# CPSC Staff Report on Asbestos Fibers in Children's Crayons

MFR/PRVLBR NOTIFIED 9/7/02
No Comments made
Comments attached
Excisions/Revisions
Firm has not requested further notice

## August 2000

## U.S. Consumer Product Safety Commission
## Washington, D.C. 20207

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## CPSC STAFF REPORT ON ASBESTOS FIBERS IN CHILDREN'S CRAYONS

**August 2000**


**Summary**

On May 23, 2000, the *Seattle Post-Intelligencer* reported finding asbestos in three major brands of crayons, Crayola, made by Binney and Smith; Prang, made by Dixon Ticonderoga, and Rose Art. The reported asbestos was believed to be found in the talc used by the crayon manufacturers as a binding agent. The specific asbestos minerals reported by the laboratories contracted by the Seattle Post-Intelligencer, tremolite, chrysotile, and anthophyllite, were identified in some of the crayons in concentrations ranging from 0.03% to 2.86% by transmission electron microscopy (TEM). Asbestos was not identified in any of the tests conducted by the three crayon manufacturers.

The U.S. Consumer Product Safety Commission (CPSC) staff examined crayons from several different boxes from the three companies to determine whether asbestos was present, evaluated the potential for exposure to children, and evaluated the potential risk.

Trace amounts of anthophyllite asbestos and larger amounts of other fibers (transitional fibers) were found in Crayola and Prang crayons by polarized light microscopy (PLM). The concentrations of asbestos ranged from below the limit of detection to 0.03%. The concentrations of transitional fibers ranged from below the limit of detection to 1.25%. The Rose Art crayons did not contain any asbestos or transitional fibers.

Based on the results of the testing and evaluation, the staff concludes that the risk a child would be exposed to the fibers through inhalation or ingestion of crayons containing asbestos and transitional fibers is extremely low. No fibers were found in the air during a simulation of a child vigorously coloring with a crayon for half an hour The risk of exposure by eating crayons is also extremely low because the fibers are imbedded in the crayon wax and will pass through the child's body.

Although CPSC staff determined that the risk is extremely low, the staff believes that as a precaution, crayons should not contain these fibers. CPSC staff asked the industry to reformulate crayons using substitute ingredients. Binney and Smith and Dixon Ticonderoga agreed to reformulate within a year to eliminate talc. Rose Art indicated that they stopped using talc in 90% of their crayons about 15 months ago and will reformulate the remaining small percentage of crayons made with talc.

CPSC will continue to monitor children's crayons to ensure they do not present a hazard.

## I. Introduction

Asbestos is not a precisely defined chemical compound. It is a collective term applied to naturally occurring silicate minerals that are used commercially because they crystallize into long, thin fibers that are easily separated and flexible enough to be woven, are resistant to heat and chemicals, and are good insulators. Historically, six silicate minerals have been commonly referred to as asbestos. They are chrysotile, crocidolite, cummingtonite-grunerite asbestos, tremolite asbestos, anthophyllite asbestos, and actinolite asbestos. Chrysotile belongs to the family of minerals known as serpentine minerals. The other five belong to the family known as amphiboles. In addition to lung cancer and mesothelioma, excess rates of lung fibrosis (asbestosis) and pleural changes have been associated with the inhalation of asbestos. These health effects have been well documented in epidemiological and animal studies and have most recently been reviewed by ATSDR (1999). Studies in humans and animals indicate that ingestion of asbestos causes little or no risk of noncarcinogenic injury. From studies in animals, there is limited evidence that oral exposure may induce precursor lesions of colon cancer.

These minerals are also described as asbestiform, a term that describes a mineral habit (Kelse and Thompson, 1989; Steel and Wylie, 1981). The habit is the shape or form a crystal or group of crystals takes on during crystallization. In the asbestiform habit, mineral crystals grow in one direction in a single dimension, forming long thread-like fibers with high aspect ratios (length to width). Under pressure, they bend instead of shattering. Fibrils of smaller diameter are produced when pulled apart. This bundling effect is referred to as polyfilamentous. The development of the asbestiform properties is a gradual process and depends on the appropriate conditions of crystallization. Thus, there are variable qualities of asbestiform fibers. For example, high quality asbestiform fibers are flexible and strong, and are termed asbestos. Poor quality asbestiform fibers of amphiboles are called byssolite, or brittle asbestos. While all asbestos is asbestiform, not all asbestiform materials are asbestos. In the non-asbestiform habit, crystal growth is random, forming multidimensional prismatic patterns. When pressure is applied, the crystals fracture easily along the cleavage planes of the materials, resulting in fragments of irregular shape. Cleavage fragments generally have lower aspect ratios. Asbestiform fibers cannot be created from nonasbestiform materials by crushing, milling, grinding, or weathering.

These mineral types are microscopically distinguishable when populations of particles are examined. The ability to differentiate minerals is more difficult when single, isolated particles are examined. An important characteristic of asbestos is their high aspect ratios (length to width). Asbestos fibers occur in many lengths and widths resulting in a wide range of aspect ratios for a given sample. As noted by Beard (1992), aspect ratios for asbestos are generally in the range of 20:1 to 100:1 or higher. However, fibers with aspect ratios less than 20:1 may be asbestos if they are part of a population of fibers having mean aspect ratios greater than 20:1. These aspect ratios apply to single fibers; bundles of asbestos fibers may be found with smaller aspect ratios. Thus, it is clear that one should look at the distribution of aspect ratios or widths to differentiate populations of particles.

Talc is used by crayon manufacturers as a binding agent. Talc is a magnesium silicate mineral that may be found associated with many types of minerals. The talc used by Crayola and Prang, and previously by Rose Art, contains mineral particles that do not fit a precise definition.

These mineral particles have been termed "intermediate fibers" by the Occupational Safety and Health Administration (OSHA), and transitional fibers, talcboles, mixed assemblage fibers, and fibrous biopyriboles by others (57 FR 24310; Michael Beard, personal communication; Bruce Case, personal communication). These fibers are complex mixed fibers in that they have morphologic features that are similar to anthophyllite and talc. These fibers are believed to represent the geological transformation of anthophyllite into talc. As noted by Dan Crane in the OSHA Preambles to the asbestos rule (57 FR 24310), "...they are the fibers with the closest morphological similarity to asbestos. They do have splintering and bundle of sticks and frayed ends as characteristics. These are characteristics that we often ascribe to truly asbestiform minerals. They do look like asbestos and if morphology is the major role in toxicity or carcinogenicity, these should be considered more important tha [n] the non-fibrous cleavage fragments of tremolite and anthophyllite."

This report: 1) describes the methodology used by CPSC to evaluate the crayons for the presence of asbestos fibers; 2) reports the results of this work; 3) discusses some reasons for the differences between the CPSC results and others; 3) reports the results of the CPSC testing to assess the release of fibers into the air during coloring with crayons; and 4) describes the CPSC staff's assessment of potential risk.

## II. Methodology – CPSC Assessment

### A. Crayon Analysis

The accurate identification of asbestos in any given sample is complicated and requires a sophisticated level of technical expertise.[1] To identify asbestos, samples are analyzed by light and electron microscopy. Asbestos can be identified by microscopy on the basis of indices of refraction, the sign of elongation, the value of the extinction angle, the presence of cleavage, and the optic orientation. Asbestos is generally recognized by such traits as high aspect ratios (generally ranging from 20:1 to 100:1 or higher for fibers longer than 5 µm), thin fibrils that are usually less than 0.5 µm in width, parallel fibers occurring in bundles, and fibers showing curvature and splayed ends. Not all traits need to be present in any given sample to make the identification for asbestos. It is not unusual to observe asbestiform fibers having aspect ratios of 10:1 or less and it is possible for non-asbestiform fibers (cleavage fragments) to have high aspect ratios[2], although most cleavage fragments have diameters larger than 1 µm.

Polarized light microscopy (PLM) is typically used to determine the mineral type, however it cannot identify fibers finer than about 1 µm in diameter even though they are visible. Transmission electron microscopy (TEM) provides greater resolution, permitting closer examination of morphology, chemistry, and structure. TEM can be used to identify fibers too small to be resolved by light microscopy and should be used in conjunction with this method. Within any given mineral population, there may be some fibers that cannot be classified.

Two laboratories examined crayon samples for CPSC, DataChem Laboratories in Cincinnati, Ohio and the OSHA Salt Lake City Technical Center (Appendix A).

[1] Detailed descriptions of methodologies can be found in mineralogy and microscopy books. A brief summary is presented here.
[2] The use of aspect ratios to identify asbestos will be discussed later in the report.

### B. Air Sampling for Fibers

To determine the potential for airborne exposure to asbestiform fibers by individuals using crayons, a quantitative measure of the release of fibers during the use of crayons was investigated through simulated exposure activities in a glove bag. MCE air filters collected particles from the glove bag air during 30 minutes of using Crayola and Prang crayons on sheets of standard copying paper. The filter samples were analyzed for fibers using phase contrast microscopy by NIOSH Method 7400 (Appendix B).

## III. Results

### A. Crayon analysis

Neither laboratory detected any fibrous material in the samples of Rose Art crayons. No fibers were found in a white Crayola crayon or in a Crayola washable crayon. Both labs detected fibers in 16 other crayon samples from Crayola and Prang by PLM and TEM analyses. Trace amounts of asbestos and larger amounts of other fibers (transitional fibers) were found in samples of Crayola and Prang crayons. The concentrations of asbestos ranged from below the limit of detection to 0.03%. The concentrations of transitional fibers ranged from below the limit of detection to 1.25%.

### B. Air sampling

No fibers other than cellulose were identified on the air filters.

## IV. Discussion of Difficulties in Analysis and Conflicting Lab Results

As discussed above, asbestos refers to six specific asbestiform minerals. Some of these minerals also exist in non-asbestiform habits When crushed, these minerals may form cleavage fragments that are fibers, but that are not asbestiform. Cleavage fragments generally have mean aspect ratios less than 10:1, while asbestiform minerals usually have mean aspect ratios greater than 20:1. Talcs can be complex mixtures of minerals. Talc may be present in a fiber form, and amphibole minerals in both the asbestiform and non-asbestiform varieties (cleavage fragments) may be present. Talc may also contain transitional (intermediate) fibers that have features that are similar to both anthophyllite and talc. Proper identification of each of these fiber types requires the use of a combination of PLM and TEM with careful analysis of the diffraction patterns and chemistry of each particle. A detailed discussion of the analysis of complex talc samples can be found in Appendix C.

Although cleavage fragments are not asbestos, the most common method used by NVLAP (National Voluntary Laboratory Accreditation Program) laboratories requires the inclusion of cleavage fragments in the asbestos fiber count. The identification of tremolite asbestos in crayons reported by the *Seattle Post-Intelligencer* is likely related to this requirement. Further, the reporting by other laboratories of greater amounts of anthophyllite asbestos than the CPSC analysis is likely due to misidentification of transitional fibers as anthophyllite fibers. The industry reported that no asbestos fibers were detected in their analyses of crayons. They did not quantify the other fibrous constituents, *i.e.*.talc fibers, transitional fibers, and cleavage fragments. Thus, although several laboratories have analyzed similar crayons, the results differ in the reporting of the presence of asbestos and the amounts of other fibers detected due to differences in definitions or methods or to incomplete analyses.

## V. Assessment of Risk

### A. Summary of Health Effects

Although the causal association between inhalational asbestos exposure and human health effects is well known, the determinants for toxicity are not specifically defined. A fiber is generally defined as having a length to width ratio (aspect ratio) of at least 3:1 and a length of 5 µm or more as determined by phase-contrast optical microscopy. These fiber criteria are not specific to asbestos, and other physical and chemical characteristics of asbestos may be found in other materials. Asbestos is a term properly used to describe a fiber of any of six specific minerals.

In humans, the health effects of inhalation exposure to talc, asbestos, silica, and many other materials include various forms of non-malignant respiratory disease and cancer (summarized by ACGIH, 1991; IARC, 1987; and HSDB, 2000).

Talc is a magnesium silicate mineral. It may be found associated with many types of minerals including calcite, dolomite, tremolite and anthophyllite (fibrous and non-fibrous), chrysotile, antigorite, quartz, kaolin, chlorite, and others Talc is commonly found as thin, tabular crystals, up to 1 cm wide, but is also found as fibrous masses. Some talcs contain transitional fibers, which closely resemble asbestos and talc but are not technically asbestos (IARC, 1987).

Talc exposure in humans is associated with a variety of health effects. The clinical picture has been described as nonspecific, with chest x-ray pictures of diffuse bilateral changes with varying degrees of widespread nodulation, usually with thickened pleura. Secondary infection alters x-ray picture. Lung function abnormalities may be present (ventilatory function and diffusing capacity may be impaired). Respiratory symptoms and impaired ventilatory function may be observed in the absence of radiographic abnormality (summarized in IARC, 1987).

Dyspnea on effort and cough are presenting symptoms. Cyanosis and clubbing with increased dyspnea, acid fast infection, emphysema, and right heart disease are complications of talc pneumoconiosis. Among workers exposed to talc used in cable and rubber manufacture, cases arise after many years of exposure. Cases steadily progress to terminal bouts of respiratory and/or cardiac failure. Talc bodies (similar to asbestos bodies) may be found in sputum as evidence of exposure (Hamilton and Hardy, 1974).

Epidemiological studies generally indicate increased respiratory disease among talc miners and millers. Evidence for bronchogenic cancer has been found in some worker populations, including New York state talc workers. The presence of asbestos (amphibole and serpentine) has been hypothesized to be the etiologic factor in many of these cases. Methodological deficiencies and exposure of workers to other materials make interpretation of studies difficult (both negative and positive results), especially for exposures not involving asbestiform minerals (summarized in IARC, 1987).

Results of studies *in vivo* are mixed. NTP conducted lifetime toxicology and carcinogenicity studies of talc (non-asbestiform, cosmetic grade) in rats and mice (NTP, 1993). Under the conditions of these inhalation studies, there was some evidence of carcinogenic activity of talc in male F344/N rats based on an increased incidence of benign or malignant pheochromocytomas of the adrenal gland. There was clear evidence of carcinogenic activity of talc in female F344/N rats based on increased incidences of alveolar/bronchiolar adenomas and carcinomas of the lung and benign or malignant pheochromocytomas of the adrenal gland. There was no evidence of carcinogenic activity of talc in male or female B6C3F1 mice.

