cleavage fragments as asbestos. That proposal led to extensive research into the health effects associated with exposure to tremolitic talc and other materials containing nonasbestiform amphiboles. Vanderbilt talc is also a focal point of study concerning the nature of talc fiber and talc/amphibole mixed fiber (a minor but observable component in this talc as well).

This paper reviews the origins and current status of each of these issues.

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ASBESTIFORM AND NONASBESTIFORM AMPHIBOLES: MINERALOGY

EARLY CONFUSION

The tremolitic talc saga begins in 1972. This was the year OSHA promulgated its first asbestos standard [5]. At that time, OSHA listed the following six minerals under the commercial, generic term "asbestos":

The serpentine chrysotile and five amphibole minerals; crocidolite, amosite, tremolite, anthophyllite and actinolite .

Having identified the minerals subject to its new standard, OSHA then provided a means of quantifying airborne exposure to these minerals utilizing the 3 to 1 aspect ratio or greater, 5 micrometers or longer, fiber counting scheme. Under this scheme, airborne particles from one of these six listed minerals can be collected on an air filter, measured and counted according to this dimensional criteria. It is **very** easy to understand and **not** terribly complicated to do.

However, as so often happens with simple schemes, OSHA had overlooked one critical factor. Besides its chemical composition, the crystal growth of a mineral has a dramatic impact on its characteristics and properties. The same mineral with the same chemical composition can be strikingly different if formed differently in nature. OSHA, as it turns out, was completely unaware of this crystal growth distinction.

Asbestiform and Nonasbestiform Varieties of Selected Silicate Minerals and Their Chemical Abstract Service Numbers (CAS)

Asbestiform Variety (CAS #)	Chemical Composition	Nonasbestiform Variety (CAS #)
Serpentine Group:		
Chrysotile (12001-29-5)	$Mg(Si_2O_3)(OH)_4$	antigorite, lizardite (12135-86-3)
Amphibole Group:		
Crocidolite (12001-28-4)	$Na_2Fe_3Fe_2(Si_8O_{22})OH,F)_2$	Riebeckite (17787-87-0)
Grunerite asbestos (amosite) (12172-73-5*)Δ	$(Mg,Fe)_7(SiO_{22})(OH,F)_2$	cummingtonite-grunerite (14567-61-4)
Anthophyllite asbestos (77536-67-5*)	$(Mg,Fe)_7(Si_8O_{22})(OH,F)_2$	Anthophyllite (17068-78-9)
Tremolite asbestos (77536-68-6*)	$Ca_2Mg_5(Si_8O_{22})(OH,F_2)$	Tremolite (14567-73-8)
Actinolite asbestos (77536-66-4*)	$Ca_2(Mg,Fe)_5(Si_8O_{22})(OH,F)_2$	Actinolite (13768-00-8)

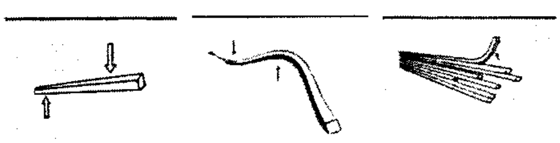
Δ The presence of an asterisk following a CAS Registry Number indicates that the registration is for a substance which CAS does not treat in its regular CA index processing as a unique chemical entity. Typically, this occurs when the material is one of variable composition: a biological organism, a botanical entity, an oil or extract of plant or animal origin, or a material that includes some description of physical specificity, such as morphology.

This table lists the six asbestos minerals OSHA listed under the heading "asbestiform." All other US regulatory agencies list these minerals as asbestos as well. Minerals listed under this column are formed in what is known as the "asbestiform" crystal growth habit. For every one of these six minerals, however, there is a corresponding mineral listed under the heading "nonasbestiform". Nonasbestiform minerals share the same chemical composition as their asbestiform analogs but they are formed differently in nature and exhibit a different crystal growth pattern. Some are called by different names - some are not. This table conforms to the nomenclature set forth by the U.S. Dept. of Interior [6].

Alarmingly, many health professionals, analytical laboratories and industrial hygienists are not aware of this distinction.

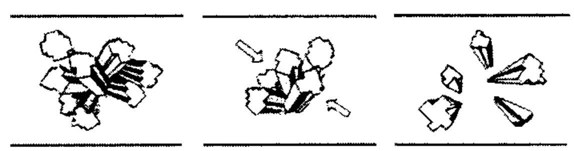
The following graphic simply illustrates the difference between asbestiform and nonasbestiform crystal growth. These drawings are not precise but will hopefully assist in the understanding of this key crystal growth difference.

ASBESTIFORM



In the asbestiform habit, mineral crystals grow in a single dimension, in a straight line until they form long, thread-like fibers with aspect ratios of 20:1 to 1000:1 and higher. When pressure is applied, the fibers do not shatter but simply bend much like a wire. Fibrils of a smaller diameter are produced as bundles of fibers are pulled apart. This bundling effect is referred to as polyfilamentous.

NONASBESTIFORM



In the nonasbestiform variety, crystal growth is random, forming multidimensional prismatic patterns. When pressure is applied, the crystal fractures easily, fragmenting into prismatic particles. Some of the particles or cleavage fragments are acicular or needle-shaped as a result of the tendency of amphibole minerals to cleave along two dimensions but not along the third. Stair-step cleavage along the edges of some particles is common and oblique extinction is exhibited under the microscope. Cleavage fragments never show curvature.

Although asbestiform crystal growth is very rare in nature, under the right geologic conditions upwards of 100 minerals may be formed in this manner – not just the six minerals we refer to as asbestos [7, 8]. This is an important point which will be addressed at greater length later in this paper.

Bearing in mind this crystal growth distinction, and recalling the OSHA asbestos fiber counting scheme, an obvious problem emerges: many nonasbestiform fragments or "cleavage fragments" will satisfy the minimal dimensional fiber counting criteria. For example, we could find a 3 to 1 aspect ratio, longer than 5 micrometer nonasbestiform cleavage fragment of actinolite or tremolite, but this would not be an actinolite or tremolite asbestos fiber. In fact, no matter what the dimension of a cleavage fragment, it is not asbestos and no mechanical manipulation or weathering will turn it into asbestos.

However, for those with no understanding of this very basic growth distinction and inclined to use the counting criteria as part of the definition of asbestos, elongated cleavage fragments will mistakenly be counted as asbestos fibers. This counting rule is not, of course, part of the definition of asbestos [8-10]. The rule is merely an arbitrary elongated particle counting scheme imported from the United Kingdom to improve consistency in asbestos fiber counting in a known asbestos exposure. With the exception of the 5 micrometer minimum length, there is no biologic relevance to this dimension.

Photographs of the actual minerals are appended to this paper (last two pages) [6]. These photographs clearly reflect this important crystal growth distinction for each of the six minerals in both habits. Note that even in hand specimens an obvious fiber crystal growth pattern can be observed for asbestos. In the asbestiform habit fiber separation is also evident. The fibers are very long and thin, curvature can be observed, and most importantly, fiber bundling is apparent. Under the light microscope at relatively low magnification, these characteristics become even more obvious.

It might be noted that under light microscopy, very few (if any) asbestos fibers will be seen that are not a bundle. Since individual fibrils are extremely thin (typically <0.25 but almost always <0.5 micrometers), most fall below the resolution limit of the microscope [11-14]. When laboratories "jump over" the use of light microscopy, they do run the risk of overlooking this bundling characteristic – the hallmark of asbestiform crystal growth. This is an especially important distinguishing characteristic in rare instances when asbestiform fibers and elongated cleavage fragments are of the same size.

In stark contrast to the asbestiform growth pattern, nonasbestiform growth is just as obvious in hand specimens as under the light microscope. In hand specimens, random prismatic crystal growth and the absence of obvious fibers is evident. When this structure is crushed or broken, prismatic cleavage fragments are formed which again show no fiber bundles, splayed ends, or marked curvature [6, 8, 10 - 16].

Cleavage fragments tend to be blocky, with a few elongated or acicular fragments that may satisfy the OSHA asbestos fiber counting criterion. These are low aspect ratio particles typically wider than 1 micrometer and shorter than 20 micrometers [11,17-19]. Optical continuity can be seen that suggests the absence of fiber bundles. The nonasbestiform tremolite pictured is from the Vanderbilt mine, and appears in the talc product at a weight percent of 40 to 60%, depending on the grade. When this rock is examined by health professionals and regulators, they often ask where the fibers are. For many, it's hard to believe that the word "tremolite" could possibly mean anything other than asbestos. More often then not, however, it does.

THE DEFINITION OF ASBESTOS:

In order to clarify the mineralogical characteristics of asbestos and the meaning of the term "asbestiform", a group of mineral scientists agreed upon the following definitions. Many of those who contributed to these definitions have published extensively on asbestos nomenclature issues [20]. While all mineral scientists may not agree with every entry in this definition, it does present a more mineralogically accurate description than does the early OSHA definition. This definition is now accepted in whole or in part by most regulatory and standards setting groups.

A. ASBESTOS — A collective mineralogic term that describes a variety of certain silicates belonging to the serpentine and amphibole mineral groups, which have crystallized in the asbestiform habit causing them to be easily separated into long, thin, flexible, strong fibers when crushed or processed. Included in the definition are: chrysotile, crocidolite, asbestiform grunerite (amosite), anthophyllite asbestos, tremolite asbestos and actinolite asbestos.

B. ASBESTOS FIBERS — Asbestiform mineral fiber populations generally have the following characteristics when viewed by light microscopy:

1. Many particles with aspect ratios ranging from 20:1 to 100:1 or higher for particles >5 μm in length.

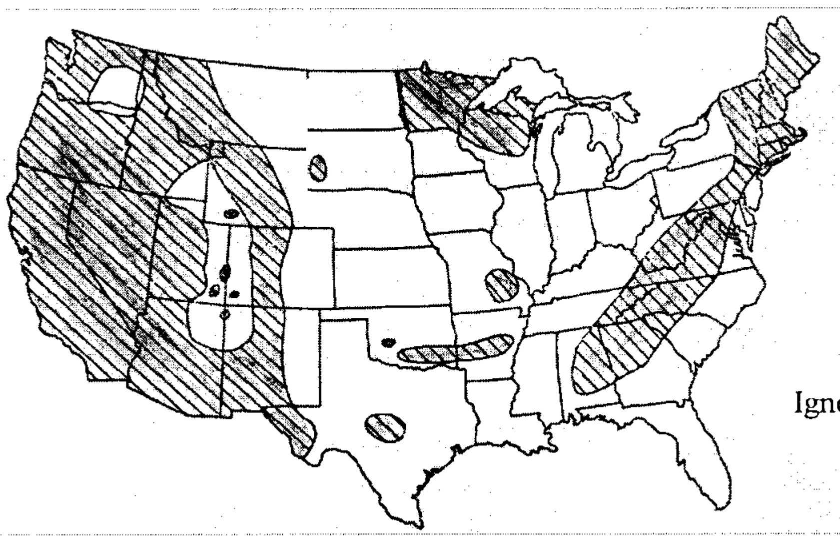
2. Very thin fibrils generally <0.5 micrometers in width.

3. In addition to the mandatory fibrillar crystal growth, two or more of the following attributes:

   (a) Parallel fibers occurring in bundles
   (b) Fibers displaying splayed ends
   (c) Matted masses of individual fibers
   (d) Fibers showing curvature

THE IMPACT OF IMPRECISION

It might be asked what would be the harm if we simply considered cleavage fragments the same as asbestos and did not concern ourselves with this crystal growth distinction? The following map shows the areas of the continental US where these minerals are commonly found in bedrock and soil. The shaded areas do not mean that every rock or soil mass in that area contains these minerals but rather that they are often present in these areas [21].



Igneous or metamorphic rocks

According to the US Bureau of Mines, if the nonasbestiform analogs of asbestos were regulated as asbestos, it would significantly impact the mining of such important mineral commodities as gold, copper, iron, crushed stone, sand, gravel and talc. Downstream users of these commodities, such as construction, smelters, ceramics and paint manufacturers would be impacted as well. The Bureau of Mines determined that such a lack of mineral discrimination would result in a very significant economic impact [(22)].

EARLY REGULATORY RESPONSE

Vanderbilt did bring the asbestiform/nonasbestiform amphibole mineral distinction issue to the attention of OSHA. At that time, OSHA gave every indication that this was an oversight that they would correct in their final asbestos standard. They stated this intention in the Federal Register in 1984 [(23)].

When OSHA formally revised its asbestos standard in 1986 [(24)], it did point out the mineral distinction just discussed. However, while recognizing this distinction, it stated that they would regulate amphibole cleavage fragments in the same way as asbestos anyway. Mysteriously, however, OSHA intended to include only the amphiboles with the same name for both habits (tremolite, anthophyllite and actinolite). Fortunately, the Secretary of Labor and the Office of the Solicitor intervened and an administrative stay was ordered pending further review [(25)].

But why, after recognizing this mineral nomenclature problem, did OSHA opt to ignore this distinction? Simply put, OSHA felt that elongated cleavage fragments posed the same health risk as asbestos fibers. OSHA reasoned that because the cleavage fragments at issue had the same chemical composition as their asbestiform analogs, were durable, could be elongated and of respirable size, it would be reasonable to expect a "same as" asbestos health effect [(24)]. The health effects most closely associated with excess exposure to asbestos include lung cancer, mesothelioma and nonmalignant respiratory disease (asbestosis).

To support this presumption, OSHA cited two mortality studies of upstate New York talc workers as evidence of a "same as" health effect for nonasbestiform amphiboles [(24)]. Upstate New York talc does contain a high concentration of nonasbestiform amphiboles (tremolite in particular). A review of these studies appears next.

ASBESTIFORM AND NONASBESTIFORM AMPHIBOLES: HEALTH

VANDERBILT LUNG CANCER EXPERIENCE

The two mortality studies OSHA cited include early work by the New York State Health Department (Kleinfeld) [26] and most significantly, a 1980 NIOSH study of Vanderbilt miners and millers [27]. These were the only health studies OSHA cited in support of the regulation of nonasbestiform amphiboles as asbestos.

The Kleinfeld studies did record excess lung cancer among upstate NY miners with exposures dating back to the 1930's and 40's. These studies did not, however, include many Vanderbilt miners and millers given the requirements for entry into the study (15 years or more of exposure between 1940 and 1969 – the Vanderbilt mine did not open until 1948). Further, there were no lung cancer cases recorded for Vanderbilt mine and mill workers (earliest lung cancer death recorded in Vanderbilt only mortality studies that met Kleinfeld's study requirements was in 1973. Thus, the Kleinfeld studies involved ore bodies never mined by Vanderbilt and dust exposure levels many times greater than any ever encountered by Vanderbilt miners and millers (5 to 10 fold greater reflected in Kleinfeld exposure tables). Accordingly, there is uncertainty regarding exposure and relevance to Vanderbilt talc. Further still, only 260 miners were included in these studies, and the characteristics of the lung cancer mortality observed did not parallel those observed in asbestos exposed cohorts. The excess lung cancer observed may have been associated with lung cancer risks such as smoking or particle overload (early talc dust exposures were very high). These studies have been used to argue for and against nonasbestiform amphiboles as a "same as" asbestos risk. Kleinfeld himself urged caution in interpreting their results.

In regard to the NIOSH study, OSHA felt it had something more up-to-date and pertinent since after 1974 the only talc mining operation in upstate New York was Vanderbilt's.

In the NIOSH study, approximately 3 times the expected rate of lung cancer mortality was observed. This is considered a moderate but statistically significant excess. The NIOSH study included anyone who had ever worked in the talc mine or mill for any period of time between 1948 through 1977. The total cohort size was 398 (also a comparatively small study group).

NIOSH attributed the lung cancer excess to a 40 – 60% amphibole asbestos exposure it believed existed at the Vanderbilt mine. Since nonasbestiform tremolite makes up 40 – 60% of this talc, it was clear that NIOSH was confusing nonasbestiform tremolite with tremolite asbestos. NIOSH has a policy (that stands to this day) which considers elongated amphibole cleavage fragments no differently than asbestos.

Looking at this overall excess lung cancer it did appear that nonasbestiform amphiboles might indeed pose an asbestos risk. However, after this internally reviewed study was formally released as a Technical Report , a number of weaknesses in the study were noted. The most significant of these included the following:

- The report stated that the relevant exposure was 40 – 60% amphibole asbestos when clearly it wasn't. The presumption of such an elevated asbestos exposure may have caused an "expectation bias". Interestingly, most actual asbestos mines contain less than 5% asbestos in the raw ore [28, 29].

- The lung cancer cases appeared highest among those least exposed to the dust. This is inconsistent with a dust dose-response connection and inconsistent with what is seen in asbestos exposed cohort studies.

- Although a critical consideration in any study involving lung cancer, there was no smoking data presented in the NIOSH work.

- No prior or post employment exposure information was provided.

In effect, Vanderbilt did not question the excess lung cancer. Vanderbilt and many health researchers question whether it was actually linked to the dust exposure [2, 30-35].

In order to address these questions, an additional 6 mortality studies were undertaken. It wasn't long before Vanderbilt talc miners and millers were among the most studied miners in the world. The six studies included the following (in chronological order):

	Pub. Yr.	Lung Cancer SMR	Cohort Size
1. Stille, W. Tabershaw [36]	1982	157	708
2. Lamm S., et al [37]	1986	220	741
3. Lamm S., et al [33]	1988	same cohort, but focus on short term workers.	
4. NIOSH HHE Update [38]	1990	207	710
5. Gamble, J. [39]	1993	same NIOSH cohort – case control study	
6. Honda, Y., et al [40]	1995	252	818

A detailed review of each of these studies is beyond the scope of this paper but the following table reflects the most up-to-date breakdown of lung cancer among Vanderbilt talc miners and millers.

LUNG CANCER CASES
Honda, Y. et al: 1995: Cohort 818 SMR: 254

Covers all talc workers 1948 to the end of 1989 who worked for any period of time

Tenure Time at GTC	Work Area	Year DOD	Smoker*	Cigarette/Per Day
1 day	**MINER**	80	yes	20
4 days	Mill	87	?	-
7 days	no exposure	86	?	-
7 days	no exposure	70	yes	20
18 days	Mill	70	yes	40
18 days	**MINER**	88	?	-
1¾ months	**MINER**	70	yes	40
1¾ months	Mill	88	?	-
2 months	**MINER**	71	yes	20
2 months	**MINER**	84	yes	40
2½ months	**MINER**	75	yes	20
2½ months	Mill	84	yes	40
4½ months	**MINER**	81	yes	20
6 months	Mill	89	?	-
7 months	no or min. exposure	85	?	-
10 months	**MINER**	73	yes	20
10½ months	**MINER**	85	?	-
2.1 years	**MINER**	82	yes	20
2.5 years	**MINER**	74	yes	20
2.6 years	**MINER**	61	yes	20
2.9 years	**MINER**	64	yes	10
3.6 years	**MINER**	89	?	-
9.9 years	min. exposure	86	?	-
12 years	**MINER**	75	yes	30
17 years	Mill	76	yes	20
17 years	**MINER**	73	yes	20
17 years	**MINER**	84	yes	50
17 years	**MINER**	85	yes	20
23 years	Mill	82	yes	20
23 years	**MINER**	79	yes	40
23 years	no exposure	88	?	-

*Smoking data obtained to 1985 (Gamble-Case Control). To that date, all cases smoked, 73% of controls smoked (includes a small proportion in both groups of ex-smokers).

Each study did find that the overall lung cancer excess recorded by NIOSH remained essentially unchanged. It was further observed that the basic characteristics of the cases (tenure, latency information, work area, etc.) did not change substantially either.

When reviewing the above table one sees a much higher number of cases among miners than among millers. This is important because dust exposure data over the years show similar overall dust levels (all categories – total dust, respirable dust, 3:1 aspect ratio fiber counts) in the mine and the mill [(41)]. Some reports suggest the mill has historically had the higher dust levels [(26, 27)]. Accordingly, there should be more cases among millers if a dust etiology is to be supported. Summary dust exposure data appears below:

Dust Exposures

	Cases	Resp. Mg/m^3 Dust Avg.	Mppcf Avg.	Fibers/cc
Mill	7	0.46	14	1.5 - 8.0
Mine	19	0.73	11	1.7 - 9.8
		(1970-85)	(1954-75)	

Mppcf Averages for Select Activities (27, 41)
Mill: Packers 16; wheeler mill operator 10, dryer 8
Mine: Crusher 17; slusher 15, trammer 7

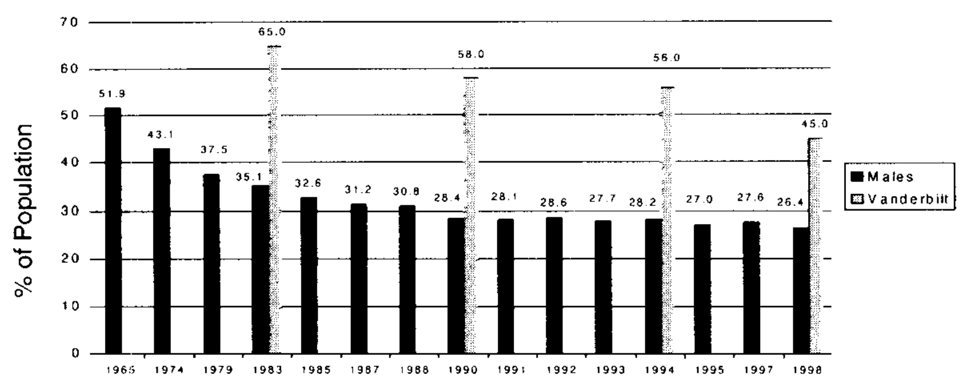
The lung cancer mortality table also shows a very high percentage of cases with very minimal exposure time (tenure) on the job. In fact, 55% of all the cases worked less than a year, and 45% worked less than 6 months. There are cases with 1 day of exposure, 4 days of exposure in an individual's entire work life. Of all the cases, 22 or 71% had less than 5 years of exposure.

If the dust were so potent as to cause lung cancer with such minimal exposure, one would certainly expect to see those exposed longer to show even higher lung cancer rates. This does not, however, occur. This is not suggestive of a dust etiology and is not what is seen when lung cancer rates are elevated among cohorts exposed to asbestos (2, 30, 35-37, 40).

A case control study published by Gamble obtained smoking data up to 1985 (39). From this study it was learned that all the lung cancer cases up to that time had been smokers. It was also learned that the controls (workers of similar age and exposure as the lung cancer cases) had also been heavy smokers with a smoking prevalence of 73%.

The following graph shows the historical prevalence of smoking among Vanderbilt talc miners and millers contrasted to national norms for US males. Smoking records for Vanderbilt workers are not reliably recorded prior to 1980 but the smoking rate was likely just as elevated - about twice the national average (based upon trend).

Cigarette Smoking (Current)
U.S. Males vs. Vanderbilt Talc Workers



U.S. Rates: Source MMWR. Vol. 49. No. 39

NIOSH concluded that smoking, although a factor, could not account for all the excess [38]. Other researchers, however, feel that it does, and that it is the most plausible explanation for the lung cancer excess [2, 39]. These researchers point out that the latency period between first smoked and death versus first exposed to tremolitic talc and death, fits a smoking latency better than an asbestos latency.

