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MISIDENTIFICATION OF ASBESTOS IN TALC

Jerome B. Krause

Colorado School of Mines Research Institute
Golden, Colorado 80401

and

William H. Ashton

Johnson & Johnson
Raritan, New Jersey 08869

Abstract

Both optical microscopy and x-ray diffraction (XRD) are widely used to detect minerals associated with talc. Optical microscopy can determine the morphology of a particle, but cannot always fully identify the specific mineral. Although XRD is an excellent screening technique for the detection of minerals associated with talc, the method can misidentify minerals due to interferences, interpretive errors, and the inability to determine morphology.

Methods for reduction or elimination of these problems include special techniques of sample preparation and x-ray diffraction, combined with microscopic examination (both optical and electron).

Key Words: Amphiboles; asbestos; chlorite; electron microscopy; fiber; morphology; optical microscopy; x-ray diffraction; talc.

Introduction

There are many ways to analyze and study any naturally occurring material. The conclusions reached will often vary widely depending on the expertise and specific interest of the investigator. That situation sums up the present status of "asbestos"; it is also the status of minerals which are associated with "asbestos"; and it is becoming the status of other minerals which can be naturally associated with talc.

Popular methods of analysis can give the wrong answer – namely that asbestos is present when it certainly is not. That problem (misidentification) is not so much one of limitations of the methods, but rather one of misinterpretation of data, and failure to recognize the mineralogical background required to certify mineral purity, for example, when analyzing sheet silicates for asbestos. Unfortunately, one main factor is that asbestos has now developed variable definitions, depending on whether the point of view is mineralogical, industrial, medical, or regulatory. The medical definition is most concerned with whether or not the particles are biologically active; the industrial definition is dependent upon flexibility and weavability; the mineralogical definition upon crystallography; and the regulatory definition upon size and aspect ratio.

The word "asbestos" stems from ancient Greek and has always referred to a very fibrous industrial mineral product. Since asbestos has historically related to a mineral exploited as an important industrial commodity, we think a combined mineralogical and industrial definition should take precedence [1,2][1]. Other presentations during this

[1]Figures in brackets indicate the literature references at the end of this paper.

workshop have amply covered the aspects of asbestos terminology, and it is not our intent to provide comprehensive coverage of that subject. Our primary objective is to review some of the basic principles of analysis, and to point out problem areas where identification of "asbestos" has been abused.

Analysis Methods and Misidentification of Asbestos

It is useful to categorize the various analytical methods which have been applied to talc to highlight inherent principles which lead to misidentifying asbestos as being present. We offer the following general comments on the three principle determinative properties (chemical composition, morphology, structure).

Chemical Composition

It is well known that every mineral has a specific chemical composition, and that each mineral has an ideal theoretical chemical formula (configuration). Unfortunately, many investigators overlook the fundamental point that chemical composition does not identify a specific mineral. A simple example will bring that point into focus:

> A pearl, an oyster shell, a slab of marble, a piece of chalk, and the minerals aragonite and calcite are obviously different materials, and yet each will be identified as calcium carbonate. That is to say, chemical analyses will identify them all as the same substance, where everyone knows that a pearl is not a piece of chalk.

The same situation exists in certain phases of asbestos analysis. For example, chrysotile, antigorite, lizardite, sepiolite, chlorite, and talc are all hydrous magnesium silicates. But a Meerschaum pipe (sepiolite) is certainly not chrysotile asbestos in spite of the fact that chemical analysis alone could lead to that misidentification.

Accordingly, chemistry alone does not identify a mineral, nor do those sophisticated instrumental methods which are based on chemical principles, such as:

Wet Chemical Analysis

- Classical (gravimetric, volumetric)
- Instrumental (atomic absorption, flame emission)

Microprobe (electron and ion)

Emission Spectrograph

Mass Spectrograph

X-Ray Fluorescence

Morphology

Although the shape of a mineral particle is one of the key characteristics in the identification of a mineral, shape alone cannot be the sole determinant of a specific mineral species. There are hosts of minerals in different mineral classes whose particles have the same shape. They exist across the spectrum of all classes of minerals and the possibilities are beyond comprehension. Even if we limit ourselves to minerals which occur in the true fibrous state, we would estimate there are up to 100. There have been instances where nonasbestos particles have been misidentified as chrysotile in talc because shape alone was the index used.