The principal toxic lesions in the rats included chronic granulomatous inflammation, alveolar epithelial hyperplasia, squamous metaplasia and squamous cysts, and interstitial fibrosis of the lung. These lesions were accompanied by impaired pulmonary function characterized primarily by reduced lung volumes, reduced dynamic and/or quasistatic lung compliance, reduced gas exchange efficiency, and non-uniform intrapulmonary gas distribution. In the mice, inhalation exposure to talc produced chronic inflammation of the lung with the accumulation of alveolar macrophages.

In other studies, USP grade talc did not induce respiratory tumors, granulomas, or mesothelial proliferation during the lifetime of Syrian golden hamsters after weekly intratracheal instillation (Stenback and Rowlands, 1978). A single intrathoracic injection of USP talc had no effect in female rats, but male mice experienced increased incidence of adenocarcinomas and lymphoid tumors of the lung (Bischoff and Bryson, 1976, as cited in IARC, 1987).

A study involving intrapleural injection of tremolite or tremolitic talc found two samples that caused pleural tumors. One sample was an asbestiform tremolite consisting of 95% tremolite with long thin fibers with parallel sides. The fibers had an average diameter of 0.4 µm, and many fibers were greater than 20 µm long. The second carcinogenic sample was obtained from a tremolitic talc consisted of 90% tremolite. Some particles had parallel sides. The average diameter was 0.5 µm. Two samples were not carcinogenic. One consisted of 95% tremolite, and contained some fiber-shaped particles with parallel sides and roughly shaped acicular fragments. There were few long thin particles. The average diameter was 0.4 µm. The second sample consisted of 50% tremolite, 35% talc, 10% antigorite, and 5% chlorite. There were platy and amorphous particles as well as long thick and thin fibers. The average diameter was 1.6 µm (Smith *et al.*, 1979).

While *in vitro* studies indicate that talcs are cytotoxic (related to fibrogenicity), one study indicated they do not have proliferative potential (related to carcinogenicity) (Wylie *et al.*, 1997).

A series of experiments involved pleural implantation of 72 samples of 12 mineral types in female rats. The samples were described as durable minerals with particles of respirable size and wide chemical and structural variation. Of the seven talc samples, three did not cause tumors, while four others caused one tumor each among their groups of about 29 animals. The authors concluded that the incidence of induced malignant mesenchymal neoplasms correlated well with the dimensional distribution of the particles. The probability of pleural sarcoma correlated well with the fibers that measured 0.25 µm or less in diameter and more than 8 µm in length. They suggested that the carcinogenicity of fibers depends on dimension and durability (resistance to mechanical breakdown and dissolution *in vivo*) rather than on physicochemical properties (Stanton *et al.*, 1981).

Asbestos fibers are clearly implicated in causing non-malignant respiratory disease and lung cancer and mesothelioma in humans. CPSC staff's review of available health effects evidence indicates that other mineral fibers, such as transitional fibers, that are long, thin, and durable may have the potential to cause similar health effects as asbestos. This view is supported by scientists from other federal agencies and medical experts.[3]

Despite some methodological problems and inconsistent and inconclusive study results, the human and experimental studies suggest that certain fiber characteristics play a role in the biological potential of a fiber to cause adverse effects. Fiber dimension appears to be an important factor, with long thin fibers thought to be most predictive of tumor probability, with probability increasing with the number of long, thin durable fibers. However, current data are not precise enough to determine at what point there is no significant carcinogenic potential. The chemistry of a fiber has also been implicated as a key factor in its pathogenicity. Available evidence does not provide a clear picture of the interaction between the physical and chemical characteristics of a fiber with respect to biological activity.

While animal studies indicate that qualitative differences in carcinogenic potential exists between clearly differentiated fiber populations ("asbestos" and "cleavage fragments"), the scientific community, as reported in the OSHA Preambles (57 FR 24310), agree that longer, thinner fibers are more potent. Durability is also thought to be an important characteristic for fiber potency.

Given that certain characteristics of asbestos minerals are responsible for their biological effects, it is reasonable to consider that the transitional fibers found in the crayons that share these characteristics may also have the potential to cause biological effects. The National Toxicology Program is currently addressing this issue by considering listing non-asbestiform talc and talc containing asbestiform fibers in the 10th Report on Carcinogens.

**B. Risk Assessment**

Risk assessment is a process of establishing information about levels of risk for an individual, group, society, or the environment, where risk is the potential for adverse consequences to human life or health. The process of risk assessment includes exposure assessment (estimating the exposure to the substance), and toxicity assessment (determining whether exposure to a substance can increase the incidence of a particular adverse health effect, determining the likelihood of occurrence in humans, and determining the relationship between the level of exposure and adverse effects), and results in a risk characterization (reviewing the toxicity and exposure information and quantifying the risk). Thus, the risk assessment considers both the potential adverse health effects associated with the substance and the expected exposure to the substance.

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[3] U.S. Environmental Protection Agency, Occupational Safety and Health Administration, National Institute of Occupational Safety and Health, Dr. Bruce Case.

### 1. Inhalation

No fibers were detected during the test for release of fibers from use of crayons. Since the test involved aggressive use of the crayons—drawing with considerable force, shading, rubbing, and breaking of crayons—no release of fibers would be expected during normal use of crayons by children. Since no exposure to fibers would be expected from use of crayons, the crayons present a low risk of health effects from inhalation of fibers.

### 2. Ingestion

Fibers in the crayons are embedded in the wax. The melting point of crayon wax is considerably higher than body temperature. Therefore, release of fibers from the wax would not be expected to occur from wax melting within the body. Further, crayons are not soluble in acid and are not expected to dissolve in the gastrointestinal tract. Thus, release of fibers from a crayon into the body would not be expected to occur after swallowing all or part of a crayon from the melting of the wax or the dissolving of the wax.

## VI. Conclusions

After receiving reports that children's crayons contain asbestos, the CPSC began an investigation to determine whether asbestos is present in crayons. Based on the results of laboratory analysis, the staff evaluated the potential for exposure to children, and evaluated the potential risk.

Trace amounts of asbestos and larger amounts of other fibers (transitional fibers) were found in Crayola and Prang crayons by PLM. The concentrations of asbestos ranged from below the limit of detection to 0.03%. The concentrations of transitional fibers ranged from below the limit of detection to 1.25%. The Rose Art crayons did not contain any asbestos or transitional fibers. The presence of these fibers was confirmed by TEM by DataChem Laboratories.

Based on the results of the testing and evaluation, the staff concludes that the risk a child would be exposed to the fibers through inhalation or ingestion of crayons containing asbestos and transitional fibers is extremely low. No fibers were found in the air during a simulation of a child vigorously coloring with a crayon for half an hour. The risk of exposure by eating crayons is also extremely low because the fibers are imbedded in the crayon wax and will pass through the child's body.

Although CPSC staff determined that the risk is extremely low, the staff believes that as a precaution, crayons should not contain these fibers. CPSC staff asked the industry to reformulate crayons using substitute ingredients. Binney and Smith and Dixon Ticonderoga agreed to reformulate within a year. Rose Art indicated that they stopped using talc in 90% of their crayons about 15 months ago and will reformulate the remaining small percentage of crayons made with talc.

**VII. References**

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# Appendix A

# Crayon Analysis

**DataChem Laboratories Analytical Report**
**PLM & TEM Bulk Asbestos Analysis using Gravimetric Reduction and PCM Fiber Quantification**

**Client: US Consumer Product Safety Commission**
**Set ID: 00-A-2735**

**Mineral Species Confirmation by TEM**
We examined preparations of four crayons using TEM to confirm the identification of the fibrous minerals detected by PLM. For each sample, we examined 20 to 25 fibers, greater than 5 microns in length, with length to width aspect ratios of 5 to 1 or more. The morphological, structural (SAED) and chemical (EDXA) data collected for each fiber were used in combination to confirm its mineral species as Talc, Transitional, Anthophyllite or Other. No attempt to quantify the percentage asbestos or other fibers was made during TEM analysis.

**Other Testing**

**Release of Mineral Fibers into the Air**
The client performed glove bag testing by collecting air filter samples while a technician colored on paper with six different crayons, Crayola Orchid, Atomic Tangerine and Blue; and Prang Yellow, Light Yellow and Periwinkle. The air filters were analyzed using the PCM method, NIOSH 7400.

**DataChem Laboratories Analytical Report**
**PLM Bulk Asbestos Analysis using Gravimetric Reduction**

**Client: US Consumer Product Safety Commission**
**Set ID: 00-A-2735**

| *SAMPLE IDENTIFICATION* | | | | | |
|---|---|---|---|---|---|
| Client ID: | Crayola-<br>Orchid | Crayola-<br>Blue | Crayola-<br>Atomic Tangerine | Crayola-<br>Wild Strawberry | Crayola-<br>Pine Green |
| DCL ID: | 00-15469 | 00-15470 | 00-15471 | 00-15472 | 00-15473 |
| | | | | | |
| Homogeneity: | Homog. | Homog. | Homog. | Homog. | Homog. |
| Color: | Orchid | Blue | Tangerine | Red | Green |
| Texture: | Waxy | Waxy | Waxy | Waxy | Waxy |
| Description: | Crayon | Crayon | Crayon | Crayon | Crayon |
| | | | | | |
| Starting Weight (g): | 2.2894 | 2.4207 | 2.1754 | 2.7493 | 2.7820 |
| Residue Weight (g): | 0.4776 | 0.4349 | 0.1112 | 0.4047 | 0.5470 |
| Weight Percent: | 20.86 | 17.97 | 5.11 | 14.72 | 19.66 |
| *PERCENT DETECTED IN RESIDUE* | | | | | |
| Anthophyllite: | 0.15 | 0 | 0 | 0 | 0 |
| Chrysotile: | 0 | 0 | 0 | 0 | 0 |
| Tremolite: | 0 | 0 | 0 | 0 | 0 |
| Transitional Fibers: | 4.38 | 3.25 | 4.25 | 3.9 | 2.49 |
| Talc Fibers: | 0 | 0 | 0 | 0 | 0 |
| Non-Fibrous Material: | 95.47 | 96.75 | 95.75 | 96.1 | 97.55 |
| *PERCENT OF MATERIAL IN SAMPLE BEFORE REDUCTION* | | | | | |
| Anthophyllite: | 0.03 | 0.0 | 0.0 | 0.0 | 0.0 |
| Chrysotile: | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 |
| Tremolite: | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Transitional Fibers: | 0.91 | 0.58 | 0.22 | 0.57 | 0.49 |
| Talc Fibers: | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Non-Fibrous Material: | 19.9 | 17.4 | 4.9 | 14.1 | 19.2 |
| Non-Asbestos Material Removed by Ashing: | 79.19 | 82.02 | 94.88 | 85.33 | 80.31 |
| Limit of Detection (Percent): | 0.03 | 0.04 | 0.01 | 0.04 | 0.05 |

*ND = None Detected* *TRACE = <1%*

Notes: Material was quantified by point count.

Shawn Smythe
Analyst

James W. Carter
Reviewer

6/29/00

**DataChem Laboratories Analytical Report**
**PLM Bulk Asbestos Analysis using Gravimetric Reduction**

Client: US Consumer Product Safety Commission
Location: Not Available
Set ID: 00-A-2735

| *SAMPLE IDENTIFICATION* | | | | | |
|---|---|---|---|---|---|
| Client ID: | RoseArt- Monster Mango | Prang- Yellow | Prang- Light Yellow | Prang- Periwinkle | Prang- Carmine Red |
| DCL ID: | 00-15479 | 00-15480 | 00-15481 | 00-15482 | 00-15483 |
| | | | | | |
| Homogeneity: | Homog. | Homog. | Homog. | Homog. | Homog. |
| Color: | Mango | Yellow | Light Yellow | Periwinkle | Red |
| Texture: | Waxy | Waxy | . Waxy | Waxy | Waxy |
| Description: | Crayon | Crayon | Crayon | Crayon | Crayon |
| | | | | | |
| Starting Weight (g): | 2.2698 | 2.5859 | 2.2840 | 2.4439 | 2.2451 |
| Residue Weight (g): | 0.2763 | 0.4309 | 0.4120 | 0.4886 | 0.2569 |
| Weight Percent: | 12.17 | 16.66 | 18.04 | 19.99 | 11.44 |
| *PERCENT DETECTED IN RESIDUE* | | | | | |
| Anthophyllite: | 0 | 0 | 0 | 0 | 0 |
| Chrysotile: | 0 | 0 | 0 | 0 | 0 |
| Tremolite: | 0 | 0 | 0 | 0 | 0 |
| Transitional Fibers: | 0 | 4.25 | 4.75 | 6.25 | 4.25 |
| Talc Fibers: | 0 | 0 | 0 | 0 | 0 |
| Non-Fibrous Material: | 100 | 95.75 | 95.25 | 93.75 | 95.75 |
| *PERCENT OF MATERIAL IN SAMPLE BEFORE REDUCTION* | | | | | |
| Anthophyllite: | 0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Chrysotile: | 0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Tremolite: | 0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Transitional Fibers: | 0 | 0.71 | 0.86 | 1.25 | 0.49 |
| Talc Fibers: | 0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Non-Fibrous Material: | 12.2 | 16.0 | 17.2 | 18.7 | 11.0 |
| Non-Asbestos Material Removed Removed by Ashing: | 87.83 | 83.29 | 81.94 | 80.05 | 88.51 |
| Limit of Detection (Percent): | 0.03 | 0.04 | 0.05 | 0.05 | 0.03 |

*ND = None Detected* *TRACE = <1%*

Notes: Material was quantified by point count.
Point Count was not performed on Rose Art - Monster Mango because no fibrous material was detected in the PLM examination of the residue.