In addition, the expected number of deaths linked to smoking falls within the confidence interval for expected lung cancer deaths. In other words, it is statistically possible that the excess was entirely due to smoking. This point, however, remains the source of debate and largely depends on which statistical model one chooses to use.

Nevertheless, whether smoking - in whole or in part - accounts for the excess, it was confirmed through a dust exposure assessment study that an inverse dose-response exposure existed. This had been strongly suggested in the earlier tenure data. Actual cumulative respirable dust exposure for the lung cancer cases was 31% below that of all the decedents [40, 41]. Such a finding is referred to as an "inverse dose-response".

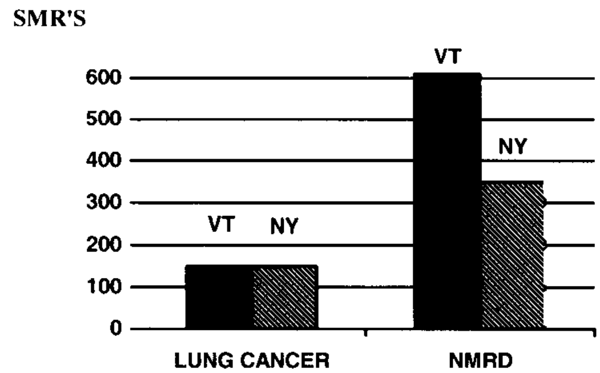
Regarding current Vanderbilt tremolitic talc exposures, it might be mentioned that "even if" the excess lung cancer recorded was linked to dust exposure, the excess existed only among underground miners – not millers. In 1995 Vanderbilt closed the underground mine. Therefore, that exposure no longer exists. With regard to downstream users of Vanderbilt talc, the talc millers are exposed to dusts that most closely matches that of the finished product. Health studies of tremolitic talc users are limited but the few that do exist show no excess lung cancer (i.e., paint manufacturers and sanitary ware ceramic workers) [42, 43]. Uses of tremolitic talc involve the blending or encapsulation of this talc into product matrix systems such as paint and wall tile. This significantly limits product linked airborne exposures to this talc, or any mineral component, similarly encapsulated [44, 45].

A COMPARISON OF NEW YORK VERSUS VERMONT TALC MINING:

In addition to studies directly involving Vanderbilt talc workers, other studies lend insight into whether exposure to Vanderbilt talc is or is not likely responsible for the excess lung cancer observed (whatever its' mineral content). At about the same time NIOSH was studying tremolitic talc and issuing a report they titled "Talc containing Asbestos", it was also working on a study involving talc miners and millers in Vermont, who mined pure, platy, cosmetic grade talc. Vermont talc was said not to contain amphibole cleavage fragments and other components that appear in Vanderbilt talc (i.e. minor talc fiber). NIOSH would later issue the Vermont report under the title "Talc not containing Asbestos" [46].

It is difficult to compare one epidemiology study with another, but the comparison shown below is reasonable for a variety of reasons. When miners and millers with more than one year of exposure are compared in both study groups, the number of talc workers in both studies was similar. Both mining populations had similar exposure years and similar overall dust exposure levels as well [47].

Mortality Comparison: Vermont & New York For Workers With >1 Year Exposure



This comparison shows that the overall lung cancer mortality is no different. Also, mortality linked to nonmalignant respiratory disease (which would include pneumoconiosis) is actually higher in Vermont. The idea that amphibole cleavage fragments (or anything else present in New York talc, but not in Vermont talc) causes lung cancer is clearly not supported by this comparison.

Interestingly, NIOSH concluded that the small lung cancer excess observed in Vermont was not linked to the dust because dust levels were about the same or higher in the mill, and most of the lung cancer cases were found among the miners. Hence, no exposure/response relationship could be seen. That same work area observation is no different than in NY. In NY, however, NIOSH incorrectly reported a massive "asbestos" exposure which became the explanation for the NY lung cancer experience. In Vermont, the excess was said to be likely due to smoking or some other "undetermined" cause.

ANIMAL STUDIES:

Besides the epidemiology work, there are also two published animal studies that directly test Vanderbilt talc against asbestos. One study was undertaken by Merle Stanton of the National Cancer Institute [48] and the second by William Smith of Fairleigh Dickinson University [49].

Dr. Stanton was testing the theory that morphology (particle dimension) is most key to fiber toxicity. He tested 72 samples measuring the lengths and widths of particles in each sample. Dr. Stanton concluded that samples containing the most fibers with a width less than 0.25 micrometers and a length greater than 8 micrometers produced the most tumors. Dr. Stanton called this minimum length and width his "critical dimension". This work is frequently cited by those who believe that only fiber morphology influences biological response.

Critics of Stanton's work argue that it is statistically flawed and that it does not show that morphology alone is involved [50 - 52]. There is no doubt that fiber dimension does play an important role – just not the only role. Dr. Stanton's critical dimension, of course, would be inclusive of most any asbestos fiber (unless found in a thick bundle), and would not include cleavage fragment dimensions. Most of his samples were asbestos-containing samples.

Among all the samples Dr. Stanton tested was an off-the-shelf sample of Vanderbilt talc, as well as several platy talc samples [53]. As the following table reflects, the Vanderbilt talc sample produced no tumors, and the platy talc an insignificant background level.

NCI ANIMAL STUDY
M. Stanton - Correlation of Fiber Dimension to Carcinogenicity

Material	Critical Dimension (log fibers/ug) ≤0.25 μm W & >8 μm L	Animals % tumors
Amosite	3.5	93%
Tremolite Asbestos	3.1	100%
Platy Talc	0	3%
Vanderbilt Talc	3.3	0%

Study involved pleurae implant in rats for periods of one year or more. 72 samples were used in the study. 7 talc samples were used, two of which were Vanderbilt talc (off the shelf).

The middle column reflects the presence of "critical dimension" fibers. This column indicates there are fibers in the Vanderbilt tremolitic talc sample that meet Stanton's critical dimension. The fibers recorded here are talc fibers and mixed talc/amphibole fibers. With these dimensions, they are clearly not cleavage fragments. These fibers do appear in Vanderbilt talc at minor, but observable levels. These interesting fibers will be discussed more fully later in this paper.

It should be noted, however, that the Vanderbilt talc sample flies in the face of Stanton's hypothesis. According to Stanton's own calculations, we should have seen upwards of 60% tumors in the Vanderbilt sample, but no tumors were observed.

The following table reflects the results of the second animal study by William Smith, who also tested Vanderbilt talc against asbestos. At the highest dose level, Vanderbilt talc as well as a concentrate of tremolite (nonasbestiform) taken from Vanderbilt talc, produced no tumors while tremolite asbestos tested under the same experimental conditions, did.

BIOLOGIC TESTS OF TREMOLITE IN HAMSTERS
William Smith

Material	Tumors/Survivors After 350	500	600 Days
Tremolite Asbestos (sample 72)	3/20	5/6	5/1
Vanderbilt Talc (sample FD-14)	0/35	0/27	0/20
Tremolite Nonasbestiform (275)	0/31	0/15	0/3

Study involved intrapleural injection in hamsters. 25 mg Dose

The next table reflects the results of a series of animal studies by Addison & Davis, who also studied animal response to tremolite asbestos as opposed to nonasbestiform tremolite. Tremolite from Vanderbilt's talc was not tested in this work, but once again, the results show a striking difference between tremolite asbestos and nonasbestiform tremolite.

ADDISON/DAVIS

Peritoneal Injection Study (rats – 10mg)
18 MONTHS AFTER INJECTION [54] *

Sample:	# Deaths	# Survivors
Tremolite Asbestos (California)	**33**	**3**
Tremolite Asbestos (Korea)	**29**	**4**
Tremolite Asbestos (Swansea)	**31**	**1**
Nonasbest. Tremolite (Italy)	**0**	**36**
Nonasbest. Tremolite (Scotland)	**1**	**32**
Nonasbest. Tremolite (Scotland)	**0**	**36**

* **The final completed study covering 24 months [55] showed a significant number of deaths late in the study for the Italian sample. These late deaths were reported by the authors as likely attributable to a small asbestos fiber sub-population later identified in this sample.**

MESOTHELIOMA:

There are currently no known mesothelioma cases reasonably linked to Vanderbilt talc or any of the mineral components in this talc (e.g., amphibole cleavage fragments). The qualifying term "reasonably linked" must be used because two reported cases are recorded in the mortality studies. However, neither case was linked to exposure to Vanderbilt talc by the authors [27, 40]. In one case the worker was exposed to Vanderbilt talc for no more than 15 years before the malignancy was diagnosed. A 20 to 40 year latency is typically expected as one indicator of a possible causal connection. In a second case a minimal exposure was reported (6 months in 1948), followed by decades of furnace and boiler repair and removal.

Since the last mortality study vital status cut-off (end of 1989), several mesothelioma deaths where also reported through the worker's compensation system. These claims were investigated in respect to work histories and diagnosis reliability by physicians experienced in this field [56, 57]. Investigation (including tissue analysis when available) suggests that these cases fell into one of two categories: those more likely than not to have been diagnosed incorrectly or those diagnosed correctly but showing clear evidence of exposure to actual asbestos including exposures within the Vanderbilt mine itself from machine brake pads and insulation materials [58].

In 2002 a case review study was published as a supplement paper that addressed mesothelioma among upstate New York talc miners(59). Although this study is not specifically linked to Vanderbilt talc, it does suggest a link between talc mined in the region and mesothelioma. The study involved a comparison of minerals found in the lungs of area miners (lung burden) with and without mesothelioma and suggests that elevated rates in one New York State county in the 1970's might be linked to regional talc mining.

In 2006 the above referenced study underwent critical review by a panel composed of pathologists, epidemiologists, mineral scientists and a risk specialist who found the document seriously flawed on several levels (60, 61). Concerns included (but not limited to): the absence of work histories beyond regional mining, limited lung content analysis with inadequate sensitivity (e.g. analytical tools used), likely case/control selection bias, dissimilar lung burden content described as similar, small numbers, questions on proper mineral identification and linkage to a county in which talc mining does not occur.

Mesothelioma is difficult to accurately diagnose given the morphological variability of the tumor. For example, malignant mesothelioma cells are difficult to distinguish from benign reactive mesothelial cells (62). There is considerable debate over the degree of association between asbestos exposure and mesothelioma. Association estimates range anywhere from 100% to as little as 13% (63) with most researchers reporting an 80 to 70% link (64, 65). There is also debate regarding the under reporting of mesothelioma when asbestos exposures are not anticipated and over reporting when they are (66). Until most recently mesothelioma has not had a unique code in the International Classification of Disease and Causes of Death, further complicating epidemiological analysis (67).

Although the exact number of confirmed mesothelioma cases not linked to asbestos exposure will likely never be known (asbestos being as pervasive as it is), it is generally recognized that there are causes other than asbestos. Though rare, the occurrence of mesothelioma in children is an example of this. Though some nonasbestos causes remain controversial, exposures to radiation, pleural tuberculosis, wood lignon constituents, the SV40 monkey virus that is said to have contaminated polio vaccines between 1954 & 1963, some herbicides, heredity links, heavy metals such as nickel and general chronic irritation from inflammatory processes like peritonitis have been reported (among others) (65).

Given such uncertainties, responsible medical groups such as the American Thoracic Society repeatedly urge caution with regard to the interpretation of reported mesothelioma. Certainly, before such a risk was unequivocally linked to Vanderbilt talc, one would want the diagnosis positively confirmed, actual exposure to the talc confirmed and a complete accounting of all lifetime exposures other than Vanderbilt talc. Such confirmatory expectations are not generally viewed as unreasonable.

Finally, with regard to tremolitic talc and mesothelioma, it should be noted that the animal studies discussed above are pleural injection and implantation studies. Tumor promotion in pleural tissue speaks more to mesothelioma induction than it does to lung cancer. Under the same test conditions, New York State talc (whatever its mineral make-up) did not produce tumors in pleural tissue while asbestos did.

NON-TALC CANCER MORTALITY STUDIES - NONASBESTIFORM AMPHIBOLES

It was noted earlier that nonasbestiform amphiboles are common rock and soil producing minerals, found throughout the earth's crust. Human studies involving nonasbestiform amphiboles other then those found in Vanderbilt talc therefore exist. Two such studies are of particular significance.

The first of these studies is the famous Reserve Mining case involving taconite (iron ore) mining in Minnesota. Reserve Mining became a major media and legal event in the early 1970s. It is a very interesting and very disturbing case. Years after Reserve Mining was forced into Chapter 11 bankruptcy, a book entitled "Judgment Reserved" was written about this sad episode.

Reserve Mining was taken to court by the EPA because their waste piles (tailings) were placed along Lake Superior and were washing into the lake. The public was outraged – especially people who used Lake Superior as their drinking water. To make matters worse, Dr. Irving Selikoff from Mount Sinai Hospital visited the area, and told the press that anyone driving past the waste piles should roll up their windows because these waste piles were riddled with asbestos. With that pronouncement, the level of public indignation and fear rose to new heights.

Emotional court battles followed, piles of papers were written, lawyers became wealthy and Reserve Mining (with several other mining companies) did seek bankruptcy protection. At the time it was felt that this hardship was justified as the EPA was saving people from asbestos.

Later, it was learned, the asbestos reported was actually the nonasbestiform variety of cummingtonite-grunerite (the nonasbestiform analog of amosite) [69]. While polluting Lake Superior with mining waste was not a wise idea, later health studies of iron ore miners, as well as studies of those who drank water from Lake Superior, showed no cancer excess [69-72].

The second study involved NIOSH and nonasbestiform cummingtonite-grunerite once again. This time, Homestake Mining, one of the countries largest gold mining operations located in Lead, South Dakota, was studied. Like Reserve Mining, a very large mining cohort was involved. The following statement appeared in a preliminary study report by NIOSH [73]:

" Environmental samples clearly showed airborne fibers to be characterized as cummingtonite-grunerite with composition identical to the commercial amosite fiber."

It is clear that NIOSH recognized it was dealing with nonasbestiform cummingtonite-grunerite and that it was different than amosite (despite the same chemical composition). But, one paragraph below, NIOSH simply turned nonasbestiform cummingtonite-grunerite into asbestos and that, they argued, was the reason for a moderate elevation in lung cancer that they initially felt they saw.

"Thus, the amosite variety of asbestos which is the asbestiform minerals found at the subject mine, must be considered the naturally occurring suspect agent in the excess malignant neoplasms of the respiratory system found in this cohort."

Homestake objected to technical lapses they felt existed in the NIOSH work. Many of these problems (absence of smoking data, error in exposure characterization, etc.) were very similar to those encountered in the Vanderbilt NIOSH study. Homestake petitioned NIOSH to return and perform a more thorough evaluation. Upon closer review, the excess lung cancer originally reported did not, in fact exist [(74)]. Other studies of Homestake miners and millers further confirmed the absence of dust linked excess lung cancer in this cohort exposed to nonasbestiform amphiboles (as well as to crystalline silica) [(75, 76)].

NONMALIGNANT RESPIRATORY DISEASE:

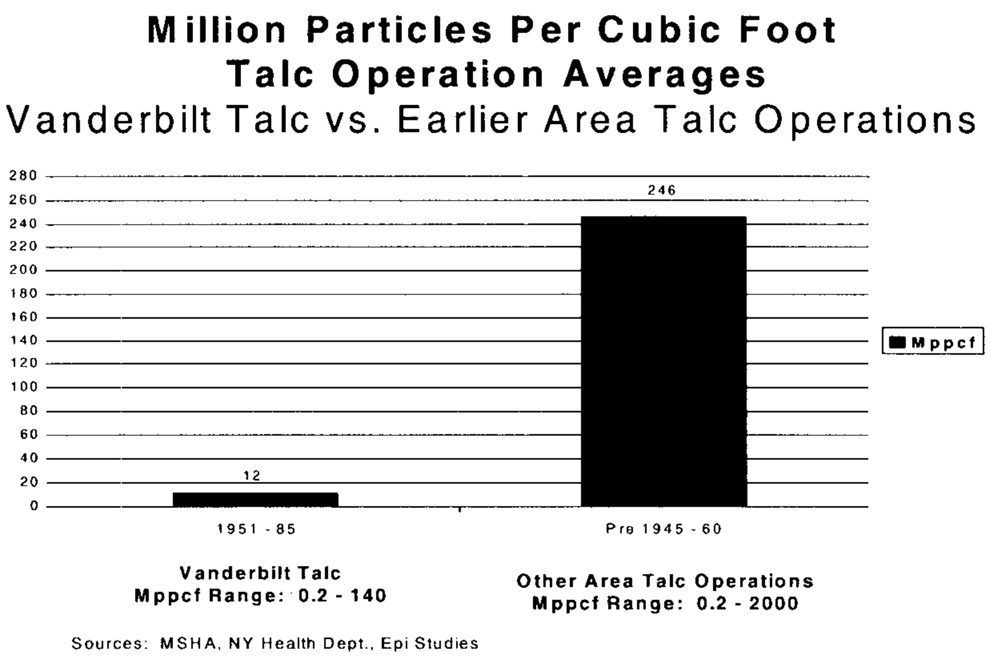
While cancer is typically the principle concern whenever asbestos (real or imagined) is addressed, excess exposure to asbestos is also associated with asbestosis. Asbestosis is a dust linked nonmalignant respiratory disease that falls under the broad term pneumoconiosis (or dusty lung). The clinical signs of asbestos are largely indistinguishable from those observed as a result of overexposure to most any durable, respirable mineral dust. These signs involve lung scarring in the lower air exchange region of the lung (interstitial fibrosis).

A profusion of scarring in this lung region results in restrictive ventilatory patterns, reduced blood oxygenation and cardio vascular stress. Some dusts are capable of producing these signs and effects at lower exposure levels and/or at a more rapid rate and are therefore viewed as posing an elevated risk. Respirable crystalline silica (silicosis) and asbestos (asbestosis) are examples of such elevated nonmalignant respiratory risks. Lower risk dusts such as kaolin (kaolinosis) or talc (talcosis) produce similar signs and effects but require extended exposure to much higher exposure levels. Smoking compromises pulmonary dust clearance defenses and thus enhances the onset and severity of all pulmonary dust disease [(77)].

Antidotal, sensationalized news reports regarding nonmalignant dust linked respiratory disease (pneumoconiosis) among Vanderbilt talc miners and millers do exist [(78)]. However, a great deal is known about the actual onset and progression of pneumoconiosis among these talc workers. Chest radiographs are routinely obtained and date back to the opening of the mine in 1948. Over the years these chest x-rays have been reviewed by many pulmonary specialists [(79)]. Pulmonary function testing is also routinely conducted and reviewed [(27)]. Such an unusually complete pulmonary record has been used to address whether or not elevated dust linked disease exists among these miners and millers. Such reviews provide further insight into whether asbestos, or something just as harmful, is present in this talc.

The historical prevalence of non malignant pulmonary disease (NMRD) among living miners (morbidity) and deaths caused or linked to nonmalignant respiratory disease was investigated and discussed in several of the health studies previously cited [(27, 36, 39, 40, 47)]. Unlike the lung cancer experience, a positive exposure/response relationship is seen in respect to NMRD and therefore supports a link between exposure to this talc and NMRD. This observation, however, does not confirm or reject an asbestos or asbestos like risk since excessive exposure to any talc dust can cause dust linked NMRD. This association has never been contested. Even here, however, some interesting observations regarding NMRD and exposure to Vanderbilt talc can be made.

Studies that have addressed NMRD among Vanderbilt talc workers do show that the NMRD observed is almost always associated with talc exposures prior to Vanderbilt talc employment [36, 37, 38, 40]. In the most recent mortality study, for example, 80% of the NMRD cases (up to 1990) had prior mining dust exposures [40]. The significance of prior dust exposure can be seen in the following table.



It is not surprising to find elevated dust linked NMRD (especially when smoking prevalence is high) in many upstate New York talc miners exposed to extremely elevated dust levels (as much as 50 times higher than those experienced at the Vanderbilt mine and mill). In 1974, the last talc mine in this region closed (except for the Vanderbilt operation) and these exceptionally high dust exposures came to an end. Vanderbilt, wishing to hire experienced talc miners, did, however, hire many talc workers from these other companies. The importance of this hiring practice is made even clearer when the health status of Vanderbilt talc workers in more recent years is addressed.

Chest X-Rays: Since 1985, Brian Boehlecke, a highly regarded occupational pulmonary specialist from the University of North Carolina, has reviewed the chest x-rays and pulmonary function tests results of all Vanderbilt talc workers every two years. The following statements by Dr. Boehlecke summarize his impressions well (as of the end of 2000) [80].

Pulmonary findings (to Jan. 2001): Brian Boehlecke, MD, MSPH

"The medical surveillance results at this time continue to support the conclusion submitted to the OSHA docket in 1990, i.e., the data do not indicate that the workers exposed to the talc at this facility are at risk for developing asbestos related pneumoconiosis."

"...essentially, no progression of pneumoconiosis related to cumulative exposure appears to have occurred in men in this workforce for whom I have had serial radiographs to review."

Current status - **"Only one man had any evidence of increased interstitial marking which could be consistent with a pneumoconiosis. These markings have not increased in profusion in the past 6 years despite continued exposure."**

It is important to note that Dr. Boehlecke does not feel he is dealing with an asbestos-like dust risk. Note that he finds very, very little in the way of pneumoconiosis among Vanderbilt talc workers in more recent years. The experience Dr. Boehlecke is reporting upon involves a workforce where 60% have worked more than 20 years at the Vanderbilt mine and 90% more than 15 years. This excellent record, likely among the best in the mining industry, is not confounded by short term workers. Also, the number of talc workers with talc exposures other than at the Vanderbilt mine is dramatically less (5% today versus over 40% ten years ago). The significant role earlier, non Vanderbilt talc exposures played in dust linked NMRD is very apparent today.

Pleural Plaques: One x-ray finding that is often a source of confusion is the fact that prolonged exposure to all talc (platy as well as industrial grade) and perhaps a host of other mineral dusts as well, can result in pleural plaques and thickening (though pleural thickening is less commonly seen among Vanderbilt talc workers). Plaques are commonly observed after 10 to 15 years of exposure. As the following table shows, about 4 to 6% of Vanderbilt talc workers currently show plaques. This is a typical finding among platy talc workers as well [81].

2002 Medical Surveillance

Pleural Plaques

Work Area	Years Worked	Dust Linked Parenchymal Opacities	Pulmonary Function
Mine	27	None	WNL
Mill	30	None	WNL
Mill	27	None	Moderate Obstructive
Mill	17	None	WNL
Mill	13	None	WNL

Represents 4.5% of Total Work Group

It is important to understand that these pleural effects are not just limited to asbestos exposures and that they are not premalignant lesions. Clinically, they have no confirmed relationship to the evolution of mesothelioma or lung cancer - these are different biologic processes involving different pathology [82-84].

As the table shows, plaques observed in Vanderbilt talc workers are not associated with pneumoconiosis or pulmonary restriction. Plaques are generally considered an abnormality but not an impairment. Pronounced pleural thickening can, however, reduce lung function, but pleural thickening is not common among Vanderbilt talc workers today.

Pulmonary Function: With regard to pulmonary function, Vanderbilt talc workers do show a fairly high prevalence of mild to moderate obstructive pulmonary disease but with little or no radiographic evidence of dust involvement. Obstructive impairment (as opposed to restrictive impairment) is most commonly associated with various forms of airway obstruction. Such effects are often linked to smoking and would be expected given the smoking patterns among these miners (see discussion above).