Methods based on morphology include:

- Optical Microscopy
- Automated Image Analyzers
- Electron Microscopy (SEM and TEM)

Structure

The configuration of atoms in the crystal lattice of a mineral does not necessarily determine a mineral species. The atomic arrangement at the molecular level does not always carry through to the external visible physical form. That is to say that methods based on molecular structure can misidentify a mineral. For example, chrysotile asbestos is classified with the sheet silicates because of its crystal structure arrangement, but it certainly does not occur in flat sheets like the micas or its sibling, antigorite.

Methods of identification which relate to molecular structure are:

Infrared Spectroscopy

Differential Thermal Analysis

X-ray Diffraction

Electron Diffraction

In general then, no single property defines a mineral, and no single method which depends on one property can identify a specific mineral.

Conversely, methods which depend on a single factor or characteristic of a mineral can give misidentifications.

Two Popular Methods

Optical microscopy and x-ray diffraction methods require some additional discussion primarily because they have received widespread attention by industry and government laboratories as possible monitoring techniques.

Although both these methods are fundamental to the science of mineralogy and are highly reliable in the hands of experts, complications arise when shortcuts are taken in the professional procedures.

Optical Microscopy

When an experienced optical mineralogist or crystallographer identifies a mineral with a petrographic microscope, he can come to a remarkably accurate conclusion. The reason for high accuracy is that not one but several specific properties are determined, such as refractive indices, extinction angle, birefringence, and optical orientation. Specific training and wide mineralogical background are required to get the right answer.

In contrast, current optical methods in federal regulatory proposals relating to asbestos presume that asbestos is present in the first place. The analyst then merely observes the mineral particle for size/shape. Consequently, those methods which depend solely on aspect ratio give misidentification. They misidentify the presence of asbestos by such simple oversights as looking at a platelet on edge and counting it as an asbestiform particle. It is not necessary to elaborate on the other shortcomings of those methods in view of the recent NBS report on the analysis of 80 industrial talcs [3] evaluating that methodology. The same shortcomings were also recently corroborated in a study conducted by Harvard University and NIOSH [4].

However, there are a few rare cases where abnormal crystal habit can be misleading and subtly can lead to a misidentification. Optical microscopy is most vulnerable to this type of misidentification. For example, talc normally occurs as micaceous plates, but rare acicular talc does exist, and one must be very careful to avoid misidentifying the rare occurrence as asbestos. As an example, our XRD examination of an industrial acicular talc sample has identified the presence of significant amphibole (probably tremolite). However, when the material was subjected to thorough petrographic examination it was found to be composed of free grains of columnar amphibole and acicular talc and composite talc-amphibole. The significance is that an erroneous conclusion could be reached by misidentifying such a rare talc variety as asbestos, if only aspect ratio and simple optical microscopy were used.

Thus, simple optical microscopy can determine the morphology of a particle, but if used alone it cannot always fully identify the specific mineral observed.

X-Ray Diffraction

Although x-ray diffraction (XRD) is a valuable technique, it cannot determine the physical shape of a mineral particle, and for that reason it cannot determine whether or not a sample is asbestos. Furthermore, it cannot distinguish between two mineral varieties in the same mineral class in cases such as the asbestos minerals and their nonasbestiform analogues. It is surprising that such a basic shortcoming continues to be overlooked by responsible investigators alleging to have identified asbestos by XRD.

One result of the inability of powder XRD to differentiate between the asbestiform and nonasbestiform varieties of a mineral is the potential error of prejudging an XRD detected phase to be the asbestiform variety. For example, preparing calibration standards of mixtures of talc plus chrysotile could have the effect of causing a serpentine peak in an unknown sample to be prejudged as the asbestiform variety, i.e., chrysotile. A mixture of talc spiked with the serpentine mineral chrysotile will give the same XRD pattern as a mixture of talc spiked with the very common platy serpentine mineral antigorite. It should be obvious that an unknown talc showing a serpentine peak cannot be prejudged or branded as containing chrysotile asbestos under such circumstances. Unfortunately, the literature has articles by responsible authors who have overlooked that error in logic [5,6,7].

For research purposes only, single crystal XRD can provide information as to whether or not the specimen could be asbestos. However, due to the difficulty of handling minute specimens, single crystal XRD is inadequate for particles smaller than about 20 x 5 μm, and, of course, is also inadequate for routine monitoring procedures.