Shawn Smythe
Analyst

James W. Carter
Reviewer

7/5/00

**DataChem Laboratories Analytical Report**
**TEM Bulk Asbestos Analysis using Gravimetric Reduction**

**DCL Sample Set ID: 00-T-2735**
**Client: US Consumer Product Safety Commission**

**TEM Data Collection Methodology:**

Any particle greater than 5 microns long with a length-to-width aspect ratio of 5:1 or higher was examined. The EPA AHERA asbestos analysis method considers a particle with an aspect ratio of 5:1 or more to be a fiber. A qualitative description of each fiber was recorded, including whether the particle was a fiber or a cleavage fragment; whether the fiber showed length-wise striations; whether the particle was a bundle of smaller fibers; and whether the particle's end splayed into separate fibers.

The SAED pattern for each fiber was qualitatively classified as Phyllosilicate (indicative of talc), Amphibole (indicative of anthophyllite), Transitional or Other, based on its general geometric arrangement. We recorded electron micrographs of those patterns that resembled Anthophyllite, plus examples of Talc and Transitional SAED patterns. Using measurements of the SAED patterns, we determined the d-spacing, the lattice planes and the zone axis represented by the pattern.

An EDXA spectrum was collected for each fiber examined, using a minimum of either 100 seconds or 500 counts. From data collected for each elemental peak in the spectrum, we determined the chemical composition of each fiber expressed as a ratio of the number of magnesium plus iron atoms to 8 silicon atoms. Ideally, pure talc would have 6 Mg to 8 Si atoms; pure anthophyllite would have a total of 7 Mg plus Fe atoms to 8 Si atoms. It is not uncommon to find some variation in these ratios within the same mineral species. If a fiber's Mg:Si ratio fell in the range expected for transitional minerals but its SAED pattern was confirmed to be an anthophyllite zone axis pattern, the fiber was considered anthophyllite.

Anna Marie Ristich
Analyst

James W. Carter
Reviewer

**DataChem Laboratories Analytical Report**
**TEM Bulk Asbestos Analysis using Gravimetric Reduction**

**DCL Sample Set ID: 00-T-2735**
**Client: US Consumer Product Safety Commission**

**Mineral Species Identification**

The morphological, structural (SAED) and chemical (EDXA) data collected for each fiber were used in combination to confirm its mineral species.

**Note on Transitional Fibers:**
These samples contain fibers that are mineralogically transitional between talc and anthophyllite. They do not conform to the chemistry or structure of either talc or anthophyllite. The ratio of magnesium to silicon falls between the acceptable ranges for talc (lower Mg than transitional) and anthophyllite (higher Mg than transitional); however, there is some overlap in the ranges. The diffraction patterns produced show overlapping geometries or forbidden spots that would not be found in either pure talc or pure anthophyllite.

**Summary of Fiber Types**

| **DataChem ID** | **00-15469** | **00-15471** |
|---|---|---|
| **Client Sample ID** | **Crayola Orchid** | **Crayola Atomic Tangerine** |
| **Talc Fibers** | 1 | 0 |
| **Transitional Fibers** | 21 | 22 |
| **Anthophyllite Fibers** | 0 | 3 |
| **Other Fibers** | 3 | 0 |

Anna Marie Ristich
Analyst

James W. Carter
Reviewer

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**DATACHEM LABORATORIES**
**TEM ANALYSIS**

**DCL Set ID NO.:** 00-T-2735
**DCL Sample No.:** 00-15480
**Client Sample No.:** Prang Yellow

| Grid & Opening | QUAL. SAED | SAED INDEXED | MAG: 15,600X 1 cm = 0 64 µm Screen Size (cm) D | L | Actual Size (µm) D | L | Aspect Ratio | Qualitative Estimate of EDXA Peak Height Ratios Na | Mg | Si | Ca | Fe | Al | S | Fibers ≥5 µm Talc | Trans | Anth | Other | NOTES | Mg·8Si |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 F10 | TR | | 1.00 | 18 8 | 0.64 | 12.1 | 18 8 | 0 | 4.0 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,R,S | 4.76 |
| F1 | PH | | 0.75 | 15.5 | 0 48 | 9.9 | 20 7 | 0 | 4.4 | 10 | 0.0 | 0 | 0 | 0 | 1 | | | | F,R | 4.90 |
| F21 | TR PH | PH | 1.30 | 33 5 | 0 83 | 21.5 | 25.8 | 0 | 3.6 | 10 | 0.3 | 0 0 | 0 | 0 | 1 | | | | F,R,S | 5.00 |
| F26 | TR | | 0.40 | 18.5 | 0.26 | 11.9 | 46 3 | 0 | 4.4 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S | 5.08 |
| F24 | TR | | 0.50 | 17 0 | 0.32 | 10.9 | 34 0 | | 4.0 | 10 | 0.1 | 0 | 0 | 0 | | 1 | | | F,S | 5.28 |
| F6 | TR | | 1.60 | 22.7 | 1.03 | 14.6 | 14.2 | 0 | 4.3 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,R,S,B | 5.28 |
| F2 | TR PH | | 1.50 | 12 3 | 0.96 | 7.9 | 8.2 | 0 | 4.4 | 10 | 0.1 | 0 | 0 | 0 | | 1 | | | F,R | 5.53 |
| F19 | TR PH | TR | 0 25 | 28.5 | 0.16 | 18.3 | 114.0 | | 4.3 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,R | 5.66 |
| F4 | TR PH | PH | 0.45 | 15.5 | 0.29 | 9.9 | 34.4 | 0 | 4 4 | 10 | 0.0 | 0 | 0 | 0 | 1 | | | | F,R | 5.66 |
| F20 | PH | | 4.00 | 40 0 | 2.56 | 25 6 | 10 0 | 0 | 4.5 | 10 | 0.0 | 0 | 0 | 0 | 1 | | | | F,R | 5.73 |
| F13 | PH | PH | 0.75 | 45 0 | 0.48 | 28 8 | 60 0 | 0 | 4.5 | 10 | 0.3 | 0 | 0 | 0 | 1 | | | | F,R,S | 5.76 |
| F16 | TR | | 0.35 | 7.8 | 0.22 | 5.0 | 22 3 | 0 | 5 2 | 10 | 0 2 | 0 | 0 | 0 | | 1 | | | F,S | 5.77 |
| F9 | TR PH | | 1.10 | 8 5 | 0.71 | 5 4 | 7 7 | 0 | 4 8 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F,R | 5.93 |
| F17 | TR | | 2.30 | 19 6 | 1.47 | 12 6 | 8 5 | 0 | 4.5 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,Sp | 5.98 |
| F15 | TR | | 2 00 | 38 8 | 1.28 | 24 9 | 19 4 | 0 | 4 6 | 10 | 0.4 | 0 | 0 | 0 | | 1 | | | F,R,S | 5.99 |
| F14 | TR | | 1.50 | 27.7 | 0.96 | 17.8 | 18.5 | 0 | 4.7 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F,R,S,B | 6.00 |
| A2 F3 | TR | | 0.50 | 9.3 | 0 32 | 6.0 | 18 6 | 0 | 4.8 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,R,S,Sp | 6.01 |
| F7 | TR | | 0.25 | 14.3 | 0.16 | 9 2 | 57.2 | 0 | 4.3 | 10 | 0.7 | 0 | 0 | 0 | | 1 | | | F,R | 6.16 |
| F5 | TR | | 1.00 | 14 6 | 0 64 | 9.4 | 14.6 | 0 | 5 0 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S | 6.17 |
| F8 | TR | TR | 0.25 | 9.5 | 0 16 | 6 1 | 38.0 | 0 | 5 0 | 10 | 0.4 | 0 | 0 | 0 | | 1 | | | F,R,S | 6.22 |
| F23 | TR | | 2 50 | 13.5 | 1.60 | 8 7 | 5 4 | 0 | 4.9 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,B | 6 28 |
| F12 | TR K | TR | 2.50 | 46 5 | 1.60 | 29 8 | 18 6 | 0 | 4.8 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.47 |
| F18 | TR A | | 0.40 | 19.7 | 0.26 | 12 6 | 49.3 | 0 | 5 0 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S | 6.53 |
| F11 | TR | | 0.90 | 11.7 | 0.58 | 7.5 | 13.0 | 0 | 5.4 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S | 6.55 |
| F22 | TR K A | A | 0.50 | 12 4 | 0 32 | 7 9 | 24.8 | 0 | 5 0 | 10 | 0.2 | 0 | 0 | 0 | | | 1 | | F,R,S | 6.74 |
| | | | | | Average Aspect Ratio. | | 28 1 | | | | | | | Total | 5 | 19 | 1 | 0 | | |

PH=Philosilicate TR=Transitional A=Amphibole V=Variable K=Kikuchi Lines F=Fiber B=Bundle S=Striated R=Ribbonlike Sp=Splayed P=Assoc. Particles C=Cleavage Fragment

Anna Marie Ristich 6/29/00
Anna Marie Ristich
Analyst — Date

James W. Carter 7/3/00
James W. Carter
Reviewer — Date

**DATACHEM LABORATORIES**
**TEM ANALYSIS**

**DCL Set ID NO.:** 00-T-2735
**DCL Sample No.:** 00-15471
**Client Sample No.:** Crayola Atomic Tangerine

MAG: 15,600X 1 cm = 0.64 µm

| Grid & Opening | QUAL. SAED | SAED INDEXED | Screen Size (cm) D | Screen Size (cm) L | Actual Size (µm) D | Actual Size (µm) L | Aspect Ratio | Na | Mg | Si | Ca | Fe | Al | S | Talc | Trans | Anth | Other | NOTES | Mg:8Si |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Qualitative Estimate of EDXA Peak Height Ratios | | | | | | | Fibers ≥5 µm | | | | | |
| A1 F3 | TR | TR | 1.50 | 68.0 | 0.96 | 43.6 | 45 3 | 0 | 4.4 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,R,S,Sp,B | 5.77 |
| F18 | TR | | 1.00 | 27.7 | 0.64 | 17.8 | 27 7 | 0 | 4 4 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,R | 5.80 |
| F21 | TR | | 0.60 | 9.3 | 0.38 | 6.0 | 15 5 | 0 | 4.4 | 10 | 0.0 | 0.5 | 0 | 0 | | 1 | | | F,S | 5.89 |
| F9 | TR | | 1.50 | 22.4 | 0.96 | 14.4 | 14.9 | 0 | 4.3 | 10 | 0 2 | 0 | 0 | 0 | | 1 | | | F,R,S,Sp | 6 01 |
| F8 | TR PH | | 1.50 | 19.6 | 0.96 | 12.6 | 13 1 | 0 | 4.4 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,R,S | 6.01 |
| F7 | TR | | 0.50 | 11.8 | 0.32 | 7.6 | 23.6 | 0 | 4.6 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,R,B, | 6.02 |
| F10 | V TR | | 0.50 | 14 2 | 0.32 | 9.1 | 28.4 | 0 | 4.3 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,S | 6.04 |
| F16 | TR | | 1.00 | 18 1 | 0.64 | 11.6 | 18.1 | 0 | 4.4 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,R | 6.04 |
| F5 | TR | | 3.30 | 17.0 | 2.12 | 10 9 | 5.2 | 0 | 4.4 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,S | 6.04 |
| F2 | TR A | | 3.30 | 56.5 | 2.12 | 36.2 | 17.1 | 0 | 4.4 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F,R,Sp | 6.22 |
| F4 | TR PH | | 1.80 | 36 6 | 1.15 | 23.5 | 20.3 | 0 | 3 4 | 10 | 0.1 | 0 | 0 | 0 | | 1 | | | F,R,S,Sp,B | 6.23 |
| F6 | TR | | 0.40 | 15.3 | 0.26 | 9 8 | 38.3 | 0 | 4 9 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,R,B | 6.28 |
| F25 | TR | | 0 50 | 20.2 | 0.32 | 12 9 | 40.4 | 0 | 4.4 | 10 | 0.1 | 0 | 0 | 0 | | 1 | | | F,S | 6.32 |
| F19 | K A | A | 2.40 | 40.6 | 1.54 | 26.0 | 16.9 | 0 | 4.4 | 10 | 0.3 | 0 | 0 | 0 | | | 1 | | F,S,B | 6.35 |
| F23 | A | A | 3.00 | 27.5 | 1.92 | 17.6 | 9.2 | 0 | 4.8 | 10 | 0.2 | 0 | 0 | 0 | | | 1 | | C | 6.46 |
| F14 | TR | | 0.90 | 9.75 | 0.58 | 6.3 | 10 8 | 0 | 4 4 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,S | 6.47 |
| F11 | TR PH | | 0.60 | 11 6 | 0.38 | 7.4 | 19.3 | 0 | 4.4 | 10 | 0 0 | 0 | 0 | 0 | | 1 | | | F,R | 6.50 |
| F24 | TR | | 0.50 | 13 7 | 0.32 | 8.8 | 27 4 | 0 | 5.2 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.52 |
| F1 | TR K A | | 2.00 | 19 2 | 1.28 | 12.3 | 9.6 | 0 | 5.3 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F | 6.55 |
| F22 | TR | | 0.40 | 22.6 | 0 26 | 14.5 | 56 5 | 0 | 4 3 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | B | 6.56 |
| F12 | A | A | 0.60 | 108.0 | 0.38 | 69.2 | 180.0 | 0 | 4 4 | 10 | 0.4 | 0 | 0 | 0 | | | 1 | | F,R,S | 6.62 |
| F15 | PH | | 0.40 | 9.75 | 0.26 | 6.3 | 24.4 | 0 | 4.9 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,R | 6.63 |
| F17 | TR | | 0.50 | 17.2 | 0.32 | 11.0 | 34.4 | 0 | 4.8 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,R | 6.92 |
| F13 | TR | | 0.25 | 12.0 | 0.16 | 7.7 | 48.0 | 0 | 5.7 | 10 | 0.1 | 0 | 0 | 0 | | 1 | | | F,S,P,Sp | 7.25 |
| F20 | TR | | 1.50 | 36 6 | 0.96 | 23.5 | 24 4 | 0 | 5.0 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,S,B | 7.28 |
| | | | | | Average Aspect Ratio | | 30 8 | | | | | | | Total | 0 | 22 | 3 | 0 | | |