2002 Medical Surveillance

PULMONARY FUNCTIONS NOT WITHIN NORMAL LIMITS (NWNL)

% of Total Group NWNL: 25%
% of NWNL that are "X" or Current Smokers: 70%

% Signs of Obstructive Impairment	% Signs of Restrictive Impairment	# With Dust Linked Parenchymal Opacities
82%	28%	1

Impairment Levels:	Borderline	Early	Mild	Moderate	Severe
	16%	26%	32%	26%	0%

Conclusion: The actual health experience of Vanderbilt talc miners and millers stands in sharp contrast to antidotal media reports of widespread dust linked respiratory disease. Confusion is somewhat understandable given elevated dust linked pulmonary disease among regional talc workers exposed to extremely high talc dust levels. Such levels, however, no longer exist and more recent health surveillance data does show a marked improvement in the avoidance of parenchymal opacities. The observation of pleural abnormalities commonly used as a marker of asbestos exposure and the prevalence of respiratory problems thought linked to dust rather than smoking have contributed to the false impression that Vanderbilt talc miners are exposed to asbestos or a dust "just as bad" when in fact they are not.

The diagnosis of any dust linked pulmonary disease does require radiographic evidence of dust involvement. Often that evidence (interstitial markings) is not as easy to identify or interpret as many believe - especially during the early stages of a dust disease. There are many confusing images seen in chest x-rays (vascular lines, pleural fat, rib cage shadows, poorly contrasted film, etc.) [82]. The "expectation" of dust disease contributes to false negative interpretations. The control of bias and the use of pulmonary specialists trained and experienced in occupational dust disease are of critical importance for this reason. It is also common to assume that a "positive" chest x-ray interpretation for pneumoconiosis is always correct while "negative" interpretations of the same chest radiograph are not correct. This is not always the case.

There is no question that New York State talc miners and millers exposed to extremely elevated dusts decades ago have suffered from dust linked disease. However, it is important to understand present day experience as it pertains to talc miners and millers exposed only to the significantly reduced dust exposures found at the Vanderbilt mine. If this is not understood, inappropriate risk perception is inevitable (linking an earlier exposure risk that no longer exist to current day exposures). Difficulties and bias factors long associated with chest radiographic interpretation must be understood as well.

OSHA MAKES A FINAL DECISION ON NONASBESTIFORM AMPHIBOLES

In 1992, 20 years after its first asbestos standard and after a week of hearings, OSHA formally adopted a mineralogically correct definition of asbestos. OSHA would not treat nonasbestiform amphiboles as asbestos [1]. The following statement appeared in the Federal Register.

"OSHA has made a determination that substantial evidence is lacking to conclude that nonasbestiform tremolite, anthophyllite and actinolite present the same type or magnitude of health effect as asbestos."

"OSHA hereby lifts the Administrative Stay, removes and reserves 29 CFR 1910.1101, and amends the revised asbestos standard to remove nonasbestiform tremolite, anthophyllite and actinolite from their scope."

Simply put, OSHA could find no evidence that would support their original regulatory plan. Since OSHA could not rely upon Vanderbilt talc studies to provide the justification, there was essentially "no" supporting evidence.

TALC AND MIXED TALC/AMPHIBOLE FIBER

With the above mineral and biological background in mind (especially the understanding that Vanderbilt talc cancer health studies do not support a "same as" asbestos health risk), a minor component in Vanderbilt talc that is far more complicated than amphibole cleavage fragments can be addressed. This component is the minor talc fiber and mixed fiber mentioned earlier.

The following reflects the actual composition (by weight %) of Vanderbilt tremolitic talc. These ranges are inclusive of all grades.

VANDERBILT TALC COMPOSITION [85]
(Weight %)

Talc:	**20 to 40%**
(Talc & Talc/amphibole fiber = 0.5 to 5.6% in whole product)*	
Tremolite (nonasbestiform):	**40 to 60%**
Serpentine (antigorite-lizardite):	**15 to 30%**
Anthophyllite (nonasbestiform):	**1 to 5%**
Quartz:	**<1% (when detected at all)**

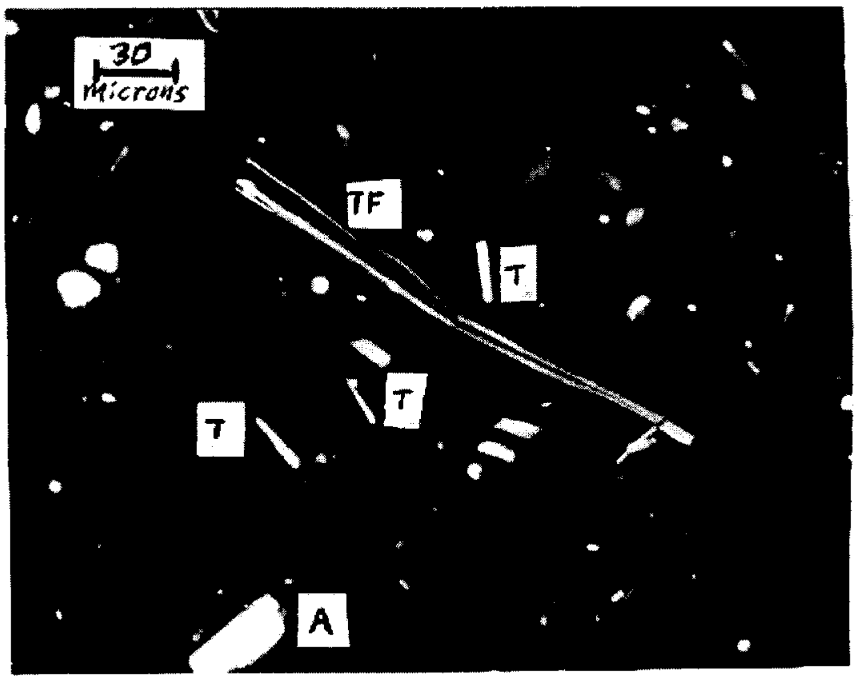
*** Of combined fiber (<0.05 to 1.8 in the whole product is asbestiform (Avg. all grades <0.50)**

The nonasbestiform amphibole component in this talc is obvious. Note also that there is a minor but measurable amount of talc fiber and mixed fiber in this talc. The mixed or "transitional" fiber is part talc and part amphibole (most probably anthophyllite), intimately mixed at the lattice level [86-98]. These are true fibers which are very long and thin. Some, but not all of these fibers do exhibit an asbestiform growth habit. These fibers have been described as academic curiosities and are relatively unrecognized outside the mineral science community. The combined weight % for those fibers that do exhibit an asbestiform growth habit typically falls around 0.5%. These fibers are not cleavage fragments, nor are they asbestos.

There are analytical laboratories that would contradict this statement. A few laboratories believe that some of these fibers are anthophyllite asbestos (though typically at an extremely trace level) [99, 100]. There is debate over whether some or all of the mixed fiber is asbestiform, and whether it should be called anthophyllite asbestos when amphibole is the dominant phase (assuming it can be determined which phase is dominant) [94]. Mineral scientists argue against this last proposition because the physical properties of these mixed fibers differ from those of either constituent, while impurities in asbestos fibers do not, in contrast, reflect significant alteration in their physical properties [101, 102].

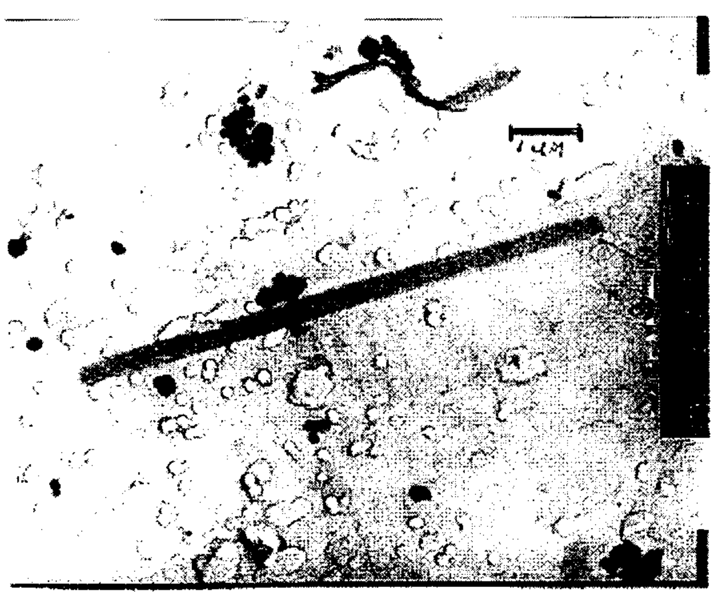
Beyond some of these more detailed issues, it is admittedly confusing to most to hear that a fiber may be "asbestiform" but not "asbestos". It does sound like a contradiction. However, it must be remembered that asbestos is a commercial term that is applied to the six minerals earlier discussed. The term "asbestiform" merely means "like asbestos". Asbestiform fibers grow like asbestos, they look like asbestos, they exhibit parallel crystal growth, they are flexible, they appear as fiber bundles with splayed terminations, they are very long and thin. However, these characteristics do not make them asbestos merely because they exhibit morphological similarities [8].

As mentioned earlier, it has been reported that upwards of 100 minerals may grow in an asbestiform habit, and the mineral talc is one of them. The following photomicrographs reflect the minor fiber content of Vanderbilt talc. The reader may wish to compare these photomicrographs with those earlier presented of asbestos fibers (last two pages).

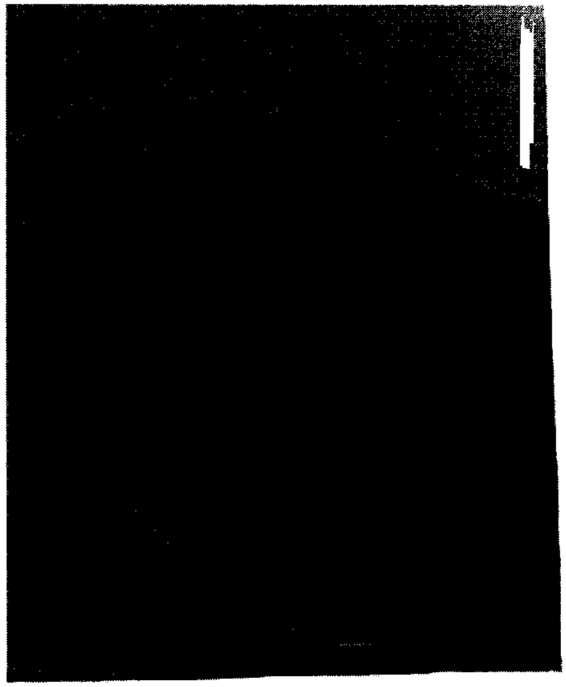


The large fiber in the center of the photomicrograph labeled "TF" is an asbestiform talc fiber. There is evidence of bundling, some curvature suggesting flexibility and it's very long and thin. The particle at the lower left labeled "A" is a prismatic anthophyllite cleavage fragment. The particles labeled "T" are elongated tremolite cleavage fragments [93]. Some laboratories fail to recognize that there are anthophyllite cleavage fragments in this talc and may misinterpret SAED patterns of these fragments as anthophyllite asbestos.

The above photomicrograph shows a more typical talc fiber found in Vanderbilt talc [94]. This fiber tends to be ribbon-like, and some feel it would not properly be called asbestiform. This is pure talc – not an amphibole or a mixed fiber.

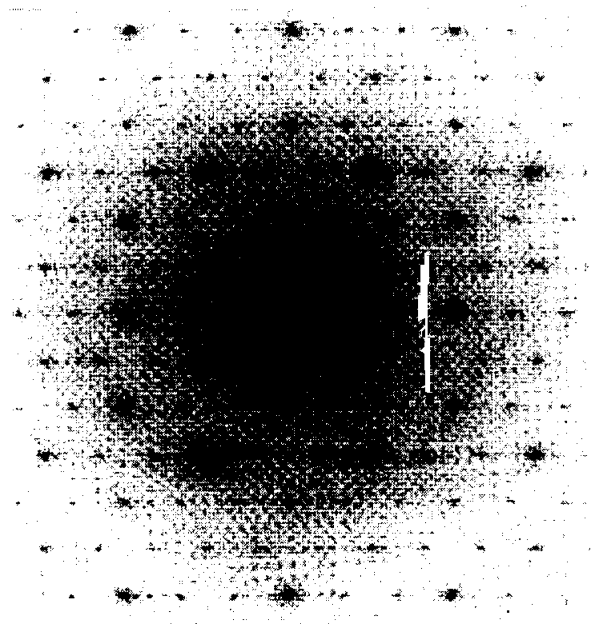


The above photomicrograph is a typical mixed fiber found in Vanderbilt talc. It is part talc and part amphibole [92]. These fibers tend to be rod-like and are also subject to controversy as to whether they are or are not truly "asbestiform".



This photomicrograph shows the termination of one of these rods [94]. Some of the mixed fiber rods exhibit flat terminations while others (pictured) suggest the pulling apart of fibrils – though this is less pronounced then that typically seen in asbestos fibers.

The above photomicrograph shows light and dark areas on a transitional fiber [94]. These areas are said to be different mineral domains – areas of talc, areas of amphibole (likely anthophyllite). If one directs an electron diffraction beam against different portions of this fiber, a different mineral fingerprint or pattern will emerge depending on where the beam strikes the fiber. This is another common area of analytical confusion.



The above diffraction pattern is common for talc/anthophyllite intergrowth [94]. Note the "triplet" spots. The center spot is linked to a talc pattern – a forbidden reflection for pure anthophyllite.

Other ways exist to distinguished the mixed fibers. For example, Polarized Light Microscopy and index oils can be used to identify the mineral with a refractive index [85]. Mixed fibers will give an index above pure talc but below the lower limit of an amphibole. Commonly applied index criteria appear below.

Mineral	α, RI	γ, RI
Talc	< 1.598	≤ 1.598
Transitional	< 1.598	> 1.598
Amphibole	≥ 1.598	> 1.598

Given the level of attention these fibers receive, it is easy to lose sight of the fact that they make up a very small component of this talc, especially on a weight basis. It is common, however, to find widely divergent percent content data for these fibers. Percentages must be interpreted with caution. Often, percents refer to particle counts and not weight. To further complicate matters, many of these fiber prevalence percents relate only to subsets and not the whole product. Widely divergent fiber content levels have also been reported based upon broad "approximations" or extrapolation from very small fractions of the material (such as those seen by TEM). Improper mineral identification and sample preparation can play a role in quantification error as well. Mineral scientists often refer to these fibers as "mineral curiosities." General public exposure to these fibers is extremely limited to nonexistent.

Still, as interesting as these fibers may be mineralogically, the key concern is always risk. It is known that the six regulated asbestos minerals (particularly amphibole asbestos) are associated with significant health risks. However, it appears that other minerals that form in an asbestiform habit show various levels of risk. Some mineral fibers like fibrous erionite (a zeolite), richterite and winchite (amphiboles) suggest a risk every bit as strong as that of asbestos. On the other end of the spectrum are talc fibers and water-soluble fibers (i.e. xonotilite) that do not pose an asbestos risk [(7)].

Besides morphology, different minerals have different biodurability, surface chemistry, friability once in the lung, harshness scores, etc. These differences do appear to influence their biological activity in whole or in part [(7, 8, 50, 103)]. This is one of the reasons it is important to recognize the physical properties of minerals and call them by their proper names. Further, the critical role of dose should not be ignored. Risk is not simply a matter of good and bad but rather a matter of degree. The common saying in toxicology that "the dose makes the poison" is no less true for asbestos than any other material.

Despite the minor fibers present in Vanderbilt tremolitic talc, it clearly does not act like an asbestos-containing material in people or in test animals. Proponents of "morphology is everything" thinking, or those who incorrectly believe the term "asbestiform" is or should be a synonym for "asbestos", argue that the reason Vanderbilt talc does not act like an asbestos-containing material is because these fibers are too few. "Well, if there were more of them, then the talc would act like asbestos", is a common refrain. The correct response to this is "Well, there aren't". This is important to note because Vanderbilt talc may well contain more of these fibers than any other talc.

Although there is no known higher exposure to these rare fibers, it would be of interest to test this dose-linked assertion because it would speak to the "morphology is everything" proposition. Accordingly, a test was undertaken to test this hypothesis. In this test a concentrate of talc (predominantly) and mixed fiber from Vanderbilt talc was tested against an equal weight of asbestos fiber in a rodent tracheal epithelial and mesothelial cell study. The findings of this study are reflected below.

Wylie, A. G., Mossman, B. T., et al – 1997 [50]

Mineralogical Features Associated with Cytotoxic and Proliferative Effects of Fibrous Talc and Asbestos on Rodent Tracheal Epithelial and Pleural Mesothelial Cells

"fibrous talc does not cause proliferation of HTE cells or cytotoxicity equivalent to asbestos in either cell type despite the fact that talc samples contain durable mineral fibers with dimensions similar to asbestos. These results are consistent with the findings of Stanton, et al (1981) who found no significant increases in pleural sarcomas in rats after implantation of minerals containing fibrous talc."

The talc fiber concentrate acted differently than the asbestos fibers, again suggesting that more than simple fiber morphology is involved in asbestos pathogenicity. This study also suggests that the demonstrated absence of an asbestos risk in Vanderbilt tremolitic talc is not simply dose related.

As desirable as it would be to find one simple, easy to recognize characteristic that predicts "fiber" risk, studies like this, as well as the entire nonasbestiform amphibole experience, suggest that we need to proceed with caution. Finding one variable linked to fiber risk (i.e. morphology) does not automatically mean that other variables can or should be ignored. At least not until scientifically discounted.

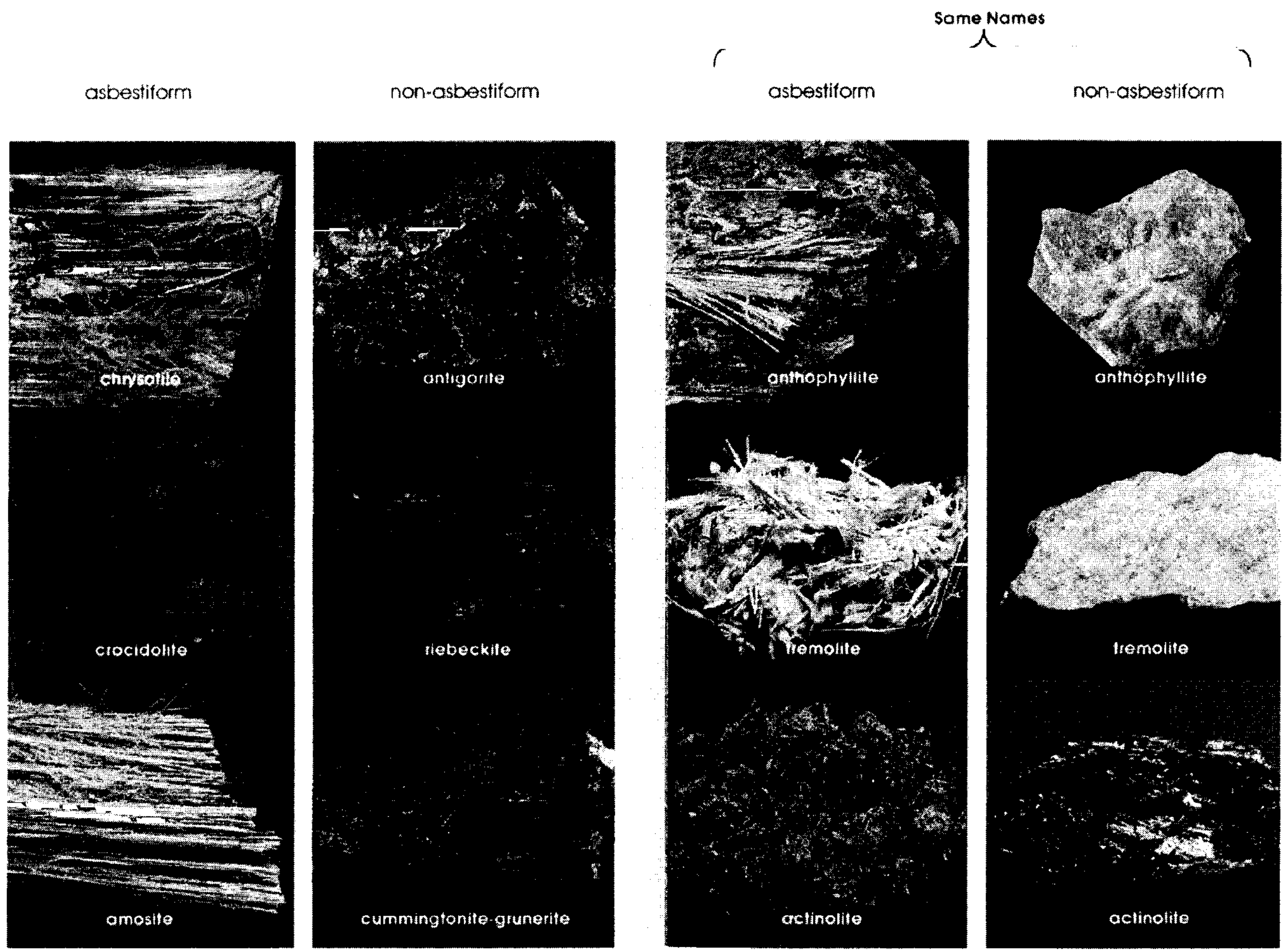
CONCLUSION - LESSONS LEARNED

It is important that we call substances by their proper names and that we control them based on demonstrated risk. When health studies characterize exposures in broad brush terms and ignore proper nomenclature, researchers are less likely to understand risk. Less discrimination in the name of prudence is a "slippery slope," one more likely to lead to the presumption of risks that do not exist rather than the avoidance of those that do. This is certainly one of the lessons of the tremolitic talc saga.

There are many reasons why Vanderbilt talc has been the source of debate and confusion for decades. Imprecise asbestos definitions [5, 15, 86-103] over zealous federal agencies inclined to champion excessive prudence over good science [2, 24, 27, 31, 32, 35, 104] imprecise asbestos analytical protocols [7, 10, 11, 13, 15, 19, 84-98, 105-108], bias/experience factors leading to possible error in difficult medical evaluations (i.e., chest x-ray interpretations, mesothelioma diagnosis and attribution), the relationship of past exposure risk to current exposure risk and irresponsible media involvement [3] are key among these reasons. The tremolitic talc story may well be one of the very best examples of a confluence of serious ongoing lapses.

Certainly there are serious risks in this world, we must be cautious and act prudently. But even prudence can be excessively stretched. While we must not ignore adverse health effects when we see them, we must not invent them either. When a risk is observed, we must control it commensurately with the threat. It does matter what we call things, especially when improper nomenclature leads to improper conclusions and the presumption of risk.

Asbestos, or something just a bad, is not a constituent of New York tremolitic talc. The health experience of New York State miners and millers does not show an "asbestos-like" risk. The health status of active tremolitic talc workers today is likely among the best in the mining industry. Such health experience (supported by animal and cell studies) argues against any risk to product users and the public. While excessive exposure to this talc is capable of producing pulmonary harm (and has), current dust exposure levels appear adequately protective.