Amphiboles

Each of the five amphibole minerals, anthophyllite, cummingtonite-grunerite, riebeckite, tremolite, and actinolite has an asbestiform variety, namely anthophyllite asbestos, amosite, crocidolite, tremolite asbestos, and actinolite asbestos, respectively. Tremolite asbestos is quite rare, and actinolite asbestos is so rare that a recent NIOSH project to prepare reference standard minerals has been unable to locate a source of pure actinolite asbestos [8].

The amphiboles (named from the Greek "amphibolos," meaning ambiguous) are characterized by similar crystal structure and wide variation in chemical composition and appearance. All amphiboles have XRD patterns which are similar, and are characterized by having their (110) or (210) diffraction peaks occur within ±0.2A of each other (Table 1, Figure 1). Reliable identification of individual amphibole species is difficult in the absence of confirming composition data.

Examination of Table 1 and Figure 1 illustrates that attempted identification of a specific amphibole on the basis of $d_{(110)}$ or $d_{(210)}$ has good potential for being in error. For example, selection of Joint Committee on Powder Diffraction Standards (JCPDS) card 13-437 as being definitive of tremolite presents serious problems. Twenty-nine additional JCPDS amphiboles have their (110) or (210) peaks within ±0.1°2θ of this tremolite (110) peak at 10.56°2θ. Identification of an amphibole as tremolite on the basis of a peak at 10.56°2θ is obviously an identification with very low reliability. In other words, a peak at that location is not necessarily the mineral tremolite since it could be one of 29 other minerals.

Table 1. Amphibole JCPDS Card No's., $d_{(110)}$ or $d_{(210)}$ peak position, and relative intensity.

JCPDS card #	Å[a]	2θ(Cu)	I	Name
23-118	8.58(1)	10.31	100	prieskaite
10-456	8.55(1)	10.35	100	richterite
20-734	8.53(1)	10.37	70	mboziite
20-378	8.52(1)	10.38	100	dashkesanite
14-633	8.51(1)	10.39	70	arfvedsonite
21-149	8.51(1)	10.39	55	hornblende
19-467	8.50(1)	10.41	100	ferropargasite, syn
20-982	8.50(1)	10.41	65	richterite, syn
23-665	8.48(1)	10.43	45	richterite, calcian, syn
23-664	8.47(1)	10.44	35	edenite, sodian, syn
23-667	8.47(1)	10.44	45	richterite, calcian, syn
23-663	8.46(1)	10.46	40	eckermanite, calcian, syn
9-434	8.45(1)	10.47	50	hornblende
13-499	8.45(1)	10.47	100	magnesioriebeckite
20-656	8.45(1)	10.47	100	magnesioriebeckite
20-470	8.44(1)	10.48	100	crossite
23-666	8.44(1)	10.48	40	tremolite, sodian, syn
20-469	8.43(1)	10.49	100	hastingsite
23-1405	8.43(1)	10.49	80	edenite
23-1406	8.43(1)	10.49	40	paragasite
20-1310	8.43(1)	10.49	40	tremolite, syn
10-428	8.42(1)	10.51	100	richterite, fluor, syn
23-603	8.42(1)	10.51	100	tirodite
10-431	8.41(1)	10.52	80	edenite, fluor, syn
19-1061	8.40(1)	10.53	100	riebeckite
20-481	8.40(1)	10.53	100	hornblende
20-1390	8.40(1)	10.53	90	winchite
23-302	8.40(1)	10.53	100	cummingtonite, mangoan
19-1063	8.39(1)	10.54	70	richterite
13-437	8.38(1)	10.56	100	tremolite
17-478	8.38(1)	10.56	65	kaersutite
23-495	8.38(1)	10.56	80	eckermanite
9-330	8.37(1)	10.57	100	tremolite, fluor, syn
17-750	8.36(1)	10.58	25	richterite, ferrian
20-386	8.35(1)	10.59	40	eckermanite, syn
22-531	8.35(1)	10.59	30	joesmithite
16-401	8.33(2)	10.62	70	anthophyllite, magnesian, syn
17-725	8.33(1)	10.62	100	grunerite
17-745	8.33(1)	10.62	100	grunerite
20-376	8.31(1)	10.65	100	crossite
17-726	8.30(1)	10.66	100	cummingtonite
20-484	8.29(1)	10.67	100	richterite
13-506	8.27(2)	10.70	80	gedrite
23-679	8.27(1)	10.70	90	glaucophane
9-455	8.26(2)	10.71	55	anthophyllite
20-453	8.26(1)	10.71	100	glaucophane
11-253	8.23(2)	10.75	100	ferrogedrite
23-310	8.20(1)	10.79	75	richterite, ferrian
13-401	8.11(2)	10.91	100	holmquistite

[a] $(110)^1$ or $(210)^2$.