PH=Philosilicate TR=Transitional A=Amphibole V=Variable K=Kikuchi Lines F=Fiber B=Bundle S=Striated R=Ribbonlike Sp=Splayed P=Assoc. Particles C=Cleavage Fragment

Anna Marie Ristich 6/29/00
Anna Marie Ristich
Analyst　　　　Date

James W. Carter 7/3/00
James W. Carter
Reviewer　　　　Date

**DATACHEM LABORATORIES**
**TEM ANALYSIS**

**DCL Set ID NO.:** 00-T-2735
**DCL Sample No.:** 00-15469
**Client Sample No.:** Crayola Orchid

| Grid & Fiber | QUAL. SAED | SAED INDEXED | MAG: 15,600X 1 cm = 0.64 µm Screen Size (cm) D | L | Actual Size (µm) D | L | Aspect Ratio | Qualitative Estimate of EDXA Peak Height Ratios Na | Mg | Si | Ca | Fe | Al | S | Fibers ≥5 µm Talc | Trans | Anth | Other | NOTES | Mg:8Si |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 F6 | A K | | 1.50 | 10 0 | 0.96 | 6.4 | 6.7 | 0 | 3.5 | 10 | 2.4 | 0 | 0 | 0 | | | | 1 | C | 4.32 |
| F16 | TR V | | 0.40 | 10.4 | 0.26 | 6 6 | 25.9 | 0 | 3.8 | 10 | 0 5 | 0 | 0 | 0 | | 1 | | | F,P | 5.13 |
| F15 | PH | PH | 0.50 | 10.7 | 0.32 | 6 9 | 21.4 | 0 | 4.5 | 10 | 0.5 | 0 | 0 | 0 | 1 | | | | F,R | 5.56 |
| F24 | TR | | 1.00 | 26.5 | 0.64 | 17 0 | 26.5 | 0 | 4.0 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S | 5.62 |
| F7 | TR V K | | 2.00 | 35.5 | 1.28 | 22.8 | 17.8 | 0 | 4.3 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S,Sp | 5.78 |
| F12 | TR | | 0.70 | 22.0 | 0.45 | 14.1 | 31.4 | 0 | 4.5 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S | 5.84 |
| F23 | TR | | 0.30 | 19.6 | 0.19 | 12 6 | 65 3 | 0 | 5.0 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,Sp,P | 5.85 |
| F13 | TR | | 0.50 | 8.0 | 0.32 | 5.1 | 16 0 | 0 | 4.0 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,P | 6.07 |
| F17 | TR | | 0.90 | 23.4 | 0.58 | 15.0 | 26.0 | 0 | 4.0 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,Sp,P | 6.11 |
| F25 | TR | | 2.00 | 34.0 | 1.28 | 21.8 | 17.0 | 0 | 4.5 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,Sp | 6.13 |
| F8 | TR | TR | 0.70 | 26.0 | 0.45 | 16 7 | 37 1 | 0 | 4.0 | 10 | 0.4 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.22 |
| F14 | V TR A K | | 1.30 | 37.2 | 0 83 | 23.8 | 28.6 | 0 | 5 0 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S | 6.24 |
| F1 | TR | TR | 1.50 | 31.0 | 0.96 | 19.9 | 20.7 | 0 | 4.5 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S | 6.34 |
| F26 | TR K | | 1.50 | 28.8 | 0.96 | 18 4 | 19.2 | 0 | 4.5 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S,Sp | 6.41 |
| F2 | TR V | | 0.25 | 21 8 | 0.16 | 14.0 | 87.2 | 0 | 4.5 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S | 6 43 |
| F10 | A K | | 1.00 | 10.2 | 0.64 | 6 5 | 10.2 | 0 | 5.0 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S,P | 6.50 |
| F4 | TR K | TR | 1.30 | 13.6 | 0 83 | 8.7 | 10.5 | 0 | 4.5 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S | 6.54 |
| F9 | TR | | 0.35 | 27.2 | 0.22 | 17.4 | 77.7 | 0 | 5.0 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,R | 6.62 |
| F5 | V TR A K | | 1.60 | 37.5 | 1.03 | 24 0 | 23.4 | 0 | 4.5 | 10 | 0.8 | 0 | 0 | 0 | | 1 | | | F,S, Sp | 6 63 |
| F18 | V | | 1.20 | 13.7 | 0.77 | 8 8 | 11.4 | 0 | 4.9 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.64 |
| F22 | TR | TR | 1.00 | 10.2 | 0 64 | 6 5 | 10.2 | 0 | 5.0 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S | 6.74 |
| F21 | TR | | 0.50 | 11.5 | 0.32 | 7.4 | 23 0 | 0 | 6.5 | 10 | 0.5 | 0.5 | 0 | 0 | | | | 1 | F,S,P | 7.35 |
| F20 | TR | | 0.50 | 8.4 | 0.32 | 5 4 | 16 8 | 0 | 5.5 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,R | 7.52 |
| F3 | TR | | 0.50 | 18.2 | 0.32 | 11.7 | 36 4 | 0 | 5 5 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,P | 8.28 |
| F11 | TR | | 0.35 | 8 7 | 0.22 | 5.6 | 24 9 | 0 | 7.0 | 10 | 4.0 | 0 | 0 | 0 | | | | 1 | F,S,P,B | 10.13 |
| | | | | | Average Aspect Ratio. | | 27.6 | | | | | | | Total | 1 | 21 | 0 | 3 | | |

PH=Philosilicate TR=Transitional A=Amphibole V=Variable K=Kikuchi Lines F=Fiber B=Bundle S=Striated R=Ribbonlike Sp=Splayed P=Assoc. Particles C=Cleavage Fragment

Anna Marie Ristich 7/10/00
Anna Marie Ristich — Date
Analyst

James W. Carter 7-10-00
James W. Carter — Date
Reviewer

**DATACHEM LABORATORIES**

**TEM ANALYSIS**

**DCL Set ID NO.:** 00-T-2735

**DCL Sample No.:** 00-15482

**Client Sample No.:** Prang Periwinkle

| Grid & Opening | QUAL. SAED | SAED INDEXED | MAG: 15,600X 1 cm = 0.64 μm Screen Size (cm) D | L | Actual Size (μm) D | L | Aspect Ratio | Qualitative Estimate of EDXA Peak Height Ratios Na | Mg | Si | Ca | Fe | Al | S | Talc | Fibers ≥5 μm Trans | Anth | Other | NOTES | Mg:8Si |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 F1 | TR | | 0.40 | 8.5 | 0.26 | 5.4 | 21.3 | 0 | 4.3 | 10 | 0.1 | 0 | 0 | 0 | | 1 | | | F,S,B | 5.70 |
| F3 | TR | TR | 0.25 | 9.5 | 0.16 | 6.1 | 38.0 | 0 | 4.4 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F | 5.75 |
| F16 | TR | | 0.60 | 13.7 | 0 38 | 8.8 | 22.8 | 0 | 5.0 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S,B | 5.99 |
| F17 | TR | | 0.50 | 18.1 | 0.32 | 11.6 | 36.2 | 0 | 4.5 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F,S | 6.00 |
| F14 | TR PH | | 0.30 | 15.1 | 0.19 | 9.7 | 50.3 | 0 | 4.4 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F | 6.07 |
| F12 | TR | | 0.50 | 9.8 | 0.32 | 6.3 | 19.6 | 0 | 4.7 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S | 6.12 |
| F15 | TR | | 1.00 | 14.8 | 0.64 | 9.5 | 14.8 | 0 | 4.4 | 10 | 0 2 | 0 | 0 | 0 | | 1 | | | F,S | 6.15 |
| F8 | TR | | 0.30 | 8.6 | 0.19 | 5.5 | 28.7 | 0 | 4.4 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.22 |
| F20 | TR | | 2.00 | 22.7 | 1.28 | 14 6 | 11.4 | 0 | 4.6 | 10 | 0.3 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.33 |
| F7 | TR PH | | 0.30 | 10.0 | 0.19 | 6.4 | 33.3 | 0 | 4.7 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,R | 6.33 |
| F6 | TR K A | TR | 2.10 | 10 5 | 1.35 | 6.7 | 5.0 | 0 | 4.7 | 10 | 0.0 | 0 | 0 | 0 | | 1 | | | C,S,B | 6.37 |
| F10 | TR | TR | 0.60 | 8.2 | 0.38 | 5.3 | 13.7 | 0 | 5.2 | 10 | 0.1 | 0 | 0 | 0 | | 1 | | | F,S,SP,B | 6.38 |
| F2 | TR | | 0.40 | 15.75 | 0 26 | 10 1 | 39.4 | 0 | 5.2 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.38 |
| F13 | TR | | 0.60 | 8.2 | 0.38 | 5 3 | 13.7 | 0 | 4.7 | 10 | 0.5 | ·0 | 0 | 0 | | 1 | | | F,S,B | 6.52 |
| F9 | TR | | 0 50 | 10.5 | 0 32 | 6 7 | 21 0 | 0 | 4.9 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.60 |
| F18 | TR | | 0.50 | 16.8 | 0.32 | 10.8 | 33 6 | 0 | 4.8 | 10 | 0.4 | 0 | 0 | 0 | | 1 | | | F,S | 6.63 |
| F5 | TR | | 0.40 | 9.0 | 0.26 | 5.8 | 22.5 | 0 | 5 2 | 10 | 0.5 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.71 |
| F11 | TR A | | 0.60 | 17.5 | 0 38 | 11.2 | 29 2 | 0 | 4.9 | 10 | 0.4 | 0 | 0 | 0 | | 1 | | | F,S,B | 6.77 |
| F19 | TR | | 0.50 | 20.6 | 0.32 | 13.2 | 41.2 | 0 | 5 0 | 10 | 0.2 | 0 | 0 | 0 | | 1 | | | F | 6.81 |
| F4 | TR A | A | 0.65 | 8.1 | 0.42 | 5.2 | 12.5 | 0 | 5.2 | 10 | 0.3 | 0 | 0 | 0 | | | 1 | | F,S | 6.93 |
| | | | | | | Average Aspect Ratio. | 25 4 | | | | | | | Total. | 0 | 19 | 1 | 0 | | |

**PH=Philosilicate TR=Transitional A=Amphibole V=Variable K=Kikuchi Lines F=Fiber B=Bundle S=Striated R=Ribbonlike Sp=Splayed P=Assoc. Particles C=Cleavage Fragment**

Anna Marie Ristich 6/29/00
Anna Marie Ristich
Analyst Date

James W. Carter 7/3/00
James W. Carter
Reviewer Date

Prang Periwinkle
Anthophyllite Fiber

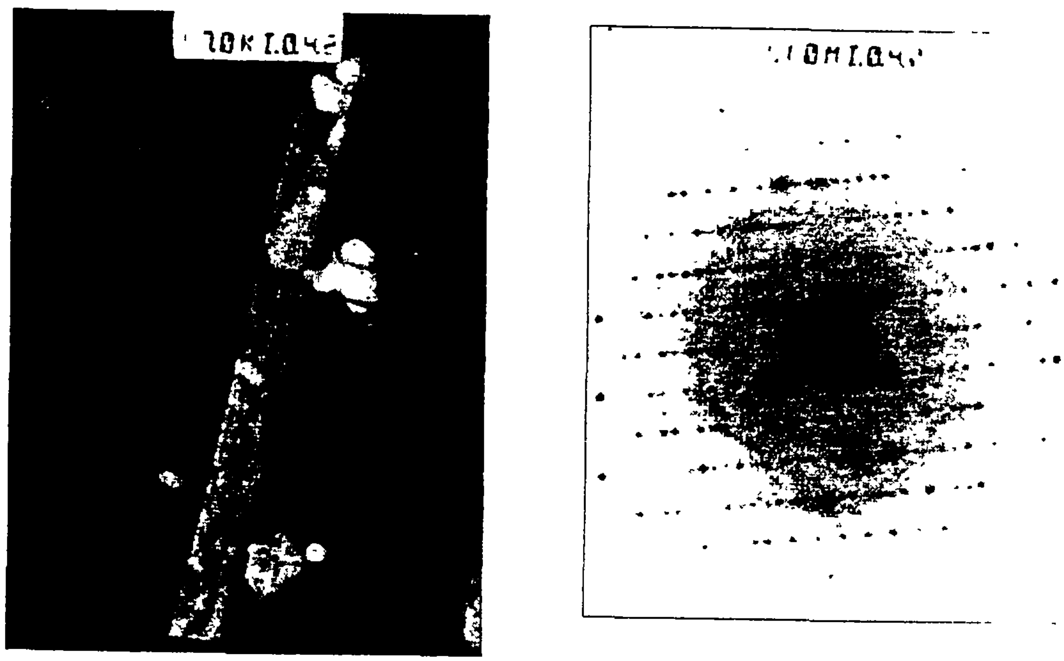


Image of anthophyllite fiber, F4, and its Selected Area Diffraction Pattern showing [121] Zone Axis; Mg:Si ratio of this fiber is 6.93:8.