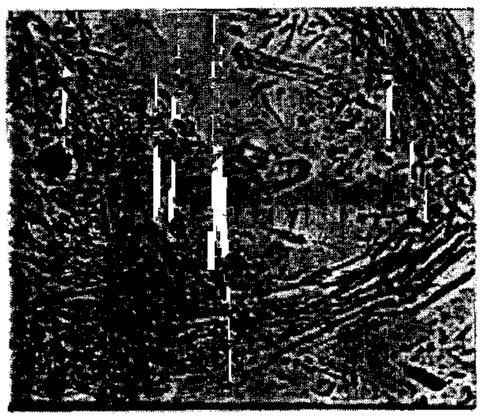

Same Names
asbestiform
non-asbestiform
asbestiform
non-asbestiform
chrysotile
antigorite
anthophyllite
anthophyllite
crocidolite
riebeckite
tremolite
tremolite
amosite
cummingtonite-grunerite
actinolite
actinolite

REFERENCE EXHIBIT 3

LIGHT MICROSCOPIC COMPARISONS......

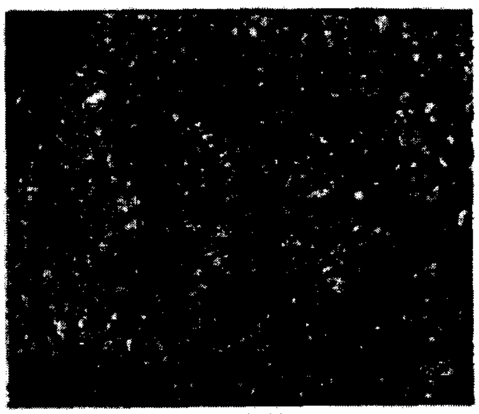
(2.75 um/divisions)

ASBESTIFORM | **NONASBESTIFORM**

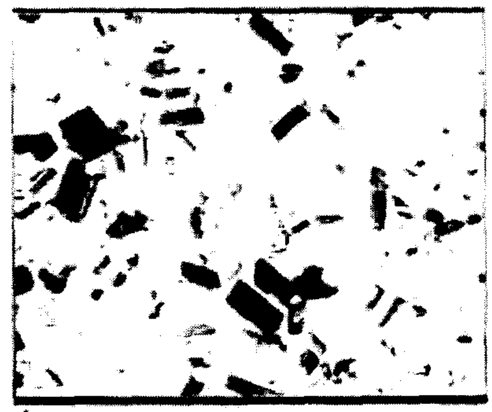


a. **chrysotile**

b. **antigorite**



c. **crocidolite**



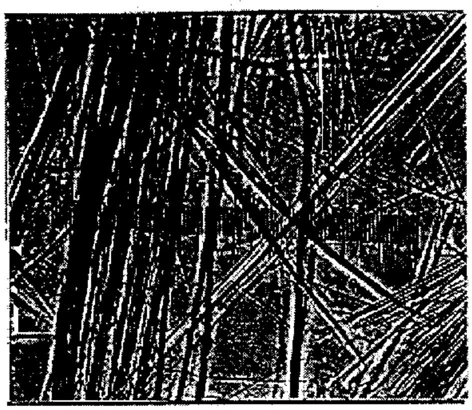
d. **riebeckite**

e. **amosite**

f. **cummingtonite-grunerite**

......Continued

ASBESTIFORM



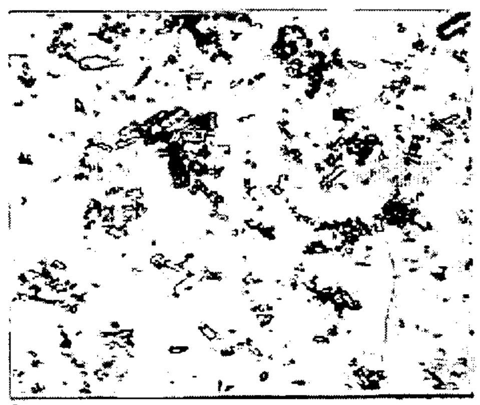
g. anthophyllite asbestos

i. tremolite asbestos

k. actinolite asbestos

NONASBESTIFORM

h. anthophyllite



j. tremolite

l. actinolite

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The Materials Characterization Specialists

November 22, 2000

Mr. John W. Kelse
R. T. Vanderbilt Company, Inc.
30 Winfield Street
Norwalk, CT 06856-5150

RE: TEM Asbestos Analysis
RJ Lee Group Job No.: LSH006444-3

Dear Mr. Kelse:

Enclosed are the results from the transmission electron microscopy (TEM) asbestos analysis of the above referenced samples using the counting rules established by the NIOSH Method 7402, issue 2, 8/15/94. The sample and volume information were provided by R. T. Vanderbilt Company, Inc. personnel.

The analysis for asbestos fibers consisted of fiber morphology, visual selected area electron diffraction (SAED) and elemental chemical analysis by energy dispersive spectroscopy (EDS), supplemented by the measurement and interpretation of micrographs of several selected SAED patterns. The samples were analyzed at a magnification of 1,000 X. Particles meeting the definition of a fiber > 5 μm in length, > 0.25 μm in width, and having a length to width aspect ratio ≥ 3:1 were classified as chrysotile, amphibole asbestos, amphibole cleavage, or transitional fiber.

The attached table lists each sample identification number, filter area, volume, area analyzed, asbestos fiber counts (f_s), analytical sensitivity, concentration of asbestos (f/cc), total fibers counted (F_s), and asbestos fiber ratio (f_s/F_s). Copies of the count sheets are presented in Appendix A. Each sheet contains sample information pertaining to structure identification, dimensions, magnification, filter size, and type.

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If you have any questions, please feel free to call me.

Sincerely,

Drew R Van Orden

Drew R. Van Orden, PE
Senior Scientist

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TEST REPORT

Asbestos Concentrations and Fiber Ratios

NIOSH 7402 Analysis

Project LSH006444-3

RJLG Sample Number	Client Sample Number	Filter Area (mm^2)	Volume (Liter)	Area Analyzed (mm^2)	Asbestos Fibers (f_s)	Analytical Sensitivity (f/cc)	Asbestos Concentration (f/cc)	Total Fibers (F_s)	Fiber Ratio (f_s/F_s)	Analysis Date
0114780HT	F-11	385	190.0	0.1155	1	0.0175	0.0175	103.5	0.01	11/16/00
0114781HT	F-12	385	300.0	0.0908	0	0.0141	< 0.0141	98.0	0	11/16/00
0114782HT	F-13	385	120.0	0.1485	0	0.0216	< 0.0216	101.5	0	11/20/00

F-11 Below mill crusher
F-12 Center mills 1, 2, 3
F-13 Over packer – NYTAL 300

Volumes provided by R. T. Vanderbilt Company, Inc. were used to calculate analytical results and sensitivities. Analytical sensitivity is calculated based on one structure in the area analyzed.

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114780HT	Grid Openings	14
Client Sample #	F-11 / Below mill crusher	Total Asbestos	1
Microscope	2000 FX	Total Non-Asbestos	102.5
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	190.0 Liters
Analyst	TWS/LH	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
1	0.5	11.00	2.00	Amphibole		X		X	Tremolite	Cleavage
1	1	20.00	3.00	Nonasbestos		X		X		TF
1	1	17.00	2.00	Nonasbestos		X		X		TF
1	1	40.00	1.10	Nonasbestos		X		X		TF
1	1	9.00	0.40	Nonasbestos		X		X		TF
1	1	11.00	1.00	Amphibole		291		29817	Tremolite	Cleavage
1	1	12.50	0.50	Nonasbestos		290		29815		TF
2	1	8.20	0.30	Nonasbestos				X		TF
2	0.5	17.00	0.60	Nonasbestos				X		TF
2	1	11.25	0.70	Nonasbestos				X		TF
2	1	7.00	0.80	Nonasbestos				X		TF
2	1	8.00	1.50	Amphibole		X		X	Tremolite	Cleavage
2	0.5	12.50	2.50	Nonasbestos		X				TF
2	0.5	7.50	0.30	Nonasbestos		X				TF
2	1	5.50	1.20	Amphibole		X		X	Tremolite	Cleavage
2	1	6.50	1.10	Amphibole		X		X	Tremolite	Cleavage
2	1	17.00	0.30	Nonasbestos		X				TF
3	1	8.25	0.80	Amphibole		X		X	Tremolite	Cleavage
3	1	11.00	0.35	Nonasbestos		X		X		TF
3	1	10.25	1.10	Amphibole		X		X	Tremolite	Cleavage
3	1	10.50	0.90	Amphibole		X		X	Tremolite	Cleavage
3	1	11.00	1.50	Amphibole		X		X	Tremolite	Cleavage
3	1	8.50	0.50	Nonasbestos				X		TF
3	1	5.20	0.90	Nonasbestos				X		TF
3	1	10.00	2.50	Nonasbestos				X		TF
3	1	6.75	0.80	Nonasbestos				X		TF
3	1	13.50	0.35	Nonasbestos				X		TF
3	1	9.50	0.30	Nonasbestos				X		TF
3	1	6.50	1.00	Nonasbestos		X				TF
4	0.5	12.00	1.10	Nonasbestos		X		X		TF
4	0.5	7.25	1.00	Amphibole		X		X	Tremolite	Cleavage
4	1	6.00	0.90	Amphibole		X		X	Tremolite	Cleavage
4	1	11.00	1.10	Amphibole		X		X	Tremolite	Cleavage
4	1	25.00	1.10	Nonasbestos				X		TF
4	1	6.00	0.40	Nonasbestos		X				TF
4	1	5.75	0.50	Nonasbestos				X		TF
4	1	10.50	1.75	Amphibole		X		X	Tremolite	Cleavage
4	1	8.50	2.00	Amphibole		X		X	Tremolite	Cleavage
5	1	5.20	0.40	Amphibole		X		X	Tremolite	Cleavage
5	1	8.50	0.60	Nonasbestos				X		TF

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114780HT	Grid Openings	14
Client Sample #	F-11 / Below mill crusher	Total Asbestos	1
Microscope	2000 FX	Total Non-Asbestos	102.5
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	190.0 Liters
Analyst	TWS/LH	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
5	0.5	22.00	0.50	Nonasbestos				X		TF
5	0.5	23.00	0.65	Nonasbestos				X		TF
5	1	10.00	0.40	Chrysotile				29822		
5	1	6.00	0.60	Nonasbestos		X				TF
5	1	9.50	1.40	Amphibole		X		X	Tremolite	Cleavage
5	1	12.50	1.50	Nonasbestos				X		TF
5	0.5	12.50	0.50	Nonasbestos		X		X		TF
5	1	10.00	2.00	Nonasbestos				X		TF
5	1	8.30	0.60	Nonasbestos				X		TF
5	1	5.40	1.25	Amphibole		X		X	Tremolite	Cleavage
6	1	10.00	3.00	Amphibole		X		X	Tremolite	Cleavage
6	1	7.00	0.80	Amphibole		X		X	Tremolite	Cleavage
6	1	10.00	2.50	Amphibole		X		X	Tremolite	Cleavage
6	1	7.25	0.40	Nonasbestos				X		TF
6	1	5.40	0.90	Nonasbestos				X		TF
7	1	22.00	1.50	Nonasbestos		X		X		TF
7	1	6.00	1.50	Amphibole		X		X	Tremolite	Cleavage
7	1	7.00	1.00	Amphibole		X		X	Tremolite	Cleavage
7	1	5.50	0.35	Amphibole		X		X	Tremolite	Cleavage
7	1	12.50	0.50	Nonasbestos	B			X		TF
7	1	7.50	0.40	Nonasbestos				X		TF
7	1	17.50	0.30	Nonasbestos				X		TF
7	1	7.00	0.20	Nonasbestos				X		TF
7	1	10.00	1.00	Nonasbestos		X		X		TF
8	1	6.50	1.40	Amphibole		X		X	Tremolite	Cleavage
8	1	7.50	0.70	Amphibole		X		X	Tremolite	Cleavage
8	1	10.00	0.30	Nonasbestos				X		TF
8	1	16.00	2.00	Amphibole		X		X	Tremolite	Cleavage
8	1	6.00	2.00	Amphibole		X		X	Tremolite	Cleavage
8	1	10.00	0.50	Nonasbestos				X		TF
8	1	5.50	0.80	Nonasbestos				X		TF
8	1	12.50	0.50	Nonasbestos				X		TF
8	1	5.50	1.00	Amphibole		X		X	Tremolite	Cleavage
9	0.5	6.50	0.70	Amphibole		X		X	Tremolite	Cleavage
9	0.5	7.00	2.00	Nonasbestos		X				TF
9	1	7.50	0.50	Nonasbestos		X				TF
10	0.5	24.00	1.00	Nonasbestos		X				TF
10	1	6.50	1.00	Amphibole		X		X	Tremolite	Cleavage
10	1	26.00	0.50	Nonasbestos				X		TF
10	1	6.00	1.20	Amphibole		X		X	Tremolite	Cleavage

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114780HT	Grid Openings	14
Client Sample #	F-11 / Below mill crusher	Total Asbestos	1
Microscope	2000 FX	Total Non-Asbestos	102.5
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	190.0 Liters
Analyst	TWS/LH	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
10	1	8.00	1.00	Amphibole		X		X	Tremolite	Cleavage
10	1	5.50	0.30	Nonasbestos				X		TF
10	1	17.00	2.00	Nonasbestos		X				TF
11	1	6.50	0.30	Nonasbestos				X		TF
11	1	7.00	0.60	Amphibole		X		X	Tremolite	Cleavage
11	1	5.50	1.00	Nonasbestos				X		TF
11	1	7.00	0.50	Nonasbestos				X		TF
11	1	6.00	0.90	Nonasbestos				X		TF
11	1	6.00	0.70	Amphibole		X		X	Tremolite	Cleavage
11	1	7.00	0.80	Nonasbestos				X		TF
12	0.5	15.00	1.50	Nonasbestos		X		X		TF
12	1	12.00	2.50	Amphibole		X		X	Tremolite	Cleavage
12	1	7.00	0.50	Nonasbestos				X		TF
12	1	18.00	2.50	Amphibole		X		X	Tremolite	Cleavage
12	1	16.00	3.00	Nonasbestos				X		TF
12	1	17.00	1.00	Nonasbestos				X		TF
12	1	19.00	0.40	Nonasbestos				X		TF
13	0.5	6.00	0.60	Nonasbestos		X				TF
13	0.5	5.50	0.60	Nonasbestos				X		TF
13	1	8.00	0.50	Nonasbestos		X		X		TF
13	1	5.50	1.00	Nonasbestos		X		X		TF
13	1	6.00	1.00	Amphibole		X		X	Tremolite	Cleavage
13	1	7.00	1.30	Amphibole		X		X	Tremolite	Cleavage
13	1	8.00	1.75	Amphibole		X		X	Tremolite	Cleavage
13	1	5.50	1.25	Amphibole		X		X	Tremolite	Cleavage
13	1	10.00	2.50	Amphibole		X		X	Tremolite	Cleavage
14	0.5	15.50	1.10	Nonasbestos		X		X		TF
14	0.5	8.00	0.45	Amphibole	M	X		X	Tremolite	Cleavage
14	1	8.00	0.60	Nonasbestos		X		X		TF
14	1	13.00	3.20	Nonasbestos		X		X		TF
14	1	18.50	2.50	Amphibole		X		X	Tremolite	Cleavage
14	1	9.00	1.75	Amphibole		X		X	Tremolite	Cleavage

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114781HT	Grid Openings	11
Client Sample #	F-12 / Center mills 1, 2, 3	Total Asbestos	0
Microscope	2000 FX	Total Non-Asbestos	98
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	300.0 Liters
Analyst	TWS/LH	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
1	0.5	5.75	0.50	Nonasbestos		X				TF
1	1	6.50	1.00	Nonasbestos		X				TF
1	1	8.25	0.60	Nonasbestos		296		29830		TF
1	1	17.00	1.50	Nonasbestos		295		29828		TF
1	0.5	13.00	1.20	Nonasbestos		X		X		TF
1	0.5	24.00	5.25	Amphibole		X		X	Tremolite	Cleavage
2	1	13.00	2.00	Nonasbestos		X				TF
2	1	8.25	2.00	Amphibole		X			Tremolite	Cleavage
2	1	7.50	1.90	Amphibole		X			Tremolite	Cleavage
2	1	20.00	3.50	Amphibole		X			Tremolite	Cleavage
2	1	8.50	2.00	Nonasbestos		X				TF
2	1	12.00	0.50	Amphibole		X			Tremolite	Cleavage
2	1	7.00	1.50	Amphibole		X			Tremolite	Cleavage
2	1	6.00	0.70	Amphibole		X			Tremolite	Cleavage
2	1	10.00	1.75	Amphibole		297		29832	Tremolite	Cleavage
2	0.5	6.75	0.50	Nonasbestos	M					TF
3	1	6.00	0.50	Nonasbestos				X		TF
3	0.5	6.50	0.45	Nonasbestos				X		TF
3	1	8.50	1.50	Amphibole		X			Tremolite	Cleavage
3	1	6.25	1.20	Amphibole		X			Tremolite	Cleavage
3	1	9.00	1.00	Nonasbestos				X		TF
3	0.5	5.25	0.40	Nonasbestos	M			X		TF
3	0.5	19.00	0.50	Nonasbestos	M			X		TF
3	1	13.50	1.00	Nonasbestos		X				TF
4	1	8.50	2.00	Nonasbestos		X		X		TF
4	1	11.50	2.00	Nonasbestos		X		X		TF
4	1	37.00	2.00	Nonasbestos		X		X		TF
4	1	7.00	0.50	Nonasbestos		X		X		TF
4	1	7.00	1.00	Nonasbestos		X		X		TF
4	1	6.00	1.00	Amphibole		X		X	Tremolite	Cleavage
4	1	6.00	1.00	Nonasbestos		X		X		TF
4	1	8.00	1.00	Nonasbestos		X		X		TF
4	1	8.00	2.00	Amphibole		X		X	Tremolite	Cleavage
4	1	8.50	1.50	Nonasbestos		X		X		TF
4	1	7.50	0.40	Nonasbestos		X		X		TF
4	1	23.00	3.00	Nonasbestos		X		X		TF
4	1	6.50	1.20	Nonasbestos		X		X		TF
5	1	10.00	0.30	Nonasbestos		X		X		TF
5	1	10.00	2.00	Amphibole		X		X	Tremolite	Cleavage
5	1	22.00	0.90	Nonasbestos		X		X		TF

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114781HT	Grid Openings	11
Client Sample #	F-12 / Center mills 1, 2, 3	Total Asbestos	0
Microscope	2000 FX	Total Non-Asbestos	98
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	300.0 Liters
Analyst	TWS/LH	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
5	1	9.00	0.50	Amphibole		X		X	Tremolite	Cleavage
5	1	17.00	5.00	Nonasbestos		X		X		TF
5	1	9.00	0.50	Nonasbestos		X		X		TF
5	1	15.00	2.00	Amphibole		X		X	Tremolite	Cleavage
5	1	5.40	0.30	Nonasbestos		X		X		TF
5	1	47.00	2.50	Nonasbestos		X		X		TF
6	1	16.00	0.30	Nonasbestos		X		X		TF
6	1	8.50	0.50	Nonasbestos		X		X		TF
6	1	15.00	2.00	Amphibole		X		X	Tremolite	Cleavage
6	1	14.00	1.00	Nonasbestos		X		X		TF
6	1	5.50	1.00	Amphibole		X		X	Tremolite	Cleavage
6	1	21.50	1.00	Nonasbestos		X		X		TF
6	1	7.00	0.50	Amphibole		X		X	Tremolite	Cleavage
6	1	5.20	0.30	Nonasbestos		X		X		TF
7	1	11.00	1.50	Amphibole		X		X	Tremolite	Cleavage
7	1	5.50	0.60	Nonasbestos		X		X		TF
7	1	5.10	0.80	Amphibole		X		X	Tremolite	Cleavage
7	1	9.00	1.00	Amphibole		X		X	Tremolite	Cleavage
7	1	9.00	1.50	Amphibole		X		X	Tremolite	Cleavage
7	1	6.00	0.40	Nonasbestos		X		X		TF
7	1	15.00	1.30	Nonasbestos		X		X		TF
8	0.5	15.50	0.50	Nonasbestos		X		X		TF
8	1	9.50	1.00	Nonasbestos		X		X		TF
8	1	5.50	0.60	Nonasbestos		X		X		TF
8	1	8.50	2.00	Nonasbestos		X		X		TF
8	1	7.50	1.00	Nonasbestos		X		X		TF
8	1	10.00	1.50	Nonasbestos		X		X		TF
8	1	8.00	2.50	Nonasbestos		X		X		TF
8	1	15.00	3.00	Nonasbestos		X		X		TF
9	0.5	6.00	0.50	Nonasbestos		X		X		TF
9	1	10.50	1.00	Nonasbestos		X		X		TF
9	1	5.20	0.60	Nonasbestos		X		X		TF
9	1	23.50	0.50	Nonasbestos		X		X		TF
9	1	23.00	3.20	Amphibole		X		X	Tremolite	Cleavage
9	1	6.50	1.50	Nonasbestos		X		X		TF
9	1	6.00	0.40	Amphibole		X		X	Tremolite	Cleavage
9	1	8.00	0.50	Nonasbestos		X		X		TF
9	1	7.50	1.00	Nonasbestos		X		X		TF
9	1	8.00	0.90	Nonasbestos		X		X		TF
9	1	6.00	1.90	Amphibole		X		X	Tremolite	Cleavage

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114781HT	Grid Openings	11
Client Sample #	F-12 / Center mills 1, 2, 3	Total Asbestos	0
Microscope	2000 FX	Total Non-Asbestos	98
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	300.0 Liters
Analyst	TWS/LH	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
9	1	7.50	1.50	Amphibole		X		X	Tremolite	Cleavage
10	0.5	15.50	1.50	Nonasbestos		X		X		TF
10	1	8.00	0.30	Nonasbestos		X		X		TF
10	1	5.20	0.80	Nonasbestos		X		X		TF
10	1	9.00	0.40	Nonasbestos		X		X		TF
10	1	16.00	2.00	Nonasbestos		X		X		TF
10	1	21.00	1.00	Nonasbestos		X		X		TF
10	1	6.00	0.70	Nonasbestos		X		X		TF
10	1	7.00	0.60	Amphibole		X		X	Tremolite	Cleavage
10	1	18.00	2.50	Nonasbestos		X		X		TF
10	1	7.50	1.00	Nonasbestos		X		X		TF
11	1	6.00	0.80	Nonasbestos		X		X		TF
11	1	20.00	6.00	Nonasbestos		X		X		TF
11	1	7.50	0.60	Amphibole		X		X	Tremolite	Cleavage
11	1	5.50	1.00	Nonasbestos		X		X		TF
11	1	9.00	2.00	Amphibole		X		X	Tremolite	Cleavage
11	1	8.00	2.00	Amphibole		X		X	Tremolite	Cleavage
11	1	6.00	0.50	Nonasbestos		X		X		TF
11	1	6.50	2.00	Amphibole		X		X	Tremolite	Cleavage
11	1	6.00	1.50	Amphibole		X		X	Tremolite	Cleavage
11	1	8.20	0.30	Nonasbestos		X		X		TF
11	1	28.50	0.70	Nonasbestos		X		X		TF
11	1	5.50	0.70	Nonasbestos		X		X		TF