Maximum $\Delta 2\theta(Cu) = 10.91° - 10.31° = 0.6°$

Table 1 illustrates the very close proximity of the (210) or (110) XRD peak of all amphiboles, showing the inability to identify a specific amphibole on the basis of $d_{(210)}$ or $d_{(110)}$.

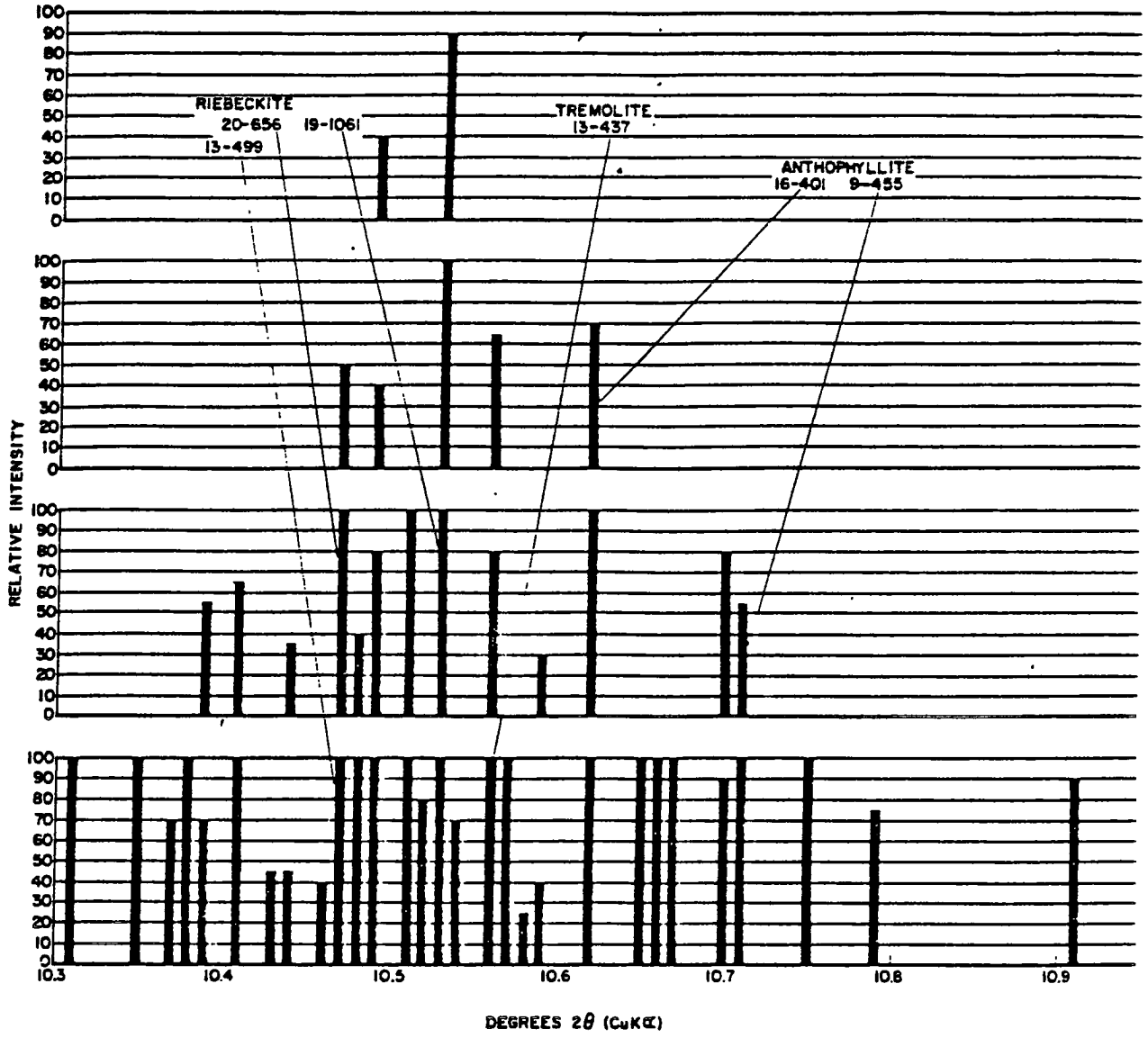

Figure 1. Amphibole $d_{(110}$ or $d_{(210)}$ — peak positions (2θ for CuK) and relative intensity.

An additional problem further affecting the reliability of identification by XRD is the effect of shift in peak position caused by slight mispositioning of the sample surface in the instrument. For example, a 100 μm mispositioning of the specimen surface will result in a shift of approximately 0.6-0.7 Å in d-spacing at low 2θ angles [9]. A slight shift in the position of the peak (from a different amphibole or mispositioning of the sample surface, for example) could go unnoticed, resulting in misidentification of an amphibole that is not even present.

In order to conclusively identify an amphibole by XRD, it is necessary to have an essentially complete diffraction pattern. In order to obtain such an XRD pattern, the sample must have a relatively high amphibole content and the pattern must be acquired with a time-consuming slow scan. Acquisition and interpretation of such patterns is time-consuming, and discourages proper application of the full procedure, especially for routine monitoring where large numbers of samples require analysis. Shortened procedures, such as single peak identification of amphiboles, provide gooc opportunity for misidentification. The shortened procedure of single peak identification was apparently used in a 1972 paper [7], where our examination of some of the same samples disagreed with identifications of serpentine, tremolite-actinolite anthophyllite, and anhydrite.

Chlorite-Serpentine