Prang Periwinkle
Transitional Fiber

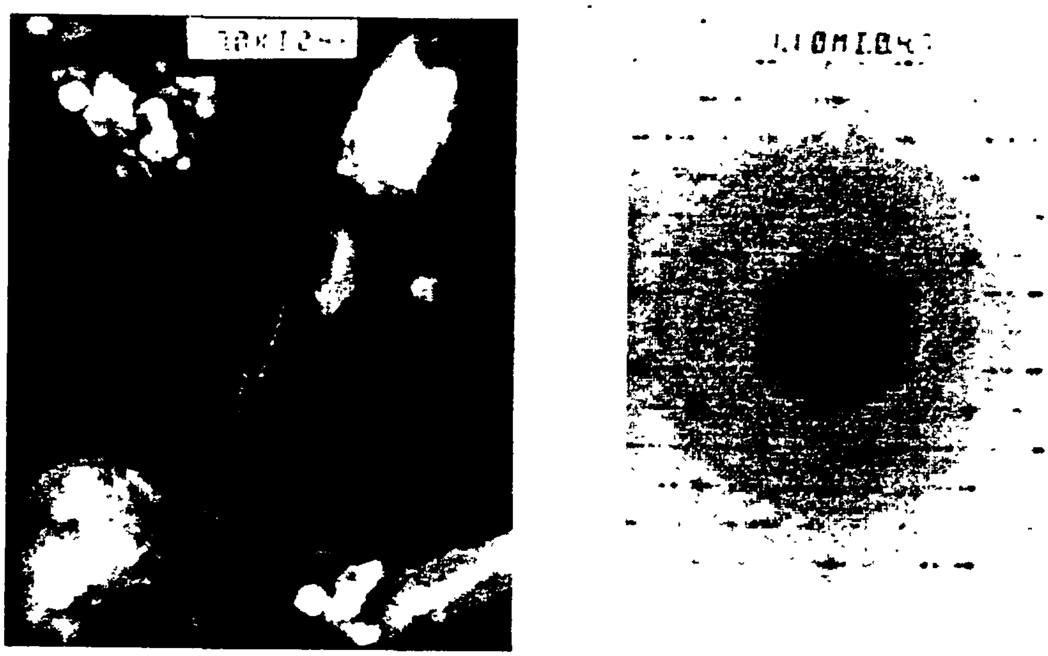


Image of transitional fiber, F10, and its Selected Area Diffraction Pattern
Mg:Si ratio of this fiber is 6.38:8.

Prang Yellow
Talc Fiber

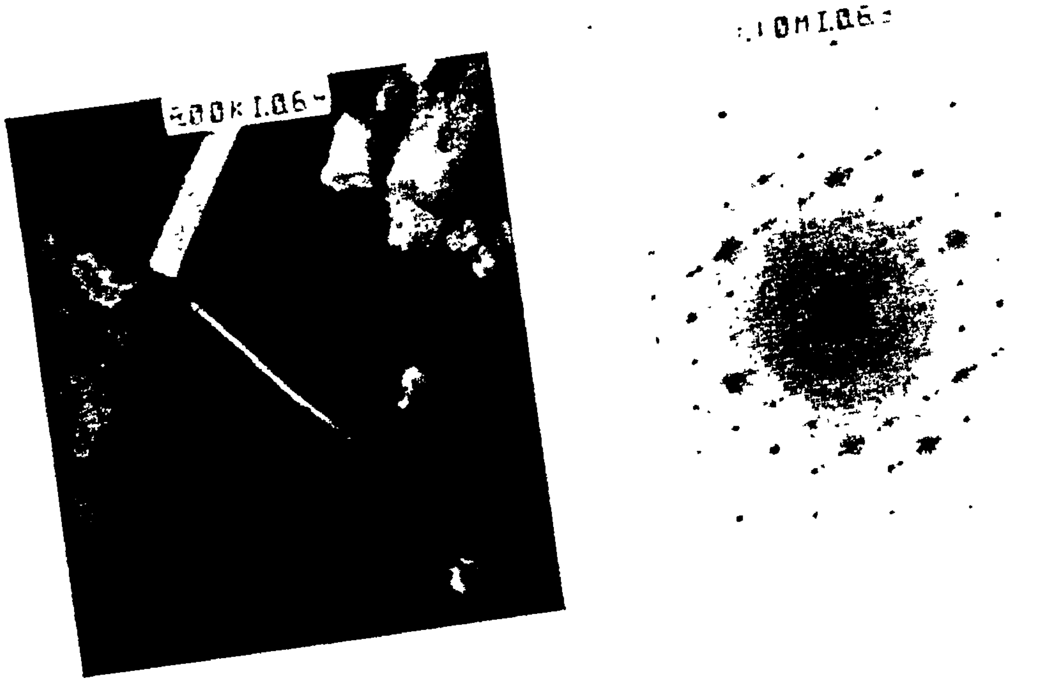


Image of talc fiber, F13, (narrow fiber running NW-SE), and its Selected Area Diffraction Pattern
Mg:Si ratio of this fiber is 5.76:8.

Prang Yellow
Transitional Fiber

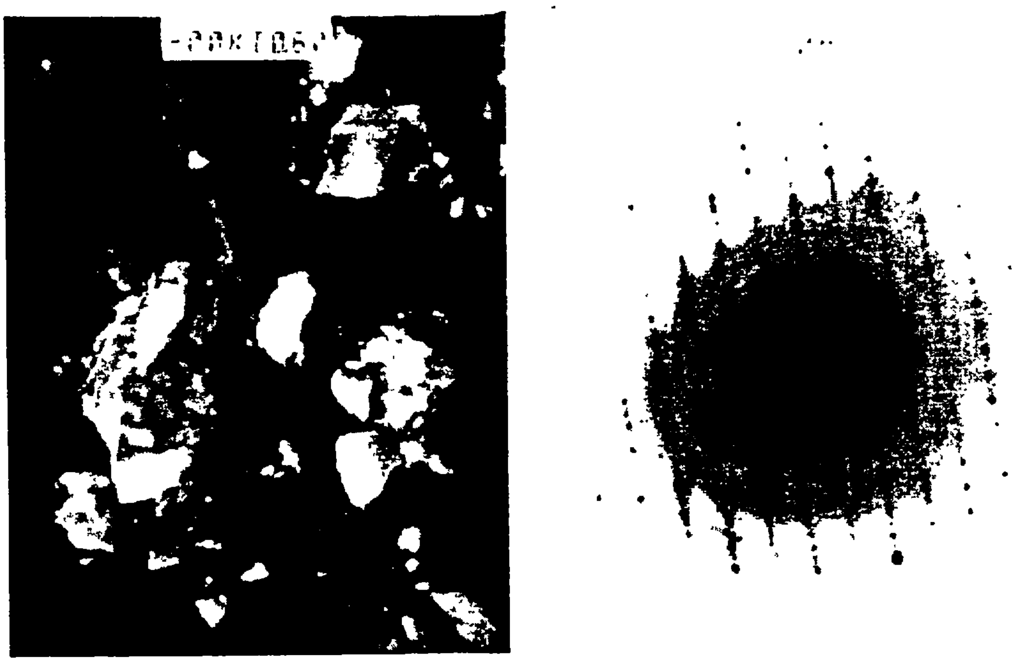


Image of transitional fiber, F12, and its Selected Area Diffraction Pattern close to the anthophyllite [121] Zone Axis; Mg:Si ratio of this fiber is 6.47:8.

Prang Yellow
Anthophyllite Fiber

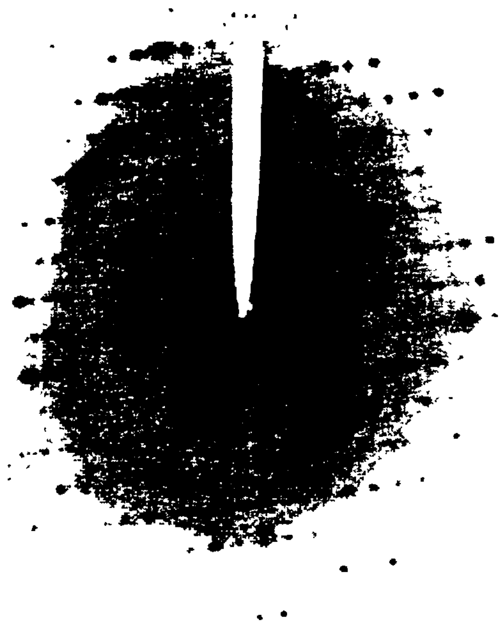


Image of anthophyllite fiber, F22, and its Selected Area Diffraction Pattern showing [121] Zone Axis; Mg:Si ratio of this fiber is 6.74:8.

Crayola Atomic Tangerine
Anthophyllite Fiber

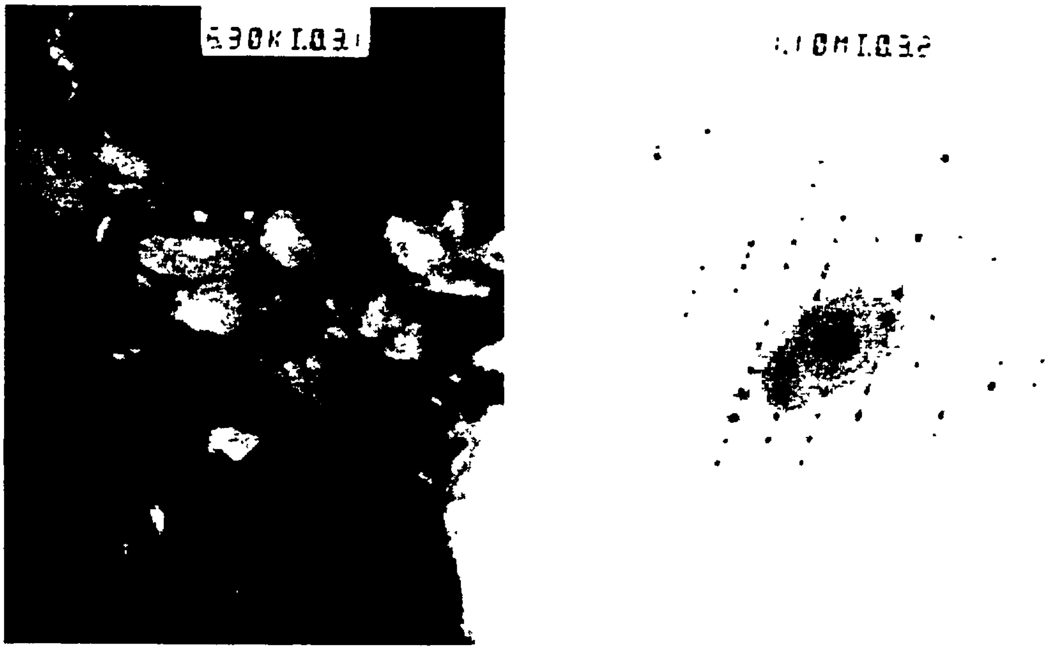


Image of anthophyllite fiber, F23, and its Selected Area Diffraction Pattern showing [121] Zone Axis; Mg:Si ratio of this fiber is 6.46:8.

Crayola Atomic Tangerine
Transitional Fiber

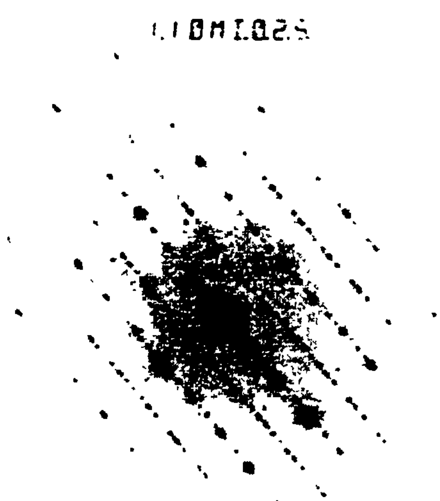


Image of transitional fiber, F12, and its Selected Area Diffraction Pattern close to the anthophyllite [101] zone axis; Mg:Si ratio of this fiber is 6.62:8.

Crayola Atomic Tangerine
Anthophyllite Fiber

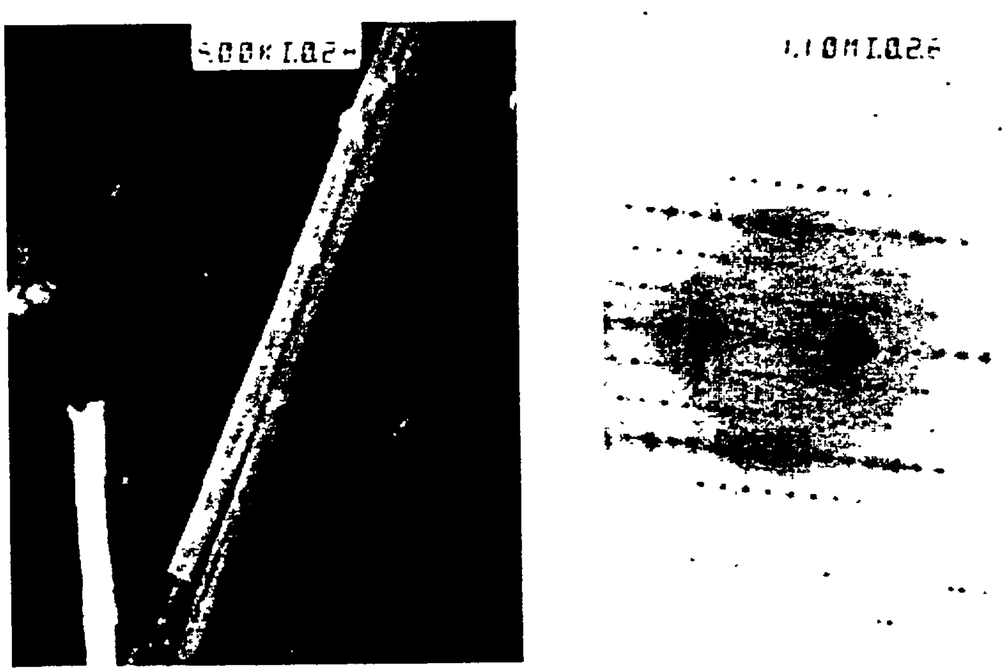
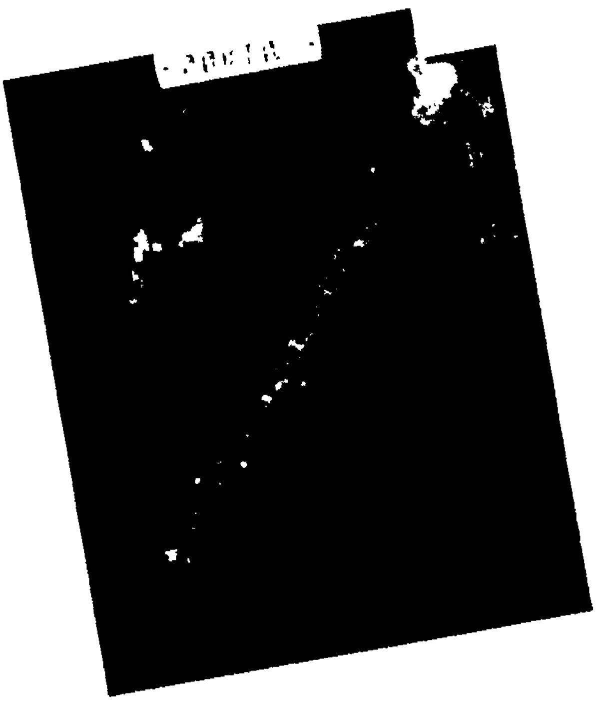


Image of anthophyllite fiber, F19, and its Selected Area Diffraction Pattern showing [100] Zone Axis; Mg:Si ratio of this fiber is 6.35:8.