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114782HT	Grid Openings	18
Client Sample #	F-13 / Over packer – NYTAL 300	Total Asbestos	0
Microscope	2000 FX	Total Non-Asbestos	101.5
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	120.0 Liters
Analyst	TWS/BF	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
1	0.5	6.00	1.30	Amphibole		X		X	Tremolite	Cleavage
1	0.5	9.50	2.00	Nonasbestos		X		X		TF
1	1	10.25	2.20	Amphibole		X		X	Tremolite	Cleavage
1	0.5	9.00	1.50	Nonasbestos		X		X		TF
1	1	7.50	0.70	Nonasbestos		299		29836		TF
1	1	8.00	2.00	Amphibole		X		X	Tremolite	Cleavage
1	1	7.25	1.75	Amphibole		298		29834	Tremolite	Cleavage
1	0.5	6.25	1.10	Amphibole		X		X	Tremolite	Cleavage
1	1	9.00	0.80	Nonasbestos		X		X		TF
1	1	12.00	2.50	Nonasbestos		X		X		TF
2	0.5	7.00	0.50	Amphibole		X			Tremolite	Cleavage
2	1	10.00	2.40	Nonasbestos		X				TF
2	1	7.25	1.10	Amphibole				X	Tremolite	Cleavage
2	0.5	5.25	0.30	Nonasbestos	M			X		TF
2	1	5.50	0.60	Nonasbestos		X				TF
2	1	6.75	1.30	Amphibole		X			Tremolite	Cleavage
2	0.5	11.00	0.50	Nonasbestos		X		X		TF
2	1	14.50	3.00	Nonasbestos		X		X		TF
2	1	6.00	1.10	Amphibole		X		X	Tremolite	Cleavage
2	1	16.00	1.80	Nonasbestos		X		X		TF
3	1	8.50	1.50	Amphibole				X	Tremolite	Cleavage
3	1	8.00	2.00	Amphibole				X	Tremolite	Cleavage
3	1	8.25	1.10	Amphibole				X	Tremolite	Cleavage
3	1	11.50	0.35	Nonasbestos				X		TF
3	1	7.00	0.50	Nonasbestos				X		TF
4	1	10.50	1.30	Amphibole				X	Tremolite	Cleavage
4	1	8.00	0.80	Nonasbestos		X		X		TF
4	1	7.50	0.80	Amphibole				X	Tremolite	Cleavage
4	1	5.25	0.60	Amphibole				X	Tremolite	Cleavage
4	1	35.00	5.00	Amphibole		X			Tremolite	Cleavage
4	1	21.00	2.20	Nonasbestos		X		X		TF
4	1	8.00	0.90	Amphibole				X	Tremolite	Cleavage
5	0.5	7.00	0.90	Amphibole		X			Tremolite	Cleavage
5	1	7.00	0.80	Nonasbestos				X		TF
5	1	6.50	1.00	Nonasbestos				X		TF
5	1	11.50	0.50	Nonasbestos				X		TF
5	0.5	20.00	5.00	Amphibole		X			Tremolite	Cleavage
5	1	11.50	0.40	Nonasbestos				X		TF
6	1	11.00	1.00	Amphibole				X	Tremolite	Cleavage
6	1	12.50	3.00	Amphibole		X			Tremolite	Cleavage

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114782HT	Grid Openings	18
Client Sample #	F-13 / Over packer – NYTAL 300	Total Asbestos	0
Microscope	2000 FX	Total Non-Asbestos	101.5
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	120.0 Liters
Analyst	TWS/BF	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
6	0.5	10.25	0.40	Nonasbestos				X		TF
6	1	5.50	1.00	Nonasbestos				X		TF
6	1	7.00	1.50	Nonasbestos		X				TF
6	1	18.00	1.50	Amphibole				X	Tremolite	Cleavage
6	0.5	5.75	0.90	Nonasbestos				X		TF
6	1	7.00	0.50	Nonasbestos				X		TF
7	1	8.50	1.75	Amphibole				X	Tremolite	Cleavage
7	1	7.75	0.40	Nonasbestos				X		TF
7	1	5.75	0.50	Nonasbestos				X		TF
7	1	9.75	0.75	Nonasbestos				X		TF
8	1	7.50	0.60	Nonasbestos				X		TF
8	1	8.00	0.75	Nonasbestos				X		TF
8	1	8.50	0.40	Nonasbestos				X		TF
9	0.5	10.50	0.80	Amphibole				X	Tremolite	Cleavage
9	0.5	6.50	1.50	Amphibole				X	Tremolite	Cleavage
9	0.5	9.00	0.45	Nonasbestos				X		TF
9	1	18.00	1.00	Amphibole				X	Tremolite	Cleavage
9	1	5.75	0.90	Amphibole				X	Tremolite	Cleavage
9	1	5.50	0.90	Amphibole		X		X	Tremolite	Cleavage
9	1	6.50	0.80	Nonasbestos				X		TF
10	0.5	6.00	1.00	Nonasbestos				X		TF
10	1	5.50	1.00	Amphibole				X	Tremolite	Cleavage
10	1	9.50	1.00	Nonasbestos				X		TF
11	1	6.50	1.80	Amphibole		X		X	Tremolite	Cleavage
11	1	12.50	0.50	Nonasbestos				X		TF
12	1	6.50	0.80	Nonasbestos				X		TF
12	1	5.20	0.60	Amphibole		X		X	Tremolite	Cleavage
12	1	6.80	1.00	Amphibole		X		X	Tremolite	Cleavage
12	1	7.00	0.40	Nonasbestos		X		X		TF
12	1	20.00	3.00	Amphibole		X		X	Tremolite	Cleavage
13	0.5	19.00	2.50	Amphibole		X		X	Tremolite	Cleavage
13	1	5.20	0.50	Amphibole				X	Tremolite	Cleavage
13	1	5.50	0.80	Amphibole				X	Tremolite	Cleavage
13	1	16.00	1.50	Nonasbestos	B			X		TF
13	1	6.10	0.60	Amphibole		X		X	Tremolite	Cleavage
14	1	7.00	1.00	Nonasbestos				X		TF
14	1	7.30	0.70	Nonasbestos		X		X		TF
14	1	9.30	1.00	Amphibole				X	Tremolite	Cleavage
14	1	7.00	1.00	Nonasbestos		X		X		TF
14	1	6.00	0.80	Amphibole		X		X	Tremolite	Cleavage

RJ Lee *Group*, Inc.
Count Sheet

Client Name	R. T. Vanderbilt Company, Inc.		
Project Number	LSH006444-3	RJLG QA Number	HQ18755
RJLG Sample #	0114782HT	Grid Openings	18
Client Sample #	F-13 / Over packer – NYTAL 300	Total Asbestos	0
Microscope	2000 FX	Total Non-Asbestos	101.5
Accelerating Voltage	120 Kv	Filter	CE 385 mm^2
Magnification	1,000 X	Volume	120.0 Liters
Analyst	TWS/BF	Grid Opening Area	0.0083 mm^2
EDS Disk		Dilution Factor	1

Field	Fiber	Length µm	Width µm	Structure Type	Morph	EDS	Photo	SAED	Amphibole Type	Comment
14	1	6.50	1.00	Amphibole		X		X	Tremolite	Cleavage
14	1	9.90	2.20	Amphibole		X		X	Tremolite	Cleavage
15	1	15.00	2.00	Amphibole				X	Tremolite	Cleavage
15	1	9.50	2.30	Amphibole				X	Tremolite	Cleavage
15	1	16.00	2.00	Amphibole		X		X	Tremolite	Cleavage
15	1	6.00	0.60	Amphibole		X		X	Tremolite	Cleavage
15	1	14.00	1.60	Amphibole		X		X	Tremolite	Cleavage
15	1	5.20	1.00	Nonasbestos				X		TF
15	1	6.50	1.50	Nonasbestos		X		X		TF
15	1	8.50	1.60	Nonasbestos		X		X		TF
16	0.5	10.40	0.60	Nonasbestos				X		TF
16	0.5	7.30	1.20	Amphibole				X	Tremolite	Cleavage
16	0.5	18.50	3.50	Amphibole		X		X	Tremolite	Cleavage
16	0.5	7.00	0.40	Amphibole		X		X	Tremolite	Cleavage
16	0.5	9.00	1.40	Amphibole				X	Tremolite	Cleavage
16	1	5.20	0.50	Nonasbestos				X		TF
16	1	6.30	1.20	Amphibole				X	Tremolite	Cleavage
16	1	6.50	0.50	Amphibole				X	Tremolite	Cleavage
16	1	8.00	2.00	Nonasbestos				X		TF
17	0.5	15.00	2.00	Nonasbestos		X		X		TF
17	1	6.00	0.40	Amphibole				X	Tremolite	Cleavage
17	1	5.50	0.60	Nonasbestos		X		X		TF
17	1	7.00	0.50	Nonasbestos				X		TF
17	1	7.50	1.00	Amphibole				X	Tremolite	Cleavage
17	1	9.50	0.60	Nonasbestos		X				TF
17	1	7.00	1.00	Amphibole				X	Tremolite	Cleavage
17	1	6.00	0.26	Amphibole				X	Tremolite	Cleavage
17	1	9.00	0.60	Amphibole				X	Tremolite	Cleavage
18	0.5	6.00	0.60	Nonasbestos	B			X		TF
18	1	14.00	0.90	Amphibole				X	Tremolite	Cleavage
18	1	6.50	0.60	Amphibole				X	Tremolite	Cleavage
18	1	7.0	0.40	Nonasbestos				X		TF
18	1	14.00	1.10	Nonasbestos		X		X		TF

OCCUPATIONAL EXPOSURE TO TALC CONTAINING ASBESTOS

Morbidity, Mortality, and Environmental Studies of Miners and Millers

I.	Environmental Study	John M. Dement[1] Ralph D. Zumwalde[1]
II.	Cross Sectional Morbidity Study	John F. Gamble[2] William Fellner[2] Michael J. DeMeo[2]
III.	Retrospective Cohort Study of Mortality	David P. Brown[1] Joseph K. Wagoner[3]

U.S. Department of Health, Education, and Welfare
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
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[3]Occupational Safety and Health Administration, DOL
Washington, D.C. 20210

February, 1980

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Printing Office, Washington, D.C. 20402

Appendix. Summary Statistics for NIOSH 1975 Industrial Hygiene Study (Tables A-1 through A-10).

Table A-1

Summary of Fiber Exposures in Mine Operations as Determined by Optical Microscopy

Operation or Job	Fiber >5 μm in Length per cc			
	Range of Individual Samples	Mean (± SE) of Individual Samples	Median of Individual Samples	Time-Weighted Average
Crusher Operator (4)	7.7 - 14.7	10.3 ± 1.5	9.3	9.8
Trammer (25)	2.3 - 14.6	6.4 ± 0.7	5.1	5.6
Driller (5)	0.9 - 6.8	3.9 ± 1.0	4.6	3.0
Cageman (5)	6.0 - 18.2	10.3 ± 2.1	8.4	9.5
Blacksmith (3)	1.2 - 4.4	3.1 ± 1.0	3.7	2.6
Mechanic (12)	0.2 - 3.9	1.9 ± 0.3	1.9	1.7

( ) Number of samples

SE Standard error

Spimes

TABLE A-2

Summary of Fiber Exposures in Mill
Operations as Determined by Optical Microscopy

Operation or Job	Fiber >5 μm in Length per cc: Range of Individual Samples	Mean (± SE) of Individual Samples	Median of Individual Samples	Time-Weighted Average
Mill Foreman (9)	2.4 - 16.0	5.8 ± 1.4	4.7	5.3
General Laborer (5)	1.5 - 13.2	5.8 ± 2.0	5.5	5.6
Crusher Operator (16)	1.7 - 11.6	5.5 ± 0.9	4.7	5.1
Hardinge Operator (14)	1.7 - 26.8	8.7 ± 1.8	6.4	7.9
Wheeler Operator (14)	2.6 - 29.1	9.9 ± 2.1	6.5	8.4
Packer (48)	0.2 - 21.0	6.9 ± 0.6	6.1	5.1
Packer Serviceman (11)	1.6 - 8.3	4.9 ± 0.7	5.5	3.6
Packhouse Foreman (5)	1.0 - 1.9	1.5 ± 0.2	1.6	1.5
Fork Lift Operator (15)	1.1 - 8.3	4.5 ± 0.5	4.6	4.0
Rail Car Liner (3)	1.3 - 5.6	3.8 ± 1.0	4.1	3.4
Bulk Car Loader (3)	1.6 - 2.4	1.9 ± 0.2	1.8	2.0
Millwright (3)	0.9 - 2.6	1.9 ± 0.5	2.3	1.9
Instrument Repairman (6)	1.2 - 4.0	2.8 ± 0.4	3.0	2.8
Machinist (3)	0.3 - 3.6	1.5 ± 1.1	0.5	1.8
Millwright Helper (2)	0.7 - 8.9	4.8 ± 4.1	4.8	4.0
Sheet Metal Worker (3)	1.2 - 2.2	1.8 ± 0.3	1.9	1.7
Oiler (4)	1.7 - 4.5	3.6 ± 0.7	4.1	4.0
Welder (3)	0.8 - 3.1	1.8 ± 0.7	1.6	1.9

( ) Number of samples

SE Standard error

RJ LeeGroup, Inc.

350 Hochberg Road
Monroeville, PA 15146
Tel: (724) 325-1776
Fax: (724) 733-1799

The Materials Characterization Specialists

November 22, 2000

Mr. John W. Kelse
R. T. Vanderbilt Company, Inc.
30 Winfield Street
Norwalk, CT 06856-5150

RE: PLM Evaluation of Talc Samples
RJ Lee Group Job No.: LSH006444

Dear Mr. Kelse:

RJ Lee Group has completed the analysis of several samples of talc. The procedure used for these analyses is based on a procedure developed by Dr. Ann Wylie. Basically, a known mass of sample is placed on a clean glass slide to which is added several drops of 1.598 refractive index oil. Twenty percent of the slide is examined in a polarizing light microscope; the dimensions of every particle with an aspect ratio of at least 3:1 (length to width) are recorded. The minerals were identified as talc, tremolite, anthophyllite, or "transitional" according to the following system:

Mineral	α, RI	γ, RI
Talc	< 1.598	≤ 1.598
Transitional	< 1.598	> 1.598
Amphibole	≥ 1.598	> 1.598

In addition, the particles were classified as "fiber" or "cleavage" using a consensus definition. Particles classified as "fiber" are asbestiform and show evidence of high aspect ratio, bundles, splayed ends, and curvature. Splayed ends are generally indicative of bundles of asbestiform fibers. There were several high aspect ratio transitional particles which did not meet the consensus definition of asbestiform (generally not displaying evidence of curvature or splayed ends).

Seven samples were submitted for analysis (NYTAL 100, NYTAL 200, NYTAL 300, NYTAL 400, NYTAL 3300, NYTAL 7700, and IT-3X). This preliminary report discusses the data generated on the NYTAL 100 and NYTAL 300 samples, with partial analyses of the other samples. Analyses of the remaining samples are progressing and will be reported as they become available.

Table 1 shows the concentration of the particles with aspect ratios of at least 3:1. The table shows two measures of concentrations, particles/mg of sample and weight percent. In the samples, the particle type with the largest concentration is tremolite. Very few anthophyllite particles were observed in any sample.

Table 2 shows the concentration of all asbestiform fibers observed in these samples. In the samples, only talc fibers were observed to be asbestiform; all other particles are cleavage fragments. Very few asbestiform fibers were observed with an aspect ratios less than 5:1.

Figure 1 compares the average lengths for the principal mineral components of the Nytal products. Figures 2 and 3 show the average width and aspect ratios for the sample products. Figure 4 shows the particle number concentration and particle weight percent for each analyzed product.

RJ Lee Group, Inc. is accredited by the National Voluntary Laboratory Accreditation Program (NVLAP), New York Department of Health Environmental Laboratory Approval Program (ELAP), and by the American Industrial Hygiene Association (AIHA). This report relates only to the items tested and shall not be reproduced except in full. NVLAP accreditation does not imply endorsement by NVLAP or any agency of the US government. These results are submitted pursuant to RJ Lee Group's current terms and conditions of sale, including the company's standard warranty and limitation of liability provisions. No responsibility or liability is assumed for the manner in which the results are used or interpreted. Unless notified in writing to return the samples covered in this report, RJ Lee Group will store the samples for a period of 30 days before discarding. A shipping and handling fee will be assessed for the return of any samples.

If you have any questions, please feel free to call me.

Sincerely,

Drew R Van Orden

Drew R. Van Orden, PE
Senior Scientist

Table 1. Concentration of All Mineral Particles With An Aspect Ratio of At Least 3:1

			particle/mg			Particle Wt, %		
Product	Slide	Mineral	3:1 - 5:1	≥ 5:1	≥ 3:1	3:1 - 5:1	≥ 5:1	≥ 3:1
Nytal 100	1	Tremolite	353	839	1,193	4.39	2.02	6.41
		Anthophyllite		12	12		< 0.01	< 0.01
		Transitional	16	265	281	0.19	3.09	3.28
		Talc	16	189	205	0.21	0.31	0.52
	2	Tremolite	289	1,042	1,331	4.09	2.69	6.77
		Anthophyllite		6	6		0.01	0.01
		Transitional		66	66		0.37	0.37
		Talc	15	114	129	0.03	0.08	0.11
	3	Tremolite	375	1,288	1,663	6.78	3.58	10.35
		Anthophyllite		4	4		< 0.01	< 0.01
		Transitional	6	101	107	0.06	1.03	1.09
		Talc	2	230	233	< 0.01	0.14	0.15
Nytal 300	1	Tremolite	843	3,638	4,481	1.04	1.29	2.33
		Anthophyllite		12	12		0.01	0.01
		Transitional	12	341	353	0.07	0.57	0.64
		Talc		1,056	1,056		0.37	0.37
	2	Tremolite	18	3,395	3,412	< 0.01	0.63	0.64
		Anthophyllite						
		Transitional		272	272		0.31	0.31
		Talc		727	727		0.08	0.08
	3	Tremolite	361	3,453	3,814	0.44	1.24	1.68
		Anthophyllite		4	4		< 0.01	< 0.01
		Transitional	8	261	269	0.01	0.35	0.36
		Talc	16	1,044	1,060	0.03	0.17	0.20

Table 1. Concentration of All Mineral Particles With An Aspect Ratio of At Least 3:1 (continued)

			particle/mg			Particle Wt, %		
Product	Slide	Mineral	3:1 - 5:1	≥ 5:1	≥ 3:1	3:1 - 5:1	≥ 5:1	≥ 3:1
Nytal 3300	1	Tremolite	337	4,376	4,713	0.28	0.89	1.17
		Anthophyllite		18	18		0.01	0.01
		Transitional	18	285	302	0.24	0.55	0.79
		Talc		1,318	1,318		0.35	0.35
Nytal 7700	1	Tremolite	123	4,486	4,609	0.04	0.27	0.31
		Anthophyllite		11	11		< 0.01	< 0.01
		Transitional		277	277		0.33	0.33
		Talc	5	2,050	2,050	< 0.01	0.15	0.15
Nytal 200	1	Tremolite	166	1,748	1,914	0.49	1.80	2.30
		Anthophyllite						
		Transitional	13	145	158	0.08	0.72	0.79
		Talc	26	950	977	0.11	0.63	0.74
Nytal IT-3X	1	Tremolite	206	1,310	1,516	1.20	1.52	2.73
		Anthophyllite	4	101	105	0.06	0.02	0.09
		Transitional	110	1,117	1,226	0.84	3.45	4.29
		Talc	35	4,844	4,880	0.48	2.20	2.68

Table 2. Concentration of All Asbestiform Mineral Fibers With An Aspect Ratio of At Least 3:1

			Fiber/mg			Fiber Wt, %		
Product	Slide	Mineral	3:1 - 5:1	≥ 5:1	≥ 3:1	3:1 - 5:1	≥ 5:1	≥ 3:1
Nytal 100	1	Talc		104	104		0.02	0.02
	2	Talc		60	60		0.05	0.05
	3	Talc		128	128		0.06	0.06
Nytal 300	1	Talc		707	707		0.29	0.29
	2	Talc		477	477		0.05	0.05
	3	Talc		879	879		0.11	0.11
Nytal 3300	1	Talc		1,099	1,099		0.32	0.32
Nytal 7700	1	Talc		1,895	1,895		0.13	0.13
Nytal 200	1	Talc	4	381	385	< 0.01	0.30	0.31
Nytal IT-3X	1	Talc	13	2,961	2,974	0.02	1.76	1.78

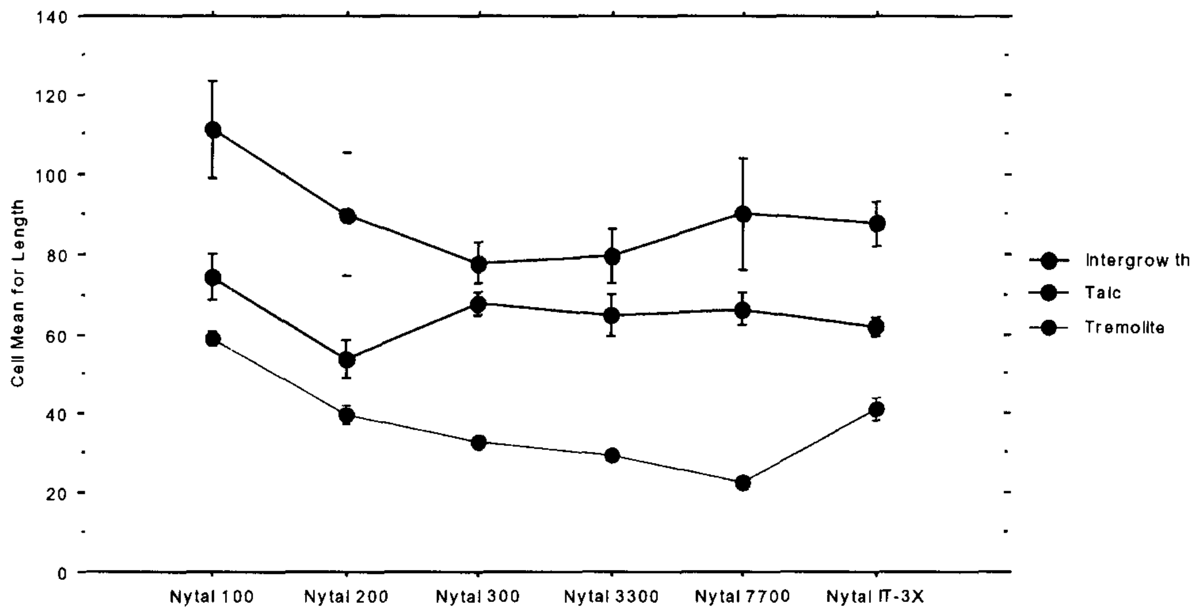


Figure 1. Comparison of particle length (µm) for Nytal products; all particles ≥ 3:1.

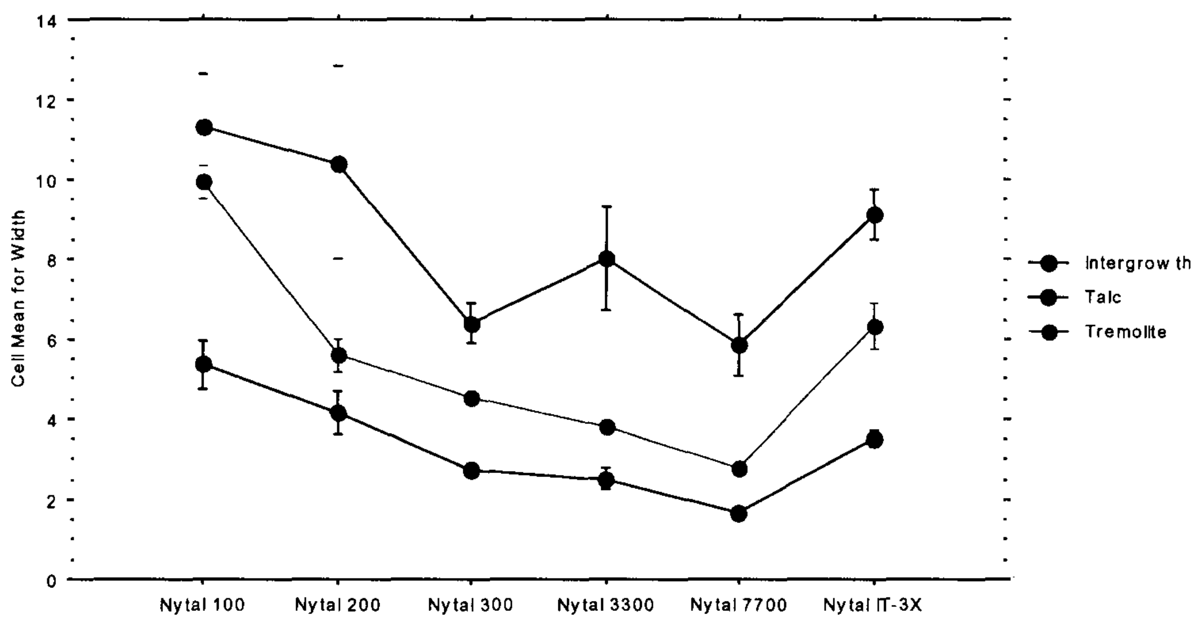


Figure 2. Comparison of particle width (µm) for Nytal products; all particles ≥ 3:1.

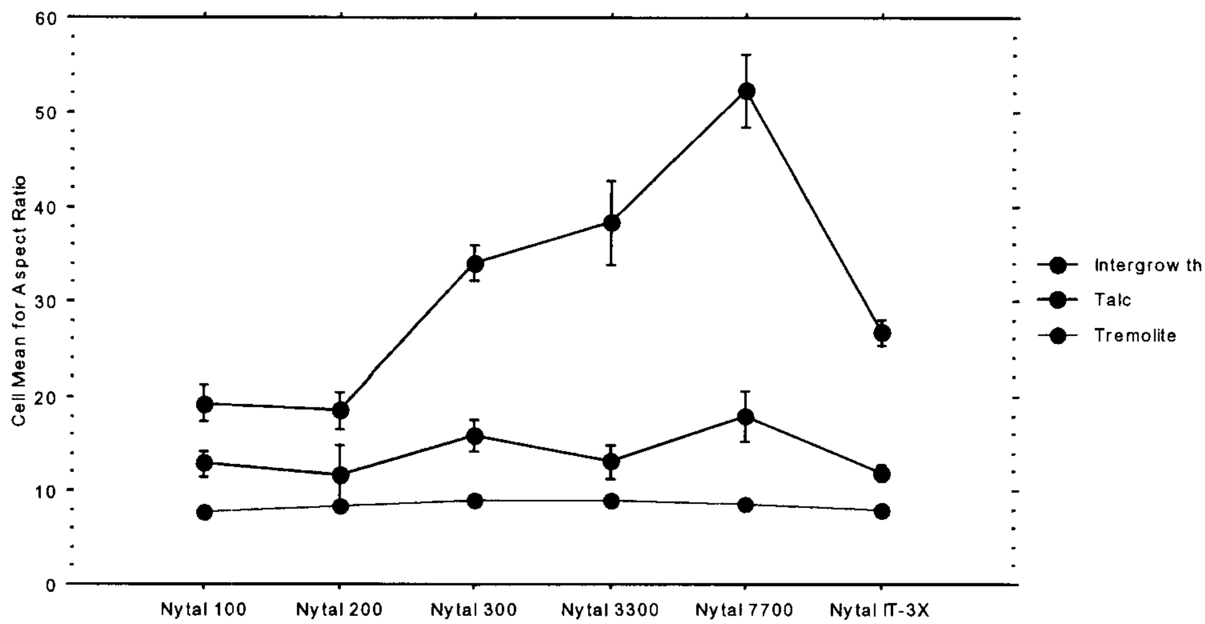


Figure 3. Comparison of Aspect Ratio for all particles ≥ 3:1 for Nytal products.

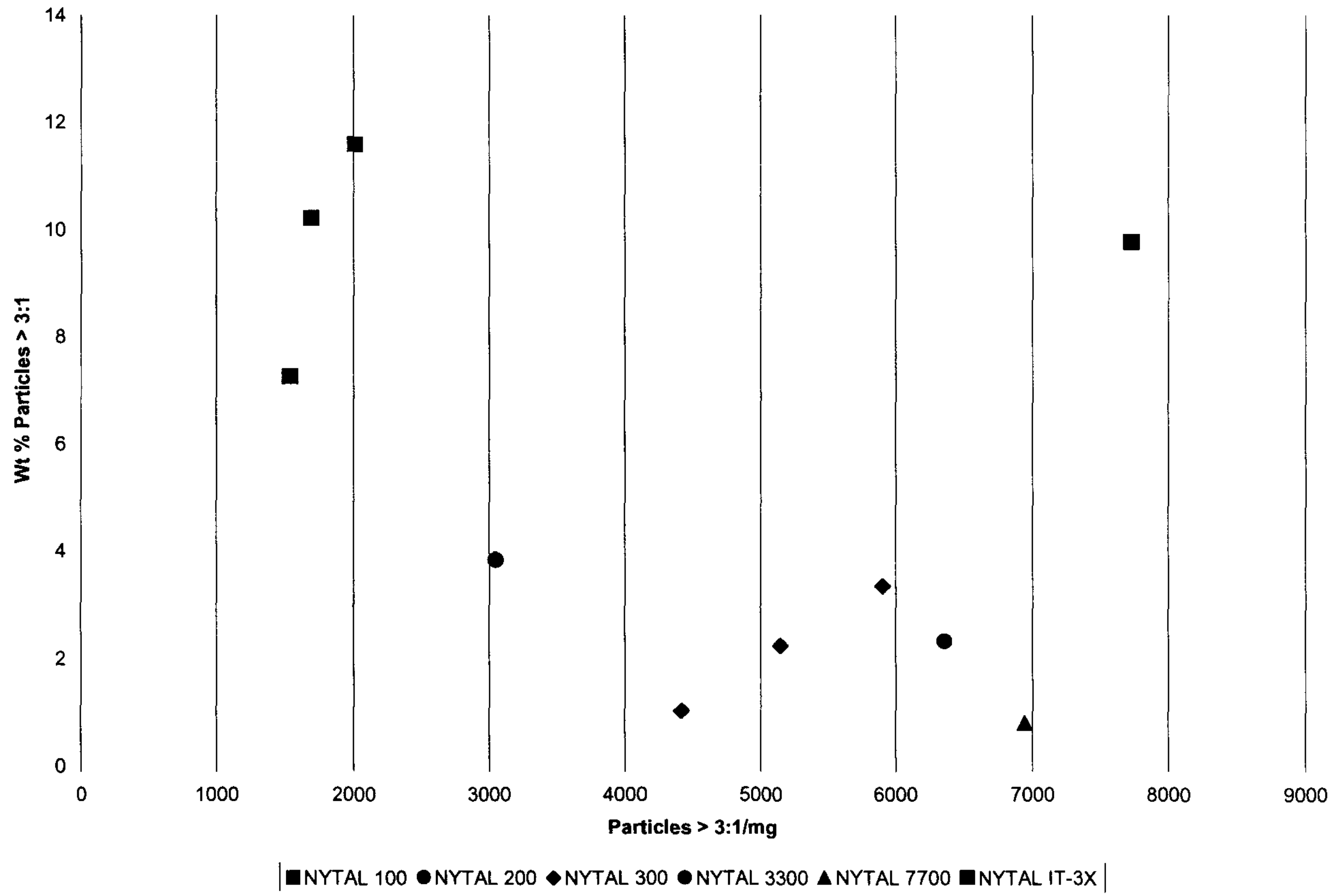


Figure 4. Comparison of particle number concentration and particle weight percent for NYTAL products.

Am. Ind. Hyg. Assoc. J. 50(11):613-622 (1989) 4008

The Regulatory and Mineralogical Definitions of Asbestos and Their Impact on Amphibole Dust Analysis

JOHN W. KELSE and C. SHELDON THOMPSON
R.T. Vanderbilt Company, Inc., 30 Winfield Street, Norwalk, CT 06855

Although a familiar occupational health topic, the term *asbestos* generally is not well understood. Significant differences between mineralogical and regulatory definitions sustain the confusion. Definitional ambiguity is addressed and its effect upon the characterization of New York State tremolitic talc are investigated. Analysis of asbestiform and nonasbestiform airborne dust populations clearly demonstrates the nonspecificity of the regulatory definition and the 3:1 aspect ratio "fiber" counting scheme. Shifting to a higher aspect ratio would reduce false positives radically without a loss in sensitivity for true asbestos. Any change in aspect ratio, however, must be accompanied by a mineralogically correct definition of asbestos if proper mineral characterization is to be assured.

Introduction

Few environmental health hazards have been as widely publicized or viewed with as much dread as asbestos. Despite this attention, considerable confusion exists as to what the generic term *asbestos* actually means. American regulatory definitions are incomplete and, in some instances, at odds with the mineralogical view of this substance. The purpose of this paper is to review this definitional problem and demonstrate its effect on one controversial dust environment.

Definitions

Regulatory

The National Institute for Occupational Safety and Health (NIOSH) has established the definitions and analysis methods for asbestos used by almost all regulatory bodies in the United States. Under this scheme, asbestos is defined as any fiber of chrysotile, crocidolite, amosite, anthophyllite, tremolite or actinolite. A *fiber* is defined as a particle with a length to width ratio (aspect ratio) of at least 3:1 and a length of 5 μm or more as determined by the phase-contrast optical microscope (PCM) at a magnification of 450X to 500X.[1] While NIOSH acknowledges that this dimensional criteria and fiber counting method is not specific to asbestos,[2] regulatory definitions offer no further description of what is or is not asbestos.

Mineralogical

In the *Glossary of Geology*, asbestos is defined simply as

> A commercial term applied to a group of highly fibrous silicate minerals that readily separate into long, thin, strong fibers of sufficient flexibility to be woven, are heat resistant and chemically inert, and possess a high electrical insulation and therefore are suitable for uses where incombustible, nonconductive or chemically resistant material is required.[3]

While chemical and electrical inertness are properties shared by almost all silicates, asbestos is unique because of its long, thin, strong, flexible fibers. Accordingly, to a mineral scientist the term *asbestos* always includes some reference to the fibrous crystal growth pattern often described as the "asbestiform habit." Mineralogically, asbestos is a matter of how a mineral grows, not simply a matter of one mineral versus another or an arbitrary dimensional concept.

Several minerals, including those designated in United States' regulations, do grow in nature in an asbestiform habit. These would include the most commonly exploited forms of asbestos: chrysotile, crocidolite, and amosite. The regulated asbestiform minerals, however, also occur in nature in a nonasbestiform habit. In all cases, the nonasbestiform habit is by far the more common. Table I lists the asbestiform and nonasbestiform habits of the six regulated minerals and their separate Chemical Abstract Service numbers. The list conforms to the nomenclature set forth by the United States Department of the Interior.[4]

It should be noted that the chemical composition is the same for each mineral in either growth habit. In all cases except chrysotile, the internal crystal structure is identical as well. Also, the first three minerals have been assigned separate names to distinguish the different growth patterns, while the last three—anthophyllite, tremolite, and actinolite—have not. For these three the nonasbestiform analogs are common rock-forming minerals found throughout the earth's crust and, therefore, routinely encountered in many industries. Figure 1 graphically depicts the basic difference in the two mineral growth patterns while Figure 2 contrasts the two macroscopically and microscopically.

While nonasbestiform particles clearly differ from asbestiform particles, many would be counted as asbestos under the current regulatory 3:1 dimensional criterion for a fiber when an ore is crushed, milled or otherwise reduced. Thus, while all asbestos is fibrous, not all fibers are asbestos. It is also important to note that asbestiform fibers cannot be created from nonasbestiform materials by crushing, milling, or grinding. Mineralogically, a particle with an aspect ratio of 3:1 would not be considered a fiber. Because the term *fiber* is interpreted in different ways, its use in this paper will be restricted

TABLE I

Asbestiform and Nonasbestiform Varieties of Selected Silicate Minerals and Their Chemical Abstract Service Numbers (CAS)

Asbestiform Variety (CAS #)	Chemical Composition	Nonasbestiform Variety (CAS #)
Serpentine Group:		
Chrysotile (12001-29-5)	$Mg_3(Si_2O_5)(OH)_4$	antigorite, lizardite (12135-86-3)
Amphibole Group:		
Crocidolite (12001-28-4)	$Na_2Fe_3Fe_2(Si_8O_{22})(OH,F)_2$	riebeckite (17787-87-0)
Grunerite asbestos (amosite) (12172-73-5*)[A]	$(Mg,Fe)_7(Si_8O_{22})(OH,F)_2$	cummingtonite-grunerite (14567-61-4)
Anthophyllite asbestos (77536-67-5*)	$(Mg,Fe)_7(Si_8O_{22})(OH,F)_2$	anthophyllite (17068-78-9)
Tremolite asbestos (77536-68-6*)	$Ca_2Mg_5(Si_8O_{22})(OH,F_2)$	tremolite (14567-73-8)
Actinolite asbestos (77536-66-4*)	$Ca_2(Mg,Fe)_5(Si_8O_{22})(OH,F)_2$	actinolite (13768-00-8)

[A]The presence of an asterisk following a CAS Registry Number indicates that the registration is for a substance which CAS does not treat in its regular CA index processing as a unique chemical entity. Typically, this occurs when the material is one of variable composition: a biological organism, a botanical entity, an oil or extract of plant or animal origin, or a material that includes some description of physical specificity, such as morphology.

in the interest of clarity to specific definitions only. To reflect the mineralogical characteristics of asbestos in a definition, a group of mineral scientists agreed to the following.[5]

A. Asbestos—A collective mineralogical term that describes certain silicates belonging to the serpentine and amphibole mineral groups, which have crystallized in the asbestiform habit causing them to be easily separated into long, thin, flexible, strong fibers when crushed or processed. Included in the definition are chrysotile; crocidolite, asbestiform grunerite (amosite); anthophyllite asbestos; tremolite asbestos; and actinolite asbestos.

B. Asbestos Fibers—Asbestiform mineral fiber populations generally have the following characteristics when viewed by light microscopy:
   1. Many particles with aspect ratios ranging from 20:1 to 100:1 or higher (> 5 μm length)
   2. Very thin fibrils generally less than 0.5 μm in width, and
   3. In addition to the mandatory fibrillar crystal growth, two or more of the following attributes:
      (a) Parallel fibers occurring in bundles;
      (b) Fibers displaying splayed ends;
      (c) Matted masses of individual fibers; and
      (d) Fibers showing curvature[5]

Many of those who contributed to this definition and support the listed criteria have published extensively on the problems associated with the NIOSH definitions and the membrane filter method.[4,6-17] This definition has been incorporated in a proposed American Society for Testing and Materials (ASTM) method submitted to committee D-22.05 (January 14, 1988). The criteria have long been endorsed by the U.S. Department of the Interior.[4,11,13]

While all mineral scientists may not agree with every entry in this definition, it does present a more mineralogically accurate description of asbestos and asbestos fibers than does the regulatory definition. This is especially true when it is applied to a dust population rather than on a particle by particle basis. The definition, therefore, will be used in the remainder of this paper as the "mineralogical" definition of asbestos. It might be noted that the width criterion (0.5 μm) represents a dimension below which all individual "fibrils" and clumps or masses of fibrils would be encountered in processed asbestos. Unprocessed clumps or masses may exceed this width, but such particles would not be representative of common airborne asbestos fibers.

The Study Environment

One of the most controversial workplace exposures associated with this definitional issue involves the mining and milling of New York State tremolitic talc. Accordingly, a study was undertaken to contrast dust data obtained in this environment with both the regulatory and mineralogical definitions discussed above.

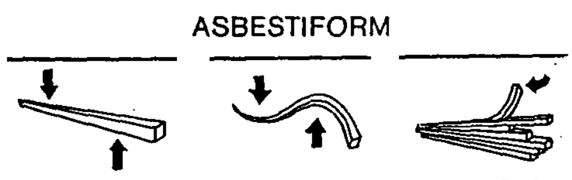
New York State tremolitic talc is an industrial grade talc used extensively in the ceramics, tile, and paint industries. Since 1974 the R.T. Vanderbilt Company, Inc., has owned and operated the only New York State tremolitic talc mine.

Talc mined from this operation varies somewhat in mineral content but an assay of the ore generally reflects 40%–60% tremolite, 1%–10% anthophyllite, 20%–40% talc, 20%–30% serpentine (antigorite-lizardite), and 0%–2% quartz.[18]

The R.T. Vanderbilt Company states that all of the tremolite and anthophyllite in its talc products appear only in the nonasbestiform habit.[19,20] In 1980, however, NIOSH published a technical report entitled *Occupational Exposure to Talc Containing Asbestos*[21] specifically addressing this mineral dust exposure. In the report, NIOSH applied its regulatory asbestos definition to bulk and airborne dust samples collected at this mine and reported over 70% asbestos for airborne fibers satisfying the 3:1 or greater aspect ratio and greater than 5-μm length limit (NIOSH PCM method). Particles were identified as tremolite and anthophyllite by standard X-ray diffraction technique.

Method of Study

Samples for particulate analysis were collected on open-faced, 37-mm diameter Millipore type AA filters (0.8-μm pore size, Millipore Corp., Bedford, Mass.). Precalibrated Mine Safety Appliances' Model G pumps were used to draw air through these filters at a rate of 1.7 L/min. Although fiber sampling technique has changed since, this technique was used in order to compare results with data previously collected. Filters were changed throughout a full work shift



In the asbestiform habit, mineral crystals grow in a single dimension, in a straight line until they form long, thread-like fibers with aspect ratios of 20:1 to 1000:1 and higher. When pressure is applied, the fibers do not shatter but simply bend much like a wire. Fibrils of a smaller diameter are produced as bundles of fibers are pulled apart. This bundling effect is referred to as polyfilamentous.

In the nonasbestiform variety, crystal growth is random, forming multidimensional prismatic patterns. When pressure is applied, the crystal fractures easily, fragmenting into prismatic particles. Some of the particles or cleavage fragments are acicular or needle-shaped as a result of the tendency of amphibole minerals to cleave along two dimensions but not along the third. Stair-step cleavage along the edges of some particles is common, and oblique extinction is exhibited under the microscope. Cleavage fragments never show curvature.

Figure 1—Asbestiform and nonasbestiform graphics

as needed to prevent overloading. In all, 22 air samples were obtained representing nine work activities in the R.T. Vanderbilt Co., Gouverneur, New York, mine and mill. Work activities sampled included milling (Hardinge and Wheeler mills), drying, packing, bag stacking, crushing, mine drilling, scraping, and tramming.

Analyses were performed by The R.J. Lee Group, Inc., of Monroeville, Pennsylvania (Project No. 86-12318). Analytical techniques employed included phase contrast microscopy (PCM), polarized light microscopy (PLM), scanning electron microscopy (SEM), computer-controlled scanning electron microscopy (CCSEM), and transmission electron microscopy (TEM). In accordance with NIOSH method 7400, all samples received PCM particle counts at 400X magnification in Walton-Beckett graticule measuring at least 5-μm long with a 3:1 or greater aspect ratio. Beyond these specified parameters, exact particle widths and lengths were not measured. For each sample, 100 fields or 100 particles, whichever came first, were counted (with a minimum of 20 fields). In all, 2295 particles were counted and sized by PCM.

A separate wedge was cut from each filter for PLM analysis. Particles were tapped, then gently scraped from the wedge to a glass slide. Any remaining particles were captured by rolling a needle moistened with 1.592 refractive index (RI) liquid over the surface of the filter wedge (RI selected for low-iron talc). Additional 1.592 RI liquid was added to the slide and used to wash particles from the needle onto the slide. It should be noted that this transfer technique could bias the PCM analysis if very fine particles were lost in the transfer. Additional analysis of particles not removed from the filter (another filter section) suggests such bias is unlikely for tremolite (see SEM particle width discussion below). PLM counts were made in a 1.592 RI oil to differentiate talc from all amphiboles on all 22 air samples. Following this basic cut, tremolite was differentiated from anthophyllite by angle of extinction (tremolite has an inclined extinction of 14° to 17°, while anthophyllite exhibits parallel extinction). Since all asbestos exhibits parallel extinction, mineral habit (asbestiform or nonasbestiform) then was decided on the basis of criteria noted in the mineralogical definition. Depending on particle concentration for each of the 22 samples, 100 to 200 points were counted and characterized at 100X magnification, yielding a minimum of 2200 particles subjected to PLM analysis. If positive particle identification could not be made at 100X total magnification, higher magnifications (up to 400X) were applied on a particle by particle basis. As in the PCM analysis, only particles with an aspect ratio of 3:1 or greater and a length of 5 μm or more were so characterized. Although exact length and width measurements were not obtained, particles were sized by basic aspect ratio categories (*i.e.*, those 3:1 or greater, 10:1 or greater, *etc.*). One additional step was taken in the PLM analysis in which particles presumed to be anthophyllite (> 1.592 RI) were tested for "transitional" phases (meaning talc intertwined with or evolving from anthophyllite and/or biopyriboles). This was accomplished by finding particles which most closely approximated the same size and morphological characteristics of these suspect particles on another portion

EXAMPLES

Amphiboles with Separate Names:

amosite

cummingtonite-grunerite

RAW ORE

Amphiboles with the Same Name:

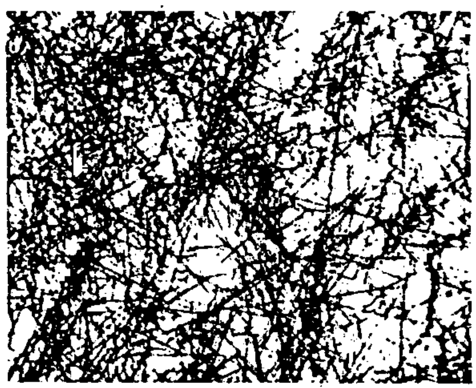
tremolite

tremolite

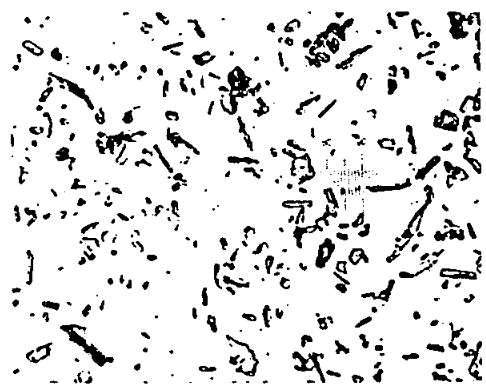
ASBESTIFORM | NONASBESTIFORM

EXAMPLES

Amphiboles with Separate Names:



amosite



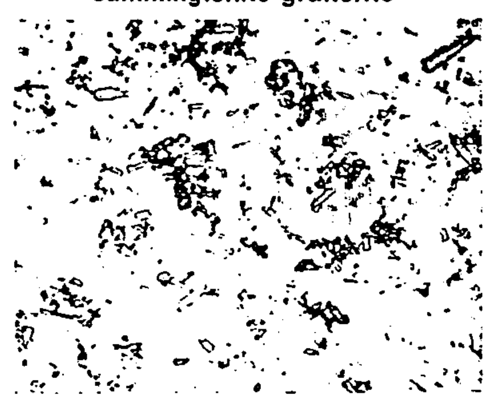
cummingtonite-grunerite

MICROSCOPIC

265X Magnification, 2.75 μm/Division

Amphiboles with the Same Name:

tremolite



tremolite

of the filter and testing them at 1.608 RI (the low gamma index for anthophyllite). Because of problems inherent in this technique, testing the same particle with different RI liquids was not possible. Particles with an index of refraction between 1.592 and 1.608 were classed as "transitional." In all, 6 samples underwent this additional analysis.