Crayola Orchid
Transitional Fiber



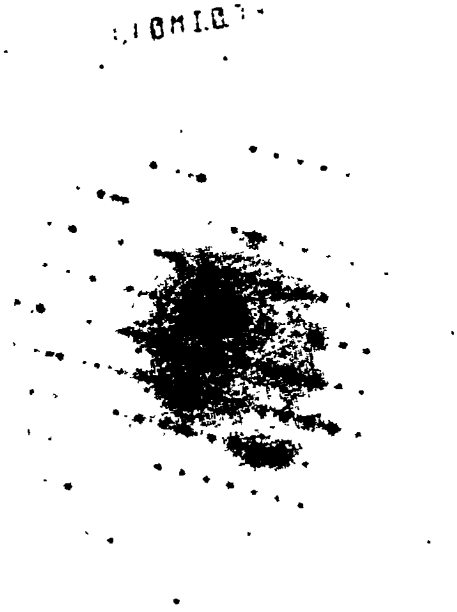


Image of transitional fiber, F22, and its Selected Area Diffraction Pattern close to the anthophyllite [121] Zone Axis; Mg:Si ratio of this fiber is 6.74:8.

Crayola Orchid
Talc Fiber

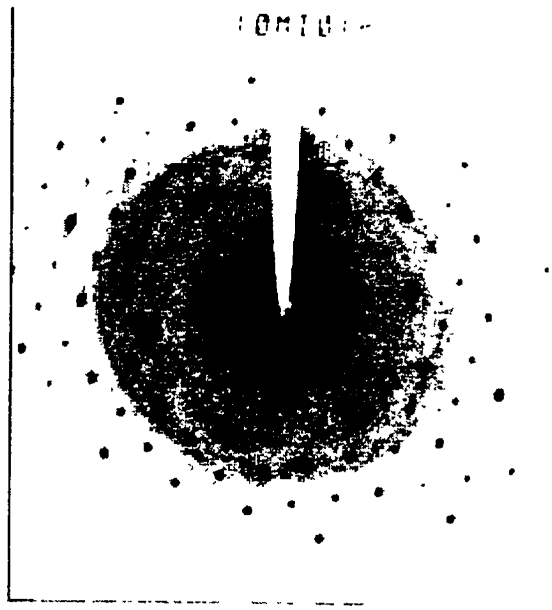


Image of talc fiber, F15, and its Selected Area Diffraction Pattern; Mg:Si ratio of this fiber is 5.56:8.

References

Phillips, William Revell and Dana T. Griffen (1981). Optical Mineralogy, the Nonopaque Minerals, W. H. Freeman and Company, San Francisco.

Perkins, R. L., and B. W. Harvey (1993) USEPA Test Method, EPA/600/R-93/116, Method for the Determination of Asbestos in Bulk Building Materials.

Hurlbut, Jr., Cornelius S., and Cornelius Klein (1977) Manual of Mineralogy (after James D. Dana) 19th edition, John Wiley and Sons, New York.

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AIHA Industrial Hygiene ACCREDITED LABORATORY

June 12, 2000

REPORT OF ANALYSIS OF CRAYONS FOR THE PRESENCE OF ASBESTOS

A number of crayons were analyzed at the OSHA SLTC to determine whether or not asbestos was present. The crayons were ashed to remove any organic material, then analyzed by phase-polar illumination (OSHA method ID 191). A particle count estimate of percentage was made to determine the fiber content. In addition, gross scans of the fibers found in the Crayola Orchid and Prang Periwinkle color crayons were examined by transmission electron microscopy with x-ray energy analysis to identify the fibers noted in the light microscope.

No fibers of any asbestos mineral as defined in 29 CFR 1910.1001 were found to be present in any of the samples analyzed. There were, however asbestiform fibers of a mineraloid intermediate in composition between talc and anthophyllite. In addition, cleavage fragment fibers of non-asbestiform tremolite were found to be present.

Discussion:

A departure from ID-191 was made for this particular analysis, the material was immersed in a liquid with a measured index of refraction 1.592 at 23°C. This was chosen because it was closest to the lowest reported index of refraction for anthophyllite. (Deer, Howie and Zussman, **Rock Forming Minerals**, Vol 2, p 211, Longman, Great Britain, 1974). This is used as a go / no-go decision as to whether there are fibers of anthophyllite or tremolite present or not. If fibers of anthophyllite or tremolite are present, they will demonstrate colors indicating indices of refraction above 1.592. The samples were also examined in the liquid 1.550 to determine whether or not chrysotile was present.

Weighed portions of crayons were ashed at 500°C for 24 hours to remove all organic matter. Finely dispersed preparations of particulate were made of the residue in liquids 1.592 and 1.550 liquids. The preparations were examined generally for the presence of asbestos minerals. None of the samples demonstrated the presence of asbestos. However, asbestiform fibers were observed and quantified by particle count as follows. The samples were imaged in dispersion stain at approximately 200x magnification. Particles greater than about 5$\mu$m and greater were counted and divided into fibers with index of refraction less than 1.592 and total particles. This resulted in the data represented in the following table.

| Crayon color / manufacturer / CPSC number (if present) | Percent asbestos fiber present | Percent asbestiform fiber present *of residue after ashing* | Fraction residue after ashing | Percent fiber |
|---|---|---|---|---|
| Crayola White | none detected | none detected | 0.186 | none detected |
| Crayola Orchid 1 | none detected | 3.15% | 0.244 | 0.77% |
| Prang Periwinkle 1 | none detected | 8.74% | 0.141 | 1.23% |
| Crayola Blue 525-1-1 | none detected | 6.14% | 0.212 | 1.30% |
| Crayola Green 525-1-3 | none detected | 4.42% | 0.200 | 0.88.% |
| Rose Art Blue 525-3-1 | none detected | none detected | 0.00516 | none detected |
| Rose Art Orange 525-4-2 | none detected | none detected | 0.0002 | none detected |
| Crayola Orchid 2 525-9-1 | none detected | 4.75% | 0.201 | 0.95% |
| Prang Yellow 530-1 | none detected | 4.06% | 0.1613 | 0.065% |
| Prang Yellow 530-2 | none detected | 5.82% | 0.2041 | 1.19% |
| Crayola Washable Blue | none detected | none detected | 0.145 | none detected |

Preparations were made of the residue of Crayola Orchid and Prang Periwinkle. Two TEM grids of each were examined to find any asbestiform fibers. Such fibers were determined to be present. All diffraction patterns were examined in situ. All were noted to have talc-like appearance excluding them from identification as anthophyllite. Chemistry determination By EDX was also made for these fibers and found to contain Si, Mg, with traces of Fe and Ca. This is consistent with anthophyllite or intermediate (transitional) mineral fibers. The Mg/Si ratio was suggestive that the fibers examined were intermediate in character between talc and anthophyllite tending toward anthophyllite. However, none of the fibers examined had chemistry sufficiently close to anthophyllite to be included in the definition for anthophyllite.

Appendix B

Air Sampling

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

JUL 12 2000

TO: Kristina Hatlelid , HS

THROUGH: Andrew Stadnik, Associate Executive Director, Laboratory Sciences

FROM: Warren K. Porter, Jr., Director, Chemistry Division

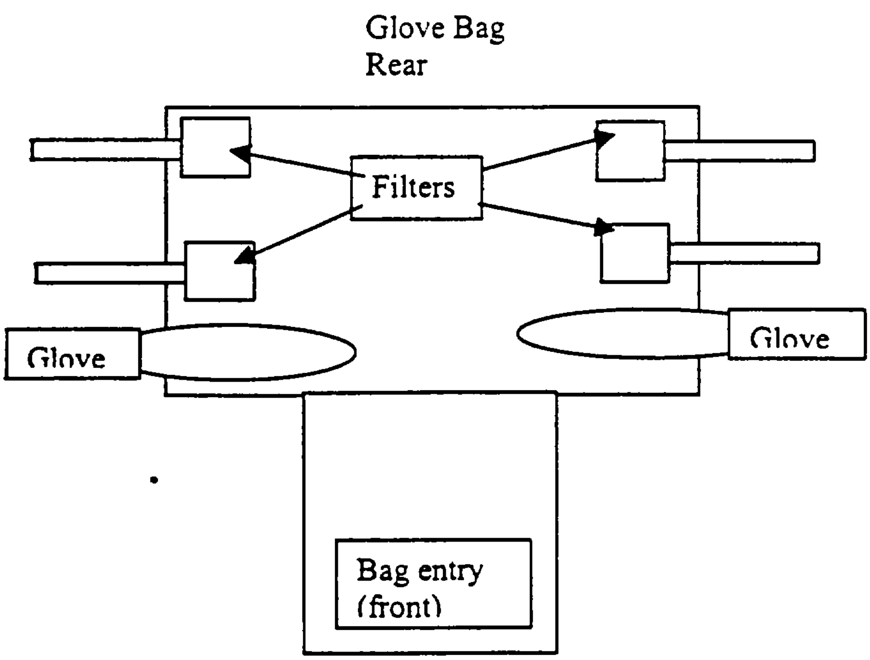
SUBJECT: Fiber release from use of wax crayons

**Introduction**

A coloring experiment was undertaken to determine if coloring paper with crayons would result in the release of any fibers that might be contained in the crayons. The following description outlines the experimental procedure used for collection of airborne material during coloring. The filters used for collecting airborne particles were analyzed by DataChem Laboratories.

**Equipment**

As shown in the diagram below, the testing set up consisted of a glove bag containing four filters. The rear of the bag had a section of semi rigid foam approximately eight inches high to prevent the bag from collapsing.



Each of the four filters in the glove bag sampled at 10 liters per minute (LPM). The bag entry was left open to provide a path for air entry.

For purposes of collecting background fiber concentrations and identification of any fibers in the laboratory air, one filter sampling air at 10 LPM was located 5-6 feet to the rear of the experimenter and a second filter was located 6-7 feet in front of the experimenter. Also, a personal air sampler operating at 2.5 LPM was attached to the collar of the experimenter.

Before any coloring activity, air was sampled for 30 minutes at all 7 locations as a control for laboratory and glove bag background concentrations. The filters were labeled and sealed for analysis. Two unopened filters, in their cassettes, one for the pre-coloring sample and one for the coloring sample were labeled as blanks and served as controls.

**Coloring:**
Coloring involved the experimenter using 6 supplied crayons supplied by DataChem Laboratories. These crayons were identified as 00-15469, **70**, **71**, **80**, **81**, an **82**. The crayons had been used previously. Some appeared to have up to one quarter of the length missing. Some samples consisted of one or more broken pieces.

About 100-150 sheets of 8.5 by 11-inch copy paper were placed in a pile in the glove bag.

The air sampling pumps were turned on.

Coloring consisted of:

1. Drawing with considerable force.
2. Drawing with considerable force with a transition to a lighter force for shading purposes.

- With 2 – 3 crayons the colored surface was rubbed with the finger for blending the color.
- 2 crayons broke during the coloring session.
- Two crayons were sharpened with a pocketknife inside the glove bag.

Each of the six crayons was used individually for five minutes of coloring on one or two sheets of paper.

After each 5-minute session, the drawing was removed from the glove bag along with the crayon and to the extent possible, the crayon parts (pieces of broken crayons and shavings from sharpening). The next crayon was put in the bag and coloring began again.

The 30-minute air sampling collected the air involved in the full coloring session with all six crayons.

The Data sheets and filters were sent to DataChem Laboratories for analysis.

DATA CHEM
LABORATORIES

6/29/00

***SUBMITTED TO:***
Lori Saltzman
US Consumer Product Safety Commission
4330 East West Highway, Room 600B
Bethesda, MD 20814

***REFERENCE DATA:***

| | |
|---|---|
| Client Sample Nos.: | 001 through Blank #2 |
| Sample Location: | NIOSH Glove Bag |
| Sample Type: | MCE Air Filters |
| Method Reference: | Airborne Fibers by Phase Contrast Microscopy (PCM) NIOSH Method 7400, Fourth Edition, (dated 8/15/94) |
| DCL Sample Set ID No.: | 00-A-2850 |
| DCL Sample Nos.: | 00-16066 through 00-16081 |

The samples indicated on the following data sheet were analyzed in accordance with the NIOSH Method 7400 outlined in the NIOSH Manual of Analytical Methods (NMAM), Fourth Edition, dated 8/15/94. The results reported are not field blank corrected. Blanks receive a 100-field count, and data are reported as Fibers/Field for use in background correction.

Results are tabulated on the following page. Results are reported in Fibers/mm$^2$, Fibers per Filter and Fibers/mL (Fibers/cc). Concentrations in Fibers/mL are based on sample volumes or flow rates and times provided by the client. Results for all samples are based on the use of a 0.8-µm pore size, 25-millimeter diameter filter having an effective collection area of 385 mm$^2$. Report applies only to portions of samples analyzed. Samples will be disposed of after 60 days unless otherwise instructed.

The limit of detection (LOD) for this method has been determined to be 7 Fibers/mm$^2$ for a sample volume of approximately 1200 Liters.

DataChem Laboratories adheres to the QA/QC guidelines set forth in this method which calls for 10% blind replicate analysis. All QA/QC data are maintained at our laboratory by the QA/QC officer.

DataChem Laboratories is NVLAP and AIHA accredited. Laboratory accreditation by the National Institute of Standards and Technology (NIST) does not in any way constitute approval or endorsement by NIST.

Alex Bell
Analyst

Anna Marie Ristich
Reviewer

# DataChem Laboratories Phase Contrast Microscopy Analytical Report

6/29/00

DCL Sample Set ID: 00-A-2850

Client: US Consumer Product Safety Commission          Sample Location: NIOSH Glove Bag

| *ANALYSIS INFORMATION* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Graticule Area ($mm^2$): | 0.00817 | | | | | | | |
| ***SAMPLE INFORMATION*** | | | ***SAMPLE RESULTS*** | | | | ***LOD*** | |
| Client Sample Nos. | DCL Nos. | Vol. (L) | Fib/Field | Fib/$mm^2$ | **Fib/Filter** | **Fib/mL** | *(Fib/$mm^2$)* | *(Fib/mL)* |
| 001 - A-1 | 00-16066 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 002 - A-2 | 00-16067 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 003 - B-1 | 00-16068 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 004 - B-2 | 00-16069 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 005 - B-3 | 00-16070 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 006 - B-4 | 00-16071 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 007 - P-G720 | 00-16072 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| Blank#1 | 00-16073 | NA | 0.000 | <LOD | **<LOD** | **NA** | 7 | NA |
| 010 - A-1 | 00-16074 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 011 - A-2 | 00-16075 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 012 - B-1 | 00-16076 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 013 - B-2 | 00-16077 | 300.00 | 0.010 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 014 - B-3 | 00-16078 | 300.00 | 0.015 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 015 - B-4 | 00-16079 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| 016 - P-G720 | 00-16080 | 300.00 | 0.000 | <LOD | **<LOD** | **<LOD** | 7 | 0.009 |
| Blank#2 | 00-16081 | NA | 0.000 | <LOD | **<LOD** | **NA** | 7 | NA |

***Comments*: Crayons used were Crayola Orchid, Atomic Tangerine and Blue; and Prang Yellow, Light Yellow and Periwinkle.

Samples 001 – A-1 through Blank#1 were collected during the first half-hour session as background samples. No crayons were used during collection of the background samples.

All six crayons were used in the glove box for the second half-hour session, when Samples 010 – A-1 through Blank#2 were collected.

For each session, four samples, designated B-1 through B-4, were collected inside the glove box; two samples designated A-1 and A-2 were collected outside the glove box; and two personal samples, designated P-G720, were collected.

*NOTES: "NA" indicates no volume was given or the sample is a blank.
All samples counted using the "A" rules.

Alex Bell
Analyst

Anna Marie Ristich
Reviewer

# Appendix C

## Analysis of Talc

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AIHA Industrial Hygiene ACCREDITED LABORATORY

June 12, 2000

BACKGROUND INFORMATION REGARDING THE ANALYSIS OF INDUSTRIAL TALCS

When OSHA first promulgated its expanded asbestos standard in 1972, it included what was understood to be the occupationally important asbestos minerals. The term asbestos is not a proper mineralogical term. It has been applied for thousands of years to minerals which were obviously fibrous and could be used for spinning and weaving, fireproofing and for composite materials in clays and pottery. It came to be applied to any of the minerals having this gross appearance and use. By the time OSHA promulgated its standard, the commercial definition was limited to chrysotile, Amosite (grunerite asbestos), crocidolite, anthophyllite asbestos, tremolite asbestos and actinolite asbestos. (29 CFR 1910.1001(b)). These were the minerals that were encountered in occupational asbestos exposures.

In addition to these six minerals, there are over one hundred other minerals known to exist in the asbestiform habit (Walter Bank, private communication , 1978). These minerals are not properly known as "asbestos." The fibers contained in these minerals have the same general growth habit and shape as the fibers of the six asbestos minerals. They can be easily parted along their length, and they generally have a high tensile strength both of which give rise to fibers with very high aspect ratios (ratio of the length to with of individual fibers). Without careful mineralogical identification, some of these minerals can easily be misidentified as one of the six asbestos minerals. In addition to any confusion brought to the table by non-asbestos asbestiform minerals, some of the asbestos minerals grow in non-asbestiform habits. When crushed, these minerals will form cleavage fragments which may be much longer than they are wide owing to preferential parting along a preferred axis. These are fibers. But, they are not asbestiform. Fibers of asbestos are asbestiform because they grew that way, not because they were crushed to make them fibrous. Some minerals have different names for the various growth habits they possess. In the case of tremolite, actinolite, and anthophyllite there is no separate name given. The asbestiform varieties must be identified by using the adjective, asbestiform or asbestos, (e.g. asbestiform tremolite).

Beyond the morphological ambiguity, minerals do not occur in exactly the same chemistry throughout the world, or even across an individual deposit. It is possible, with adequate representative samples, to identify a particular mine from which a mineral was removed. The elements present, the temperature, pressure, time, and exposure all contribute to the composition and structure of a given mineral. Along with chemical variations, there also exist structural differences and accidents which occur because of particular conditions present at the formation of the mineral and through subsequent time. A mineral once formed in a process may be changed either rapidly or slowly to another mineral given a proper set of circumstances.

Historically, it has been the analyst's task to sort out, identify and classify minerals according to a set of optical criteria. The results of these optical tests performed in a polarizing microscope, will identify most minerals. It is not always possible, nor desirable, to perform every test for every particle because the particle is too small to give a result, or only some tests are required where the mineral identification is limited to a small number of possibilities.

This is the case with the asbestos minerals. When determining the type and percent of commercial asbestos minerals, in a product to which it was intentionally added, it is only necessary to determine two of the three major indices of refraction, the sign of elongation, the angle of extinction, and observe that the mineral is birefringent. Where only commercial asbestos is present, there are no serious interferences and this limited set of information is adequate to identify the presence of chrysotile, Amosite, crocidolite, tremolite asbestos, actinolite asbestos and anthophyllite asbestos. If other, asbestiform minerals are present, or if non-asbestiform cleavage fragments of one or more of the asbestos minerals is present, an analyst may encounter difficulty in determining which fibers are asbestos and which are not.

Relatively recently, x-ray diffraction, transmission electron microscopy, microprobe analysis, and scanning electron microscopy have been added to the arsenal of the mineral analyst. These tools allow the analyst to investigate the crystal structure and the chemical content of minerals. They also introduce a new set of confounding information which can confuse and mislead an analyst trained mainly to look for commercial asbestos minerals.

The tremolitic industrial talcs such as those found in New York present a difficult analytical problem. The material has a high component of non-asbestiform tremolite, some mostly non-asbestiform anthophyllite, some massive and some asbestiform talc, some quartz, and some intermediate or transitional asbestiform mineraloids along with traces of other minerals.

This mineral assemblage presents two red herrings for asbestos analysts. This group of products has cleavage fragments of non-asbestos tremolite and anthophyllite which, while meeting the definition used for phase contrast counting (aspect ratio longer than or equal to 3 to 1 and longer than or equal to 5 micrometers), are not covered by the OSHA definition of asbestos. Secondly, there are asbestiform fibers in the products which range in composition from nearly that of anthophyllite to talc. Except for a very few fibers occasionally found to be anthophyllite asbestos, these fibers are generally not covered by the OSHA asbestos standard.

The first problem is complicated by two factors. The first is that cleavage fragments are not covered by federal standard while the most common method used by NVLAPS laboratories requires the inclusion of cleavage fragments. The second is that it may not be possible to determine whether an individual fiber is a cleavage fragment or an asbestiform fiber if it has an aspect ratio less than about 20 to 1. Asbestiform minerals usually have average aspect ratios in excess of 100 to 1, while cleavage fragment distributions typically have mean aspect ratios below 10 to 1. Some help is afforded by the information in OSHA method ID-191 or of Bureau of Mines Information Circular IC8715. These document some of the analytical clues. A determination for a mineral is usually made if the average aspect ratio appears to be very large or the cleavage fragments are generally free of longitudinal striations or they are acicular or other non-asbestiform fiber shape.

The second problem leading to false identification of asbestos in these talcs is the presence of the asbestiform intermediate or transitional fibers. It is thought that these fibers were once anthophyllite and have undergone a mostly completed retrograde metamorphosis to talc. Their appearance is strikingly asbestiform. The selected area diffraction patterns obtained in the usual manner for asbestos analysis appear almost like those of anthophyllite asbestos. This is due to the peculiar crystal structure of the talc in this mineraloid. If one looks directly at the crystal structure using high resolution electron microscopy, the structure of the fiber can be seen to consist of randomly distributed chains of amphibole (anthophyllite), talc, and pyroxene chains. The individual fibrils (smallest asbestiform fiber structure) are constructed of a fine mixture of minerals on a scale too fine to be resolved by a light microscope. This particular arrangement of atoms gives a diffraction pattern with enough amphibole character to mis-identify it as anthophyllite.

The same structure also lead to erroneous identification of the chemistry. In pure end-member talc, there are 6 magnesium atoms for every 8 silicon atoms. In the magnesian end member for anthophyllite, there are 7 magnesium atoms for every 8 silicon atoms. The EDX spectra for such fibers are almost indistinguishable by observation alone. It is only by very careful calibration and quantitative analysis that an analyst is able to differentiate these intermediate fibers from anthophyllite. The average analysis for these fibers puts the concentration of magnesium at between 6.5 and 6.8 magnesium atoms per 8 silicon atoms. A fiber having a magnesium population at or above 6.8 would be considered to be anthophyllite if it has a corroborating Selected Area Electron Diffraction (SAED) pattern, with an internal standard (gold), to be indexed as anthophyllite.

It is generally observed that PLM laboratories do not always perform the TEM because they see the cleavage fragments and call them asbestos. Conversely, TEM laboratories do not perform the PLM and call the fibers seen anthophyllite with some tremolite.

When the techniques are combined, it is noted that the asbestiform fibers have indices of refraction almost exclusively below 1.592. Also, there are some cleavage fragments of tremolite having indices of refraction above that in the range 1.620 and very occasionally a fiber appearing to be asbestiform with indices of refraction in the range of 1.620 which is probably anthophyllite. It is rare to see a fiber clearly identifiable as anthophyllite in the PLM.

Conversely, when viewed in the TEM, almost all of the fibers appear to be anthophyllite using the usual techniques of asbestos analysis applied to the asbestos abatement industry. The diffraction patterns are sufficiently similar that using only pattern recognition, a mistake is made. The usual check on this mis-identification is to look at the EDX chemistry. It is so similar to the anthophyllite that it only confirms the identification of anthophyllite.

What TEM says is there is denied by PLM. The cure, in this case, is careful analysis. Pattern recognition for SAED contains a number of pitfalls which should be avoided by indexing wherever practical. Whenever general mineralogical materials might be present beyond the commercial asbestos minerals, it is very important to step beyond the short set of identification criteria and fully identify the fibers present.

In summary, the difficulty and novelty of the minerals present and the complexity of the regulatory environment led to an identification of asbestos where none exists. The relative risk of exposure to non-asbestos asbestiform minerals was not addressed in any of this discussion and inclusion or non-inclusion of any mineral should not be taken as a statement of risk by OSHA.

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

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***SENT BY CERTIFIED MAIL — RETURN RECEIPT REQUESTED***

August 11, 2000

Mr. Thomas Sinwald
Director of Research and Development
Dixon Ticonderoga Company
195 International Parkway
Heathrow, FL 32746-5036

Dear Mr. Sinwald:

Thank you for providing comments on the draft, *CPSC Staff Report on Asbestos Fibers in Children's Crayons*. The CPSC staff has reviewed and carefully considered your comments contained in your July 19, 2000 letter. The staff agrees with several of your comments concerning how the risk is expressed in the summary and conclusion sections of the report, and has revised these sections accordingly. Draft copies of the revised sections are enclosed. Your comments, however, do not alter the CPSC staff's conclusion that anthophyllite asbestos and transitional fibers were found during laboratory analysis of Prang crayon samples. The staff does not agree with your comment that a positive result for any anthophyllite asbestos fibers in your crayons was not found. A more detailed response to your comments regarding the identification of fibers in your crayons follows.

**Comment: Only one of the laboratories contracted by the CPSC (DataChem) found asbestos fibers in Prang crayons.**

**Response:** A difference between DataChem results and OSHA results does not negate the positive finding by DataChem Laboratories. OSHA's analysis was limited to the characterization of the fibers present. OSHA looked at a limited number of fibers by transmission electron microscopy (TEM). The amount of anthophyllite fiber present in the sample is very low and therefore it is not surprising to have two separate analyses where one may find a few fibers and the other not find any.

**Comment: DataChem claims to have found two singular fibers of anthophyllite utilizing transmission electron microscopy (TEM), but their findings were not confirmed in their own polarized light microscopy (PLM) analysis.**

**Response:** PLM is limited by the smallest fibers that can be imaged by visible light. Fibers much smaller than 1 micron in diameter are difficult to see and analyze. Fibers thinner than about 0.2 to 0.5 microns in diameter are not visible depending upon the particular microscope platform used. It is not surprising that there might be some very fine fibers missed using PLM. Individual fibers of much smaller diameter can be viewed and analyzed using TEM.

**Comment: The anthophyllite in the Prang crayon residue was misidentified because it did not contain iron.**

**Response:** Anthophyllite (an amphibole mineral) is identified in mineralogy texts as a solid solution series chain silicate having a compositional range from $Mg_7Si_8O_{22}(OH)_2$ to $Fe_2Mg_5(Si_4O_{11})(OH)_2$. Iron freely substitutes with Mg in anthophyllite, but is not required to be present. The composition of a particular anthophyllite depends upon the available elements when it formed and the environment in which it has existed since formation. With a few exceptions, most anthophyllite does contain some iron, however the Gouveneur talc deposit in New York State is one of the exceptions. As mineralogists examine the amphibole family of minerals more closely, it becomes obvious that these minerals exhibit subtle changes in chemistry and/or structure, even in so-called "standards."

A decision whether a fiber is anthophyllite is made on the basis of a composition having at least 80% of the tetrahedral sites different from talc filled with Mg, Fe, or Mn. In this case, the sites were filled with Mg, so that the analysis yielded a formula in excess of $Mg_{6.8}Si_8O_{22}(OH)_2$, where talc, normalized to 8 silicon atoms per unit cell is $Mg_6Si_8O_{20}(OH)_4$ and anthophyllite is $Mg_7Si_8O_{22}(OH)_2$, as above.