To test further the differences and similarities between asbestiform dust populations and the tremolitic talc dust environment, electron microscopy was employed on 5 samples most representative of common mine and mill exposures (*e.g.*, product packaging). SEM with energy dispersive X-ray (EDX) first required the mounting of another 1/8 filter wedge from each sample on a carbon-coated stub. Fifty fields at 2000X magnification then were analyzed for count, size, and identity of all particles in every field with an aspect ratio greater than 3:1 and a length greater than 5 μm. For the five filters, a total of 183 particles were characterized in this way. Particles below and above a width of 0.25 μm were noted as well. This width was selected primarily because it is used in references against which the findings of this study shall be compared.[6,7,22,23] These references generally refer to this width as the approximate lower resolution limit of the light microscope.[24] While other references report lower width sensitivity,[25,26] it generally is agreed this lower limit varies with the quality of the microscope, use of dispersion staining and background contrast, magnification, and the microscopist involved. CCSEM with EDX was used on the same carbon-coated filter wedges to scan a total of 2500 particles (500 per sample) at magnifications of 35X, 100X, and 500X. Particles were sized by the preselected parameters, and the chemical composition of all particles was noted. Particle distribution was expressed in volume percent and all tremolite particles were counted. TEM with selected area electron diffraction (SAED) also was employed on new carbon-coated filter wedges from the same five filters. Chemical composition by EDX analysis and SAED patterns of individual fibers which measured 10 μm or greater on four grid squares per wedge were obtained after the filter matrix was dissolved from the carbon film. While considerable data were thus generated from this multiple analytical approach, only data summaries which directly address the definitional comparison are included in this paper.

It should be noted that the EDX chemistries obtained through the CCSEM analysis and the SAED patterns obtained through TEM analysis were not adequate to distinguish talc and anthophyllite. While an in-depth discussion of this problem is beyond the scope of this paper, in summary it should be said that talc may present the same X-ray spectrum as anthophyllite because talc displays a similar 2:1 Si/Mg ratio and overlapping range. Regarding SAED patterns, talc in the fibrous form often reflects the same 5.3 Å spacing as anthophyllite. Talc/anthophyllite in an intermediate or transitional phase poses further identification problems when electron diffraction analysis is restricted to one point per particle. This is more fully described in other papers.[27,28]

Study Results and Definitional Comparison

Table II contrasts bulk tremolite asbestos particles described in the literature[12] to tremolite particles reflected on five New

TABLE II
Ratio Comparison of Bulk Tremolite Asbestos[A] to N.Y. State Tremolite in Five Air Samples[B] by Optical and Electron Microscopy

	Ratio of Tremolite Particles				
Samples	**3:1 aspect ratio (a.r.) or Greater to Total Tremolite (> 5 μm length) SEM[C]**	**10:1 a.r. or Greater to Total Tremolite (> 5 μm L) SEM**	**20:1 a.r. or Greater to Total Tremolite (> 5 μm L) SEM**	**10:1 a.r. or Greater to 3:1 a.r. or Greater Opt[D]**	**SEM**
Tremolite asbestos[E]	1 in 1.6	1 in 2.6	1 in 4.6	1 in 1.6	1 in 1.6
Tremolite asbestos[F]	1 in 1.8	1 in 2.3	1 in 2.5	1 in 1.6	1 in 1.2
# total tremolite particles per sample (all sizes): 200	(approx. 55%)	(approx. 41%)	(approx. 31%)	1 in 1.5 (66%)	
Tremolite in 5 N.Y. air samples[B]	1 in 6.2	1 in 949 or greater	0 in 949	Opt. 1 in 141 or greater	CCSEM 1 in 152 or greater
# total tremolite particles (all sizes): 949	(16%) CCSEM	(0.1%) CCSEM	(0%) CCSEM	1 in 146 or greater (0.6%)	

[A]Data from U.S. Dept. of Interior, Bureau of Mines Report of Investigation 8367, page 13, Table 2 (1979).[12]

[B]Present study: CCSEM analysis of 5 air samples at 35X, 100X, and 500X magnifications. (2500 total particle count [all sizes]). Optical (PCM and PLM) analysis of the same 5 samples up to 400X magnifications (534 total particles with a 3:1 a.r. or greater > 5 μm length).

[C]Particles counted using SEM with magnification up to 50 000X.

[D]Particles counted using optical-light microscopy at 1250X magnification (200 tremolite particles counted per filter).

[E]Obtained from California (no other description of literature). Wiley milled.

[F]Obtained from museum sample from Rajasthan, India. Wiley milled.

TABLE III
Average of 22 Mine and Mill Air Samples (2295 Particles) by Composition, Aspect Ratio 3:1 or Greater (> 5 μm length), and Mineral Habit by Light Microscopy[A]

	% of Total			Particles per CC (TWA)			Total Particles per CC	% Asbestiform by
Aspect Ratio:	3:1-10:1	> 10:1-20:1	> 20:1	3:1-10:1	> 10:1-20:1	> 20:1	(8-hr TWA)	Mineralogical Def.
Tremolite	35.8	.33	0	.45	.009	0	0.459	0
Transitional[B]	0.0	.76	0	0.00	.015	0	0.015	0
Talc	58.2	4.60	0	.67	.058	0	0.728	0
All particles	93.0	7.00	0	1.12	0.082	0	1.210	0

[A]Mineral type and % by aspect ratio were obtained by PLM analysis at 100X to 400X magnification. Total particles per cc were obtained by PCM at 400X magnification.

[B]% Talc/anthophyllite transitional particles were extrapolated from 6 of 22 air samples based on a refractive index between 1.592 and 1.608 for the gamma index. No pure anthophyllite particles were noted in the fields analyzed.

York state tremolitic talc air samples by both optical and electron microscopy. In this comparison, the ratio of tremolite particles which satisfy the regulatory definition of a fiber (3:1 or greater aspect ratio, > 5 μm length) and those that exceed a 10:1 and 20:1 aspect ratio (> 5 μm length) are addressed.

Of the 2500 total particles scanned by CCSEM on 5 air samples, 38% or 949 were tremolite. Of these tremolite particles, 16% or 152 satisfied the regulatory size criteria for a fiber. This represents a ratio of 1 tremolite regulatory fiber in every 6.2 tremolite particles. In contrast, tremolite asbestos reflected an average of 1 regulatory size fiber in every 1.7 particles (55%). Most striking, however, is the difference reflected at 10:1 and 20:1 aspect ratios. For the New York state tremolite, only 1 tremolite particle in 949 (total counted) exceeded a 10:1 aspect ratio (0.1%). For tremolite asbestos this ratio was approximately 1 in every 2.5 particles or 40%. At a 20:1 aspect ratio or greater, no New York tremolite particles were counted, while 1 in every 3 (approximately) were found for tremolite asbestos. Significant variation in these ratios was not noted under optical microscopy for the same samples at the magnifications applied.

While a bulk to airborne particle comparison is not ideal, the dimensional differences likely would be even greater if two airborne particle distributions were compared, since wider width, lower aspect ratio particles are more common in bulk particle distributions. Published particle distributions for airborne asbestos dust populations support this contention and support the basic dimensional similarity of tremolite asbestos to other asbestiform minerals (see the extended discussion on airborne particle aspect ratio distributions below). Accordingly, on a tremolite to tremolite basis, an entirely different particle-size distribution would be expected in the New York state tremolitic talc samples if this tremolite were asbestiform.

Table III reflects the average of all 22 air samples by percent mineral composition, aspect ratio (3:1 or greater), and crystal growth habit (asbestiform or nonasbestiform). Results in this table reflect the combined application of the PCM and PLM methods outlined above.

In the fields analyzed by PLM, no particles exceeded a 20:1 aspect ratio or showed splayed ends, curvature, or parallel fibers occurring in bundles. Using the mineralogical definition, therefore, no asbestos was found; however, 0.459 particles/cc would be noted if the regulatory definition were used (talc and transitional particles excluded). A total of 1.21 particles/cc would be reported if talc and transitional particles were counted. Proper characterization of talc, anthophyllite and transitional particles is extremely difficult in this ore body except by PLM. While PLM air sample data reflect no asbestiform fibers, both talc and transitional particles can appear in a fibrous, asbestiform and/or nonasbestiform habit in this ore body.[27] If misclassified as anthophyllite, these asbestiform fibers would be characterized as asbestos under both the regulatory and mineralogical definitions. TEM/SAED analysis with multiple electron diffraction patterns (each indexed) confirmed the presence of both nonasbestiform and asbestiform transitional and fibrous talc particles in a random scan of fields not included in the PLM analysis. No effort to quantify these fibers was made. Because of the rarity of these fibers and their marginal significance to the definitional distinctions being addressed here, further detail in this area is beyond the scope and intent of this paper.

Table IV reflects a comparison of fiber counts obtained in this study with data previously obtained in the same mine and mill (same or similar work activities). These data confirm a marked difference in what is reported as asbestos, depending upon the definition used. Note that the average of all regulatory fibers counted by PCM (Column 2) shows far less variance between investigators than the percent of particles considered asbestiform (Column 5). Mineralogical distinctions made reflect consideration of the characteristics described in the mineralogical definition. Although none of the particles in the study dust population exceeded a 20:1 aspect ratio by light microscopy, this factor alone did not dictate habit characterization for the 22 samples analyzed. Although the lack of 20:1 aspect ratio particles in a dust population certainly suggests a nonasbestiform dust environment, aspect ratios alone are not pivotal in a mineralogical sound definition of asbestos.

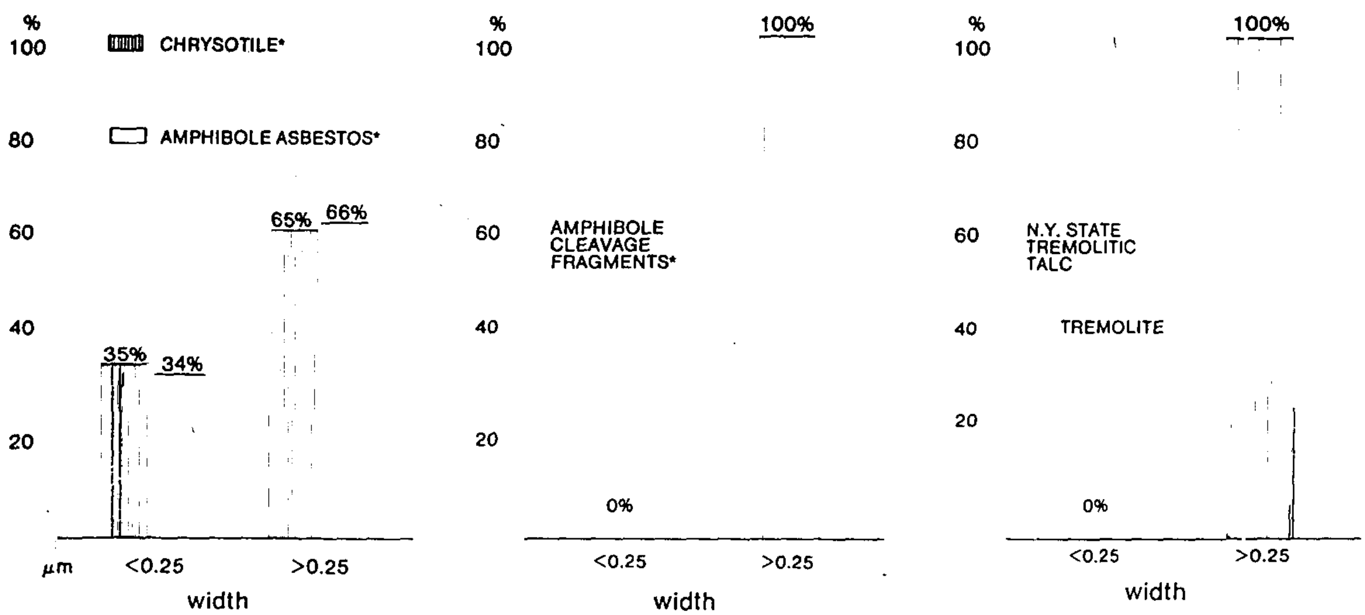
To test definitional specificity further, a comparison of basic dimensional characteristics common to asbestiform dust populations, nonasbestiform (cleavage fragment) amphi-

TABLE IV
Historical Air Samples[A] by Definitional Approach

Source and Year	Average of All Particles/CC Mill and Mine	Range Particles/CC Mill and Mine[(n) B]	Definitional Approach	% Particles/CC Classed as Asbestos	Particles/CC Considered Asbestos
R. Lee (1988)	1.21	0.14-3.56[(22)]	mineralogical	0.00	0.000
MSHA (1984-85)[C]	2.39	0.14-18.40[(38)]	mineralogical	0.40	0.009[D]
Insurance (1984)[E]	1.8	1.38-2.15[(5)]	not classed	—	—
NIOSH (1975)[F]	4.6	1.5-8.4[(221)]	regulatory	72.00	3.312
Dunn (1982)[G]	0.65	0.03-1.38[(8)]	mineralogical but classification completed on bulk samples only	—	—

[A]All particles 3:1 or greater in aspect ratio, > 5 μm in length and resolvable under the light microscope.
[B](n) = number of air samples.
[C]Mine Safety and Health Administration Survey Reports dated: 7/17/85, 7/30/85, 5/22/85, 6/12/84, 1/9/84.
[D]MSHA performs analysis for fiber type only on filters with elevated total fiber counts. Of the 38 filters, 22 were so analyzed. Of these, 2 filters were reported as containing 2% asbestiform fibers. All other filters were found or assumed to contain 0%.
[E]Hartford Insurance Company Report dated November 1984 to R.T. Vanderbilt Company, Inc.
[F]NIOSH Technical Report, *Occupational and Exposure to Talc Containing Asbestos*, Table 7 (1980).[(21)]
[G]Dunn Geoscience Corp. report to R.T. Vanderbilt Company (1985).

bole dust populations, and the study dust population was undertaken. Figure 3 compares airborne asbestiform and nonasbestiform particles which fall above and below a width of 0.25 μm, described in the literature,[(22)] with study dust population particle widths obtained by SEM. With regard to the tremolite found in the talc air samples (the only amphibole noted), all tremolite particles (88 out of 183 total particles) were wider than 0.25 μm. Particle widths noted in



*From: J.G. Snyder, R.L. Virta, and J.M. Segret: "Evaluation of the Phase Contrast Microscopy Method for the Detection of Fibrous and Other Elongation Mineral Particulates by Comparison with a STEM Technique," *Am. Ind. Hyg. Assoc. J. 48(5)*:471-477 (1987) Table IV. Average of 17 air samples.

From: Average of 5 air samples analyzed by SEM (represents 88 particles out of 183 total particles).

Figure 3—Average airborne particle width comparison by electron microscopy (all particles 3:1 or greater aspect ratio, 5 μm or more length).

TABLE V
Aspect Ratio Comparison

Airborne Asbestos Particles[A] (Mining and Bagging) > 0.25 μm Width, > 5 μm Length					Airborne Cleavage Fragments[B] (Approx. 4500 Total Particles) > 0.25 μm Width, > 5 μm Length				
	% of Particles Seen at:					% of Particles Seen at:			
Aspect Ratio:	3:1	10:1	15:1	> 20:1	Aspect Ratio:	3:1	10:1	15:1	> 20:1
Crocidolite	100	100	91.5	64.5	cummingtonite	100	24	10	6
Amosite	100	100	89.5	58.0	cummingtonite	100	32	7	3
Chrysotile	100	100	86.0	37.0	actinolite	100	15	4	3
Average:	100	100	89	53	grunerite/actinolite	100	8	0	0
					tremolitic talc[C]	100	7	ND[D]	0
					Average:	100	17	5	2.4

[A]Taken from G.W. Gibbs and C.Y. Hwung, *Dimensions of Airborne Asbestos Fibers*, IARC Scientific Pub. #30 Lyon, France, pp. 79-86.[23]

[B]Taken from A.G. Wylie, R.L. Virta, and E. Russek, "Characterizing and Discriminating Airborne Fibers: Implications for the NIOSH Method," *American Industrial Hygiene Association Journal*, Vol. 46, pp. 197-201.[5]

[C]Data taken from the R.J. Lee Group Dust Analysis Project prepared for the R.T. Vanderbilt Co., Inc., 1988. Reflects PCM/PLM analysis of 22 fillers; % represents 2295 total particles.

[D]ND = not determined.

asbestiform dust populations by STEM differ markedly, with an average of 35% (ranging from 9% to 81%) reported to fall below a 0.25-μm width.[22] The similarity between amphibole cleavage fragment particle width and tremolite widths noted in the study dust population, therefore, suggests a nonasbestiform habit. It also might be noted that, since all tremolite particles exceeded a 0.25-μm width, they should all be resolvable at the lower magnifications used for both PCM and PLM analysis. Further, it is unlikely that particles of this width would be lost in the transfer of particles from the filter to the glass slide in preparation for the PLM analysis.

In terms of aspect ratio, major differences between nonasbestiform amphibole cleavage fragments and asbestiform particles also exist. Table V makes such a comparison for airborne particles which meet or exceed a 3:1 aspect ratio and a greater than 5-μm length. Variances shown in this table typically are found in the literature.[6,7,23] Figure 4 graphically depicts these data and further clarifies the difference. In terms of the study dust population, particle aspect ratio distribution is included in Table V under the cleavage fragment column where it best fits. Interestingly, total particulate aspect ratios noted in this study (based on 2295 particles) would represent the low end of the cleavage fragment line in Figure 4. Unfortunately, an airborne dust size characterization for asbestiform tremolite could not be found for inclusion in this comparison. Although asbestiform tremolite is rare and is not exploited for commercial use, localized occurrences do exist in the United States (*i.e.*, California, Montana). At least one industrial hygiene study exists of a mining operation containing asbestiform tremolite, but detailed airborne size characterization is not available.[29] An aspect ratio distribution, however, was obtained on bulk asbestiform tremolite from this mine.[30] For particles longer than 5 μm, 88% fell above 10:1, 70% above 15:1, and 52% above 20:1. These ratios correlate most closely to the average airborne asbestos ratios reflected in Table V and Figure 4 of 100%, 89%, and 53%, respectively.

In summary, when the study dust population is contrasted with the mineralogical definition—as well as the dimensional characteristics of asbestiform and nonasbestiform particles reflected in the literature—the nonasbestiform nature of New York state tremolitic talc is quite apparent. The authors believe this reaffirms the nonspecificity of the NIOSH PCM method and the regulatory definitions it underpins when applied to mineral dust environments containing common nonasbestiform cleavage fragments.

Corrective Measures

Given the differences between asbestiform and nonasbestiform particulates, the least dramatic change necessary to improve specificity would involve an upward adjustment in the aspect ratio. As seen in Figure 4, airborne asbestiform particles exceed a 10:1 aspect ratio with very few less than 15:1. Cleavage fragments, in contrast, rarely exceed a 10:1 aspect ratio with fewer still exceeding 15:1. Any aspect ratio adjustment, however, should be applied as a screening tool only because there is some aspect ratio overlap between asbestiform and nonasbestiform particles. It, therefore, is considered essential that a mineralogically correct definition of asbestos and criteria specific to asbestos should be reflected in regulations.

Discussion

Although it is not the intent of this paper to address health issues, the subject cannot be ignored in any discussion regarding the definition of asbestos. It can be argued, for example, that regulatory definitions are designed to address human health concerns and not the realities of physical science. This argument suffers, however, when it is under-

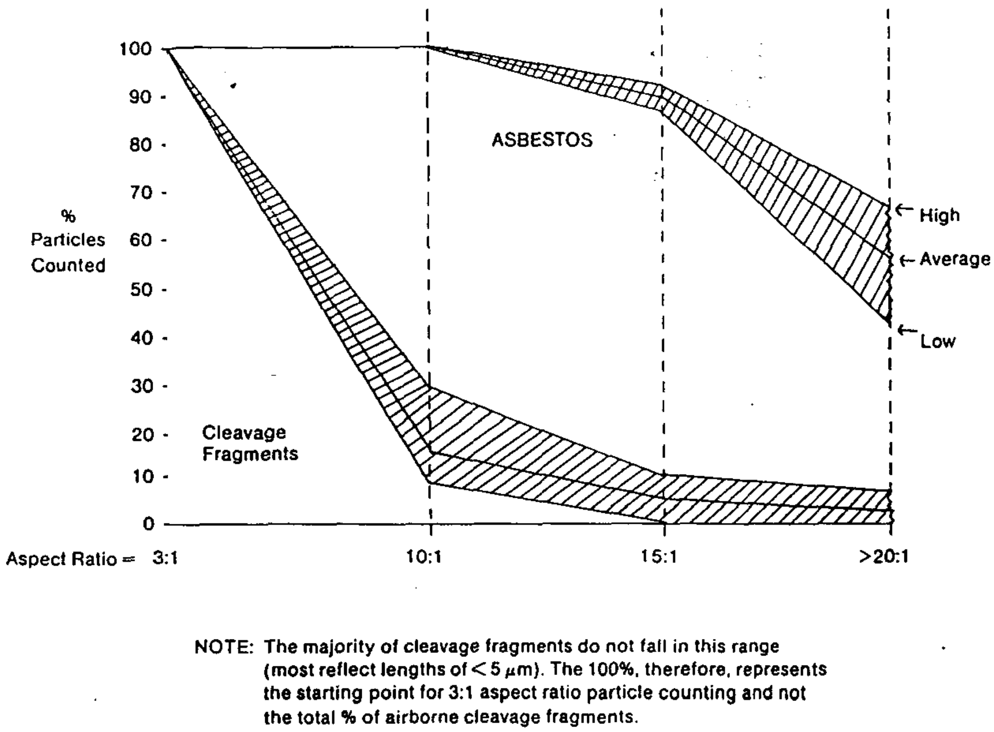


Figure 4—Airborne asbestos versus cleavage fragment aspect ratio comparison (particules with an aspect ratio of 3:1 or greater, > 5 μm length, > 0.25 μm width). From Table V.

stood that health effects attributable to asbestos are not reasonably demonstrated for nonasbestiform exposures.[31-38] Moreover, it can be argued that any environmental exposure ought to be studied and regulated for what it is. To do otherwise presents needless bias.