**Comment: DataChem took only one SAED pattern and several patterns from different positions are necessary to identify a fiber as asbestos. OSHA states that they took two patterns from each sample and excluded all fibers from identification as anthophyllite.**

**Response:** The statement concerning the need for several patterns from different positions to identify asbestos is incorrect. Although it is necessary to acquire two different "zone axis" SAED patterns to adequately describe the unit cell of a crystalline material, only one indexed zone axis pattern is necessary to identify the substance. The chemical data obtained through Energy Dispersive X-Ray Analysis (EDXA) is used to reinforce the conclusion arrived at by SAED. Multiple SAED patterns or chemistry determinations on this particular material would not have given results different from those reported.

Apparently there is some confusion as to how many SAED patterns were done on fibers by OSHA. The only reference in OSHA's report to two of anything was to two grids. Fibers from two grids were examined for each crayon analyzed. Only one pattern was obtained from each fiber observed.

**Comment: DataChem accepted aspect ratios of less than 20:1 for fibers identified as asbestos.**

**Response:** In commercial asbestos deposits, asbestiform fibers have very long average aspect ratios, in excess of 100:1. Coarser, poorer deposits may have average aspect ratios much less than that. In any deposit of asbestos or asbestiform mineral, there are fibers which have relatively short aspect ratios, even down to 3:1. Applying an average group definition, such as aspect ratio, to individual fibers is not appropriate. In addition, what is recovered from the crayon is from a product that is not necessarily representative of the ore body. It has been beneficiated and sized to provide a uniform commercial product (i.e., it is not in it's natural state). It is for this reason that high aspect ratio was not a critical consideration in determining which fibers were identified as asbestos.

Thank you for your comments. We plan to release the final report in the next several weeks, but not sooner than ten (10) working days after you receive this letter. We will provide you with a copy of the final report, at which time you may of course feel free to quote its conclusions. If you have any questions please call me at (301) 504-0554.

Sincerely,

Ronald L. Medford

Ronald L. Medford

Enclosures

**8/10/00 draft**

# CPSC STAFF REPORT ON ASBESTOS FIBERS IN CHILDREN'S CRAYONS
**August 2000**

## Summary

On May 23, 2000, the *Seattle Post-Intelligencer* reported finding asbestos in three major brands of crayons, Crayola, made by Binney and Smith; Prang, made by Dixon Ticonderoga, and Rose Art. The **reported** asbestos was believed to be found in the talc used by the crayon manufacturers as a binding agent. The specific asbestos minerals **reported by the laboratories contracted by the Seattle Post-Intelligencer,** tremolite, chrysotile, and anthophyllite, were identified in some of the crayons in concentrations ranging from 0.03% to 2.86% by transmission electron microscopy (TEM). Asbestos was not identified in any of the tests conducted by the three crayon manufacturers.

The U S. Consumer Product Safety Commission (CPSC) staff examined crayons from several different boxes from the three companies to determine whether asbestos was present, evaluated the potential for exposure to children, and evaluated the potential risk.

Trace amounts of anthophyllite asbestos and larger amounts of other fibers (transitional fibers) were found in Crayola and Prang crayons by polarized light microscopy (PLM). The concentrations of asbestos ranged from below the limit of detection to 0.03%. The concentrations of transitional fibers ranged from below the limit of detection to 1.25%. The Rose Art crayons did not contain any asbestos or transitional fibers.

Based on the results of the testing and evaluation, the staff concludes that **the risk a child would be exposed to the fibers through** ~~children are at a low risk from~~ inhalation or ingestion of crayons containing asbestos and transitional fibers **is extremely low.** No fibers were found in the air during a simulation of a child vigorously coloring with a crayon for half an hour. The risk of exposure by eating crayons is also **extremely** low because the fibers are imbedded in the crayon wax and will pass through the child's body.

Although CPSC staff determined that the risk is **extremely** low, the staff believes that as a precaution, crayons should not contain these fibers. CPSC staff asked the industry to reformulate crayons using substitute ingredients Binney and Smith and Dixon Ticonderoga agreed to reformulate within a year to eliminate talc. Rose Art indicated that they stopped using talc in 90% of their crayons about 15 months ago and will reformulate the remaining small percentage of crayons made with talc.

CPSC will continue to monitor children's crayons to ensure they do not present a hazard.

### 1. Inhalation

No fibers were detected during the test for release of fibers from use of crayons. Since the test involved aggressive use of the crayons—drawing with considerable force, shading, rubbing, and breaking of crayons—no release of fibers would be expected during normal use of crayons by children. Since no exposure to fibers would be expected from use of crayons, the crayons present a low risk of health effects from inhalation of fibers.

### 2. Ingestion

Fibers in the crayons are embedded in the wax. The melting point of crayon wax is considerably higher than body temperature. Therefore, release of fibers from the wax would not be expected to occur from wax melting within the body. Further, crayons are not soluble in acid and are not expected to dissolve in the gastrointestinal tract. Thus, release of fibers from a crayon into the body would not be expected to occur after swallowing all or part of a crayon from the melting of the wax or the dissolving of the wax.

## VI. Conclusions

After receiving reports that children's crayons contain asbestos, the CPSC began an investigation to determine whether asbestos is present in crayons Based on the results of laboratory analysis, the staff evaluated the potential for exposure to children, and evaluated the potential risk

Trace amounts of asbestos and larger amounts of other fibers (transitional fibers) were found in Crayola and Prang crayons by PLM. The concentrations of asbestos ranged from below the limit of detection to 0.03%. The concentrations of transitional fibers ranged from below the limit of detection to 1.25%. The Rose Art crayons did not contain any asbestos or transitional fibers The presence of these fibers was confirmed by TEM by DataChem Laboratories.

Based on the results of the testing and evaluation, the staff concludes that **the risk a child would be exposed to the fibers through** ~~children are at a low risk from~~ inhalation or ingestion of crayons containing asbestos and transitional fibers **is extremely low.** No fibers were found in the air during a simulation of a child vigorously coloring with a crayon for half an hour. The risk of exposure by eating crayons is also **extremely** low because the fibers are imbedded in the crayon wax and will pass through the child's body.

Although CPSC staff determined that the risk is **extremely** low, the staff believes that as a precaution, crayons should not contain these fibers CPSC staff asked the industry to reformulate crayons using substitute ingredients. Binney and Smith and Dixon Ticonderoga agreed to reformulate within a year. Rose Art indicated that they stopped using talc in 90% of their crayons about 15 months ago and will reformulate the remaining small percentage of crayons made with talc.

8/10/00 draft

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July 19, 2000

U.S. Consumer Product Safety Commission
ATTN: Ron Melford
Office of Hazard Identification and Reduction
Washington, D.C. 20207

Dear Ron:

Thank you for sending a draft copy of the CPSC Staff Report on Asbestos Fibers in Children's Crayons. The report is very thorough. We were pleased with the CPSC's genuine effort to explain the technical complexity and uniqueness of New York State tremolitic talc.

We would like to make a few suggestions for the Report's Summary (to also be included in the Conclusion Section) by addressing language semantics and the inclusion of a technical overview There are also a few text clarifications needed to ensure that readers correctly understand the Report

Semantics

We wanted to point out differences in language semantics between the CPSC's Press Release (dated June 13, 2000) and the Report's Summary and Conclusion. I believe the implicit support regarding the safety of our products in the press release as compared to the generality in the Report will likely lead to confusion regarding the safety of crayons.

Please notice the following excerpts from the CPSC's Press Release:

- "However, the amount of asbestos is so small it is scientifically insignificant"
- "... the risk a child would be exposed to the fibers either through inhalation or ingestion is extremely low and there is no scientific basis for a recall".
- "CPSC tests concluded that there is no cause for concern"

Whereas, the final Report's Summary and Conclusion only state

- "... children are at a low risk from inhalation or ingestion of crayons containing asbestos and transitional fibers"

Since the Report is recent and final, the general public may surmise that further detrimental information was found regarding crayon safety. We specifically oppose the language of "crayons containing asbestos" implying that our crayons meet the definition of having asbestos. Below, we argue the validity of two, scientifically insignificant fibers that one of your two laboratories claims to have found. Furthermore, if the average reader actually read the complex, technical report in its entirety, they would most likely be left more confused and concerned about using our crayons.

To preclude any suspicions of impropriety or crayon safety, the Report's Summary and Conclusion should, at a minimum, reflect the language of the press release. Specifically, please include "extremely" as the adjective for "low", as well as the other affirmative, safety-oriented statements found in the press release.

Technical Overview

Anyone requesting this report is seeking clarification between the various laboratory results provided in the media, but the Summary and Conclusion does not provide a reasonable synopsis of the entire situation. We believe the Summary and Conclusion misleads the reader. We specifically would like to include a statement in the Summary and Conclusion stating "Although one of the laboratories contracted by the CPSC found one scientifically insignificant fiber in two separate samples of Prang crayons, OSHA (also contracted by the CPSC) and two separate, independent laboratories contracted by Dixon Ticonderoga Company did not find asbestos and any asbestos fibers".

The exclusion of a discussion regarding the technical difficulties of identifying singular asbestos fibers in the Summary is obvious and damaging. The statement "New York State talc and their uniqueness, and how, even by following accepted procedures, it is still easy to misidentify non-asbestos fibers as asbestos" as stated in Appendix C will likely lead the requesting party to read the report completely and carefully. Therefore, please include the above statement in the Summary and Conclusion.

Clarifications Needed

A contradiction between the two labs contracted by the CPSC appears on page 4 - III. Results, Crayon Analysis. The Report mentions that both labs detected fibers in 16 of the crayons tested. The next sentence reports that trace amounts of asbestos were found in samples of Crayola and Prang crayons. This makes it appear that both labs found asbestos, when really only DataChem and only through TEM analysis. PLM Analysis by both labs contracted by the CPSC does not show anthophyllite or any other asbestiform fibers. Salt Lake Technical center found no asbestos fibers in any of the crayons. This is definitely not made clear in the Summary or Conclusion.

The Summary begins with a reference to the Intelligencer. We would prefer all reference to the Intelligencer removed to prevent credence being given to both the reporting methods and the inconclusive findings of laboratories using incorrect bulk testing methods. If this is not accomplished, the entire first paragraph needs clarification. Sentence 2 should read: "The reported asbestos... ". The third sentence begins with "The specific asbestos minerals... " which leads the reader to conclusive findings. It should specify either preferably "reported" or "by laboratories contracted by the Intelligencer". We hope the CPSC's intention was only to share what the Intelligencer had reported and not to imply that your "facts" support their reporting.

The last sentence of the first paragraph on Page 1 refers to the tests conducted by the manufacturers and should, perhaps, go into a separate paragraph to ensure clarification. We would also like to point out that the CPSC, in its Summary, has dedicated 5 ½ lines to what the Intelligencer reported, yet only one sentence regarding the manufacturers position.

We believe a clarification paragraph three such as "Only one of the two laboratories contracted by the CPSC found scientifically insignificant trace amounts...." would be appropriate.

Paragraph four states "children are at a low risk from inhalation or ingestion of crayons" which is misleading. There is no risk of inhalation based on your own testing and, in the first paragraph of the Introduction on Page 2, the CPSC states that "Studies... indicate that ingestion of asbestos causes little or no risk of noncarcinogenic injury". The sentence would be more appropriate by stating "children are at little or no risk... ".

On Page 5, Section V. Assessment of Risk, A. summary of health Effects, summarizes the effects of asbestos in general, but such a broad explanation is not necessary and confuses the reader. We believe the Report should only focus on asbestiform fibers found in tremolitic talc, and perhaps even more specifically, concentrate only on the tremolitic talc from the New York mines. The inclusion of a detailed summary of the health effects caused by all asbestos leads the reader to assume crayon use or ingestion may incur these same health effects.

CPSC's Laboratory Results

We question the choice of having DataChem's results placed before OSHA's results, which are more favorable to the industry and much easier to read. We would prefer to have the order reversed with OSHA's test results placed before DataChem's test results.

DataChem claims to have found two singular fibers of anthophyllite utilizing TEM, but their findings were not confirmed in their own PLM analysis. We contend that the two fibers found by DataChem are incorrectly identified because neither fiber contains iron. Since the composition of anthophyllite consist of magnesium with iron and silicon, positive identification of two singular fibers that do not contain iron can not conclusively be ruled as anthophyllite asbestos. Furthermore, it is almost impossible to distinguish between 'anthophyllite' that does contain iron and fibrous talc.

When using SAED, to determine whether a sample is a mixed fiber, you must take several patterns on the same fiber at different positions. It appears that DataChem took only one pattern of each sample, but OSHA clearly states that they took two patterns from each sample. OSHA's observation "excluded all fibers from identification as anthophyllite" and states that "none of the fibers examined had chemistry sufficiently close to anthophyllite to be included in the definition of anthophyllite".

It is also unlikely that any asbestos component would be dominated by particles having aspect ratios of less than 20:1. (Prang Periwinkle sample's aspect ratio is only 12.5:1) Moreover, most asbestos components would have average aspect ratios in excess of 100:1. (Prang Yellow sample's aspect ratio is only 24.8:1) Since the two fibers do not display the additional asbestiform characteristics, by definition, they should not be considered asbestos.

For these reasons, we do not believe a positive result for any anthophyllite asbestos fibers in our crayons was found. We strongly object to the statement "children are at a low risk from inhalation or ingestion of crayons containing asbestos and transitional fibers" since our crayons do not contain asbestos or a singular fiber of anthophyllite asbestiform fibers. Two independent laboratory tests, contracted by us, also conclude that all our crayons are asbestos free.

Ron, again we would like to thank you for sharing your draft report and look forward to working with you to develop the final Report. Due to travel requirements for both Rick Joyce and myself, please contact Jennifer Brooks or Jo Carol Walton with any questions.

Sincerely,

for Thomas Sinwald

Thomas Sinwald
Director of Research and Development
Dixon Ticonderoga Company