It also has been argued that any change in the regulatory definition of asbestos would confuse the extensive data base developed for commercially used asbestos. Nonasbestiform amphiboles, however, cannot and are not used for applications typically reserved for asbestos (*e.g.*, insulation, structural binding, fire proofing, brake linings, *etc.*). Accordingly, this asbestos data base would not be affected significantly if a mineralogically correct definition of asbestos were adopted. The definitional ambiguity discussed here relates to dust populations which do contain nonasbestiform mineral cleavage fragments. Such environments commonly involve hard rock and aggregate mining operations and industries who use their mineral products (*e.g.*, ceramics, construction, paint, *etc.*). Whatever asbestos data exist for these environments may be misleading and, therefore, ought to be corrected.

Conclusion

Major differences in crystal growth patterns, lengths, and widths exist between asbestiform particles and common, hard rock-forming mineral cleavage fragments. Current regulatory asbestos definitions and fiber quantification methods do not address these distinctions adequately. Thus, nonasbestiform dust populations can and have been mistaken as asbestiform. Confusion is likely to persist until a regulatory definition and analytical approach specific to asbestos is adopted.

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6 May 1988; Revised 19 June 1989

RJ Lee*Group*, Inc.

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FAX 412/733-1799

February 5, 1992

Mr. John W. Kelse
Corporate Industrial Hygienist
Manager, Occupational Health & Safety
R. T. Vanderbilt Company, Inc.
30 Winfield Street
Norwalk, CT 06856-5150

RE: Project No. AOH110601

Dear John:

Enclosed is the Asbestos Analysis Report for the 24 air samples received October 7, 1991. The sample and volume information were supplied by you and accompanied the cassettes.

These results are submitted pursuant to RJ Lee Group's current terms and conditions of sale, including the company's standard warranty and limitation of liability provisions, and no responsibility or liability is assumed for the manner in which the results are used or interpreted.

If you have any questions, please do not hesitate to call us.

Sincerely yours,

W H Powers / BAS

W. H. Powers, Manager
Bulk Materials Analysis

cc: R. J. Lee
B. A. Smith

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Asbestos Analysis Report

Project No. AOH110601
February 5, 1992

On October 7, 1991, 24 air samples were received from Mr. John Kelse of the R. T. Vanderbilt Company, Inc. It was requested that these air samples be analyzed for asbestos content through the application of mineralogically correct criteria specific to asbestos and to compare this analysis with the nonspecific NIOSH 7400 method for fiber counting.

In following the NIOSH 7400 method, a portion of the filter (1/4 circumference wedge) was removed and mounted on a glass slide using acetone vapor and triacetin. The preparation was then covered with a No. 1-1/2 glass coverslip and allowed to sit until the filter wedge became transparent. The method requires that 100 fields be counted, or at least a minimum of 20 fields, depending upon fiber concentration. All fibers or fiberlike particles measuring 5 micrometers (μm) in length and having a length-to-width aspect ratio equal to or greater than 3:1 were counted. This count considers particles typically referred to as "federal fibers" and does not distinguish asbestos fibers from elongated nonasbestos particles. These results are presented in Table I.

During the fiber count, the particles counted were "defined" based on the guidelines set forth in the testimony presented before OSHA by Dr. R. J. Lee, March 9, 1990. Dr. Lee proposed that PCM be used as a screening technique to overcome the intrinsic limitations of the current PCM method (i.e., nonspecificity). The advantage of the proposed method is that it retains and builds on historical federal fiber data (fibers >5 μm length, ≥3:1 aspect ratio) which has been developed under the P&CAM 239 and NIOSH 7400 methods. Basically, the proposed method categorizes federal fibers by width. If the ≤1 μm diameter plus bundles >1 μm in width federal fiber count is statistically below the permissible limit, the analysis is terminated; otherwise additional analysis can be performed by scanning electron microscopy (SEM) or transmission electron microscopy (TEM) to determine the portion of the count that is asbestos. A copy of this approach with supporting data is enclosed.

Table II gives the fiber diameter breakdown for each sample. The column identities are shown on page 2 of Table II. Columns B and E were identified as possibly asbestos based on the morphological characteristics of asbestos. The fibers in column C were considered "fibrous" (long and thin), but not asbestiform, and those in column D were clearly cleavage fragments. Table III presents a comparison of the PCM counts as determined by the NIOSH 7400 method and the proposed method. The NIOSH 7400 method column is the calculation of all the fibers counted during the PCM analysis. The proposed method column is the calculation using only those fibers ≤1 μm in diameter and fiber bundles >1 μm in diameter (columns B, C, and E of Table II).

In following this protocol, SEM analysis should have been the next method of analysis, due to the concentration of fibers in columns B, C and E of Table II. SEM, though, has not been a good analytical tool in differentiating between fibrous talc, anthophyllite, and talc-anthophyllite intergrowth because of the confusion that stems from similarity of their elemental chemistries (i.e., similar silicon to magnesium ratio). Therefore, in an attempt to identify the various species on the filters, we undertook the polarizing light microscopy (PLM) analysis using the following approach.

Each slide which had been prepared for PCM was scanned by PLM at approximately 200X magnification, during which time 100 fibers were counted and characterization attempted. However, severe limitations were placed on the analysis by using a medium much lower than one would use in identifying the particles by normal PLM. The PCM preparation has a refractive index of 1.46; and to the best of his ability, our analyst categorized the fibers he counted as talc, anthophyllite, tremolite, and miscellaneous. The miscellaneous particles included all 5 µm, 3:1 particles that did not fit into any of the previous categories, and the majority of these were cellulose, glass, and quartz.

Unfortunately, we did not feel confident with the results of this analysis, and those results are not included in this report. However, the analysis did give us information on the morphology of the fibers.

It was felt that by starting "fresh" with a sample that could be analyzed by PLM using the proper refractive index liquid, an accurate identification of the mineral species present could be made. The final step performed in this analysis was correlating the data accumulated from the fiber count by PCM and that obtained by the PLM morphological interpretation. Based on the PLM observation, we identified the fibers in columns B and E of Table II as talc fibers and talc fiber bundles. The "federal fibers" in column C were elongated (between 0.5 and 1.0 µm in width) but not asbestiform and were identified as anthophyllite. The fibers in column D were cleavage fragments and included a portion of the anthophyllite and all of the tremolite.

Results

Based upon this analysis, <u>none</u> of the "federal fibers" observed should be considered asbestos. Although the particle size distribution and mineral mix varies somewhat from that observed in previously examined R. T. Vanderbilt tremolitic talc, the cleavage fragment and talc fiber observations are consistent with prior observations relative to the absence of chrysotile and amphibole asbestos. Differences from prior analysis may, in part, be attributable to a mixed dust environment (i.e., not a pure talc sample) and to some methodological differences in sample handling dictated by sample loading.

Table I

Total Fiber Concentrations
PCM Air Analysis

Project AOH110601

Sample Number	Client Sample Number	Analyzed Area (sq. mm)	Volume (Liters)	Fibers	Fields	Concentration (fibers/sq. mm)	Concentration‡ (fibers/cc)	90% Confidence Limit‡ Lower	Upper	Limit of Quantification‡
0402365BHPC	1491-F	0.6123	24.48	100	78	163.3186	2.5685	1.6237	3.5133	0.1102
0402366BHPC	1478-F	0.5495	21.42	100.5	70	182.8935	3.2873	2.0787	4.4959	0.1259
0402367BHPC	1485-F	0.6123	32.13	100.5	78	164.1352	1.9668	1.2437	2.6898	0.0840
0402368BHPC	1479-F	0.5495	15.3	100	70	181.9836	4.5793	2.8949	6.2638	0.1763
0402369BHPC	1383-F	0.4239	38.25	100.5	54	237.0842	2.3863	1.5090	3.2637	0.0705
0402370BHPC	1393-F	0.4318	39.78	103	55	238.5640	2.3089	1.4621	3.1557	0.0678
0402371BHPC	1475-F	0.785	Blank	1	100	1.2739*	§	§	§	§
0402372BHPC	1487-F	0.4632	19.89	102.5	59	221.3106	4.2838	2.7119	5.8557	0.1356
0402373BHPC	1481-F	0.4632	29.51	102	59	220.2310	2.8732	1.8184	3.9280	0.0914
0402374BHPC	1490-F	0.785	26.82	21	100	26.7516	0.3840	0.1970	0.5710	0.1006
0402375BHPC	1462-F	0.2905	14.9	100.5	37	346.0148	8.9407	5.6536	12.2277	0.1810
0402376BHPC	1456-F	0.4318	35.76	100	55	231.6155	2.4936	1.5764	3.4109	0.0754
0402377BHPC	1457-F	0.314	14.9	101	40	321.6561	8.3112	5.2571	11.3654	0.1810
0402378BHPC	1398-F	0.785	0	0	100	<7.0064*	§	§	§	§
0402379BHPC	1452-F	0.4475	165.39	102	57	227.9584	0.5306	0.3358	0.7255	0.0163
0402380BHPC	1348-F	0.4239	27.55	100	54	235.9047	3.2967	2.0840	4.5093	0.0979
0402381BHPC	1381-F	0.4946	27.55	100.5	63	203.2150	2.8398	1.7958	3.8839	0.0979
0402382BHPC	1378-F	0.5495	17.4	101.5	70	184.7134	4.0870	2.5859	5.5882	0.1550

‡ Analytical results based upon the volumes provided by R.T. Vanderbilt Company.
§ Sample is a Blank, or no volume was supplied. Calculation could not be done.

* Results Below Analytical Sensitivity
Prepared, Counted, and Calculated in accordance with NIOSH 7400

Authorized Signature
Date Tuesday, February 4, 1992

RJ Lee Group, Inc.
Headquarters
350 Hochberg Road
Monroeville, PA 15146
Phone (412)325-1776
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Table I

Total Fiber Concentrations
PCM Air Analysis
Project AOH110601

Sample Number	Client Sample Number	Analyzed Area (sq. mm)	Volume (Liters)	Fibers	Fields	Concentration (fibers/sq. mm)	Concentration‡ (fibers/cc)	90% Confidence Limit‡ Lower	Upper	Limit of Quantification‡
0402383BHPC	1377-F	0.5888	14.5	101.5	75	172.3992	4.5775	2.8962	6.2588	0.1860
0402384BHPC	1375-F	0.4632	18.85	101	59	218.0719	4.4540	2.8173	6.0907	0.1431
0402385BHPC	1344-F	0.785	Blank	0	100	<7.0064*	§	§	§	§
0402386BHPC	1386-F	0.5338	24.65	102.5	68	192.0195	2.9991	1.8986	4.0996	0.1094
0402387BHPC	1384-F	0.6673	13.05	102	85	152.8662	4.5098	2.8542	6.1655	0.2067
0402388BHPC	1387-F	0.4161	23.2	101	53	242.7593	4.0285	2.5482	5.5089	0.1163
0402389BHPC	1389-F	0.369	23.2	100	47	271.0394	4.4979	2.8434	6.1523	0.1163
0402390BHPC	1394-F	0.4004	20.3	101.5	51	253.5282	4.8083	3.0423	6.5743	0.1329
0402391BHPC	1396-F	0.2277	8.7	103	29	452.4489	20.0222	12.6788	27.3655	0.3101
0402392BHPC	1372-F	0.785	Blank	0	100	<7.0064*	§	§	§	§

‡ Analytical results based upon the volumes provided by R.T. Vanderbilt Company.

§ Sample is a Blank, or no volume was supplied. Calculation could not be done.

* Results Below Analytical Sensitivity

Prepared, Counted, and Calculated in accordance with NIOSH 7400

Authorized Signature
Date Tuesday, February 4, 1992

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Table II

Project No. AOH110601
Fiber Diameter Breakdown - Based on PCM Analysis

Sample No.	Number of Fibers* A	B	C	D	E
1348-F	100.0	16.0	9.0	60.0	15.0
1375-F	101.0	8.5	8.0	78.5	6.0
1377-F	101.5	6.5	16.0	73.0	6.0
1378-F	101.5	9.5	19.5	69.0	3.5
1381-F	100.5	9.5	14.0	69.5	7.5
1383-F	100.5	17.5	17.5	59.5	6.0
1384-F	102.0	16.0	5.0	75.0	6.0
1386-F	102.5	8.0	4.5	84.0	6.0
1387-F	101.0	15.0	10.0	71.0	5.0
1389-F	100.0	11.0	8.5	76.5	4.0
1393-F	103.0	19.5	9.5	69.0	5.0
1394-F	101.5	7.5	9.5	78.0	6.5
1396-F	103.0	18.5	7.0	68.5	9.0
1452-F	102.0	17.5	19.0	58.0	7.5
1456-F	100.0	7.5	16.5	65.0	11.0
1457-F	101.0	16.0	12.0	67.0	6.0
1462-F	100.5	18.0	8.5	67.0	7.0
1478-F	100.5	8.5	19.5	67.5	5.0
1479-F	100.0	9.5	22.5	59.0	9.0
1481-F	102.0	14.0	5.5	73.0	9.5
1485-F	100.5	12.0	20.0	59.0	9.5

Table II (Cont'd)

Project No. AOH110601
Fiber Diameter Breakdown - Based on PCM Analysis

Sample No.	Number of Fibers* A	B	C	D	E
1487-F	102.5	20.0	10.5	62.5	9.5
1490-F	21.0	6.0	1.5	10.5	3.0
1491-F	100.0	15.0	12.5	59.5	13.0

*Column Identities

A-Particles >5μm long; ≥3:1 aspect ratio; all diameters

B-Particles >5μm long; ≥3:1 aspect ratio; ≤0.5μm diameter

C-Particles >5μm long; ≥3:1 aspect ratio; >0.5/≤1.0μm diameter

D-Particles >5μm long; ≥3:1 aspect ratio; >1.0μm diameter

E-Particles >5μm long; 3:1 aspect ratio; >1.0μm diameter-bundles

Table III

Project No. AOH110601
Fiber Count Comparison Between NIOSH 7400 and Proposed Method
Based on PCM Analysis

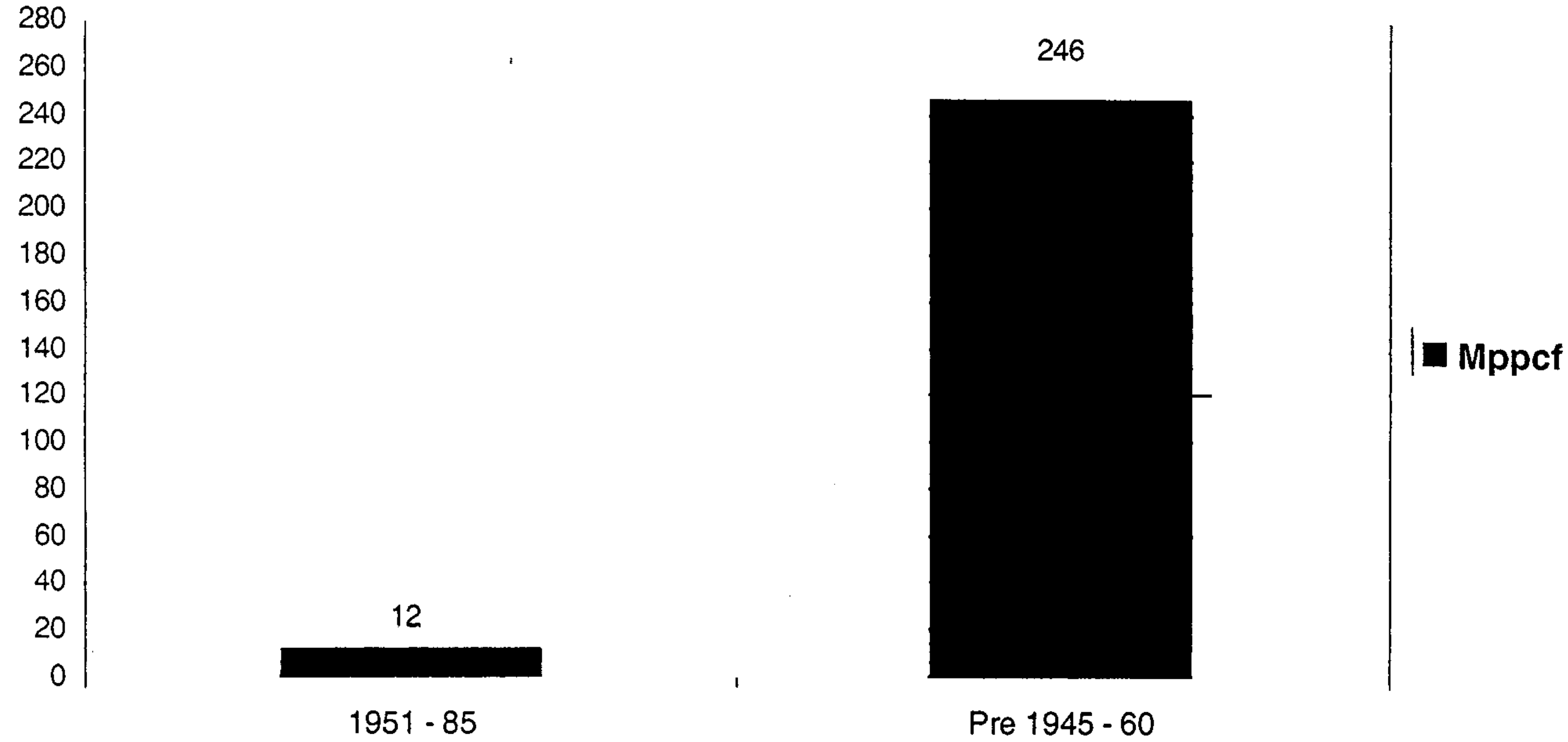
Sample No.	NIOSH 7400 Fibers per cc	Proposed Method Fibers per cc
1348-F	3.2967	1.3187
1375-F	4.4540	0.9922
1377-F	4.5775	1.2853
1378-F	4.0870	1.3087
1381-F	2.8398	0.8760
1383-F	2.3863	0.9735
1384-F	4.5098	1.1938
1386-F	2.9991	0.5413
1387-F	4.0285	1.1966
1389-F	4.4979	1.0570
1393-F	2.3089	0.7621
1394-F	4.8083	1.1132
1396-F	20.0222	6.7064
1452-F	0.5306	0.2289
1456-F	2.4936	0.8728
1457-F	8.3112	2.7978
1462-F	8.8407	2.9802
1478-F	3.2873	1.0794
1479-F	4.5793	1.8775
1481-F	2.8732	0.8169
1485-F	1.9668	0.8121

Table III (Cont'd)

Project No. AOH110601
Fiber Count Comparison Between NIOSH 7400 and Proposed Method
Based on PCM Analysis

Sample No.	NIOSH 7400 Fibers per cc	Proposed Method Fibers per cc
1487-F	4.2838	1.6717
1490-F	0.3840	0.1920
1491-F	2.5685	1.0402

Million Particles Per Cubic Foot
Talc Operation Averages
Vanderbilt Talc vs. Earlier Area Talc Operations



Vanderbilt Talc
Mppcf Range: 0.2 - 140

Other Area Talc Operations
Mppcf Range: 0.2 - 2000

Sources: MSHA, NY Health Dept., Epi Studies

Table 2.—*Deaths and Expected Mortality From Cancer of the Lung and Pleura and Gastrointestinal Tract and Peritoneum Related to Age in Talc Workers*

Age Group	Total Deaths	Deaths From Malignant Causes: Lung and Pleura	Deaths From Malignant Causes: G I* and Peritoneum	Proportional Mortality: Lung and Pleura: Observed	Proportional Mortality: Lung and Pleura: Theoretical	Proportional Mortality: G I and Peritoneum: Observed	Proportional Mortality: G I and Peritoneum: Theoretical
<40	2	0	0	0		0	
40-59	38	2	2	5.3	5.5†	5.3	5.5†
60-79	47	8	4	17	3.9‡	8.5	6.9†
80+	4	0	1	0		25	4.3
Total	91	10	7	11	3.2‡	7.7	5.3†

* Gastrointestinal tract.
† Difference between observed and theoretical values is not statistically significant.
‡ Difference between observed and theoretical values is statistically significant ($P = <0.01$).

to bronchopneumonia. The lapsed time from first talc exposure to death from pneumoconiosis or complications, or both, averaged 25.9 years, with a range from 15 to 39 years. In this group there were 11 talc millers, seven talc miners, and nine who had been both millers and miners. All 28 had their initial exposure before 1945 when more effective engineering controls, including wet drilling in the talc mines, were introduced.

All Other Causes.—Of the 11 deaths in this category, four were due to cerebrovascular accidents, two to lobar pneumonia, and the remaining five, to one of the following: bleeding duodenal ulcer, strangulated inguinal hernia, perforated diverticulum with peritonitis, acute glomerulonephritis, and mesenteric arterial occlusion.

Environmental Exposure.—Of the 91 death cases, data on environmental exposure were available in 80. The mean duration of exposure for this group was 24.7 years with a range of 15 to 47 years. The dust exposure consisted predominantly of talc admixed with other silicates such as serpentine and tremolite, carbonates, and a small amount of free silica. The comparative dust counts in the talc mines and mills prior to 1945 and between 1946 and 1965 are shown in Table 3.

Comment

Malignancies.—The data on carcinoma of the lung and pleura shows an overall mortality from carcinoma of the lung and pleura to be approximately four times that expected. However, the significant increase appears to occur in the age group of 60 to 79 years rather than in the 40 to 59 year age group. This is at variance to what we have observed among workers exposed to asbestos dust where the observed values in the 40 to 59 as well as 60 to 79 year age groups were significantly different from the expected values (Table 4). The asbestos group consisted of 152 asbestos insulators who had 15 or more years of exposure in 1945 or achieved 15 years between the period of 1945 to 1965. The overall mortality was 46 or 30.3%. The reason for the earlier occurrence of an increased incidence of lung or pleural cancers in the asbestos workers com-

Table 3.—*Comparative Dust Counts in Talc Mines and Mills, Northern New York**

Work Type	Before 1945: Low	Before 1945: Medium	Before 1945: High	Before 1945: Average	1946-1965: Low	1946-1965: Medium	1946-1965: High	1946-1965: Average
Mines								
Drilling	83	413	2800	818	0	3	10	5
Mucking	2	30	475	120	3	5	9	5
Scraping	No Dust Counts Made				5	8	13	9
Mills	(up to 1948)				(1949-1965)			
Crushing	22	69	690	180	3	13	360	42
Screening	43	61	136	69	8	37	68	37
Milling	32	75	271	92	5	20	70	25
Garners and separators	58	70	728	278	5	27	60	27
Pulverizers	No Dust Counts Made				25	28	31	28
Bagging	26	129	520	151	5	23	69	27
R R car and truck load	No Dust Counts Made				18	63	169	73
Blow Room	115	1196	2480	1227	Discontinued			
Open chutes	21	83	440	125	Discontinued			

* Concentration in millions of particles per cubic foot of air.

Start of CTC-1948