Chlorite is one of the most common accessory minerals found associated with talcs. The chlorite group of minerals are somewhat analogous to amphiboles in that they exhibit a wide variation in chemical composition and all have a similar crystal structure. The diagnostic chlorite basal XRD peaks (001), (002), and (004) are characteristic, and occur at about 14Å, 7Å, and 3.5Å, respectively. As in the case for the amphiboles, specific identification of a particular chlorite species by XRD is difficult. The XRD problem with chloritic talcs is that the serpentine first order basal peak overlaps the chlorite (002) peak, and the corresponding serpentine second order basal peak overlaps the chlorite (004) peak. Generally, however, the chlorite (004) and serpentine second order peaks are separate enough to allow unambiguous determination of the presence of both phases when present in adequate amounts to give definable peaks. Tables 2 and 3 and Figures 2, 3, and 4 are compilations of JCPDS data for the positions of the (004) basal peak for chlorites and (002), (004), or (0012) basal peak for serpentines, respectively.

Table 2. Chlorite JCPDS Card No's., $d_{(004)}$ peak positions, and relative intensity.

JCPDS card #	Å	2θ(Cu)	I	Name
10-183	3.60	24.73	100	penninite
20-671	3.60	24.73[a]	90	kämmererite.
16-351	3.59	24.80	70	chlorite 1b
12-185	3.57	24.94	85	kotschubeite
7-160	3.58	24.87	60	kotschubeite
19-749	3.56	25.01	80	clinochlore
7-77	3.558	25.03	50	sheridanite
16-362	3.55	25.08	80	chlorite 1a
19-751	3.55	25.08	65	sudoite
22-712	3.55	25.08	45	nimite
7-165	3.545	25.12	60	grochauite
7-78	3.541	25.15	60	thuringite
7-171	3.541	25.15	80	diabantite
12-242	3.54	25.16	100	leuchtenbergite
7-76	3.537	25.18	50	ripidolite
13-29	3.53	25.23	80	thuringite
7-166	3.523	25.28	50	daphnite
12-243	3.52	25.30	92	aphrosiderite
21-1227	3.52	25.30	100	thuringite
3-67	3.49	25.52	100	thuringite

[a] $d_{(115)}$.

Table 2 illustrates variation in position of the chlorite $d_{(004)}$ XRD peak. Table 2 should be compared with Table 3 to see that the chlorite and serpentine XRD peaks overlap and interfere with each other. Identification and quantification of serpentine in the presence of chlorite is extremely difficult at best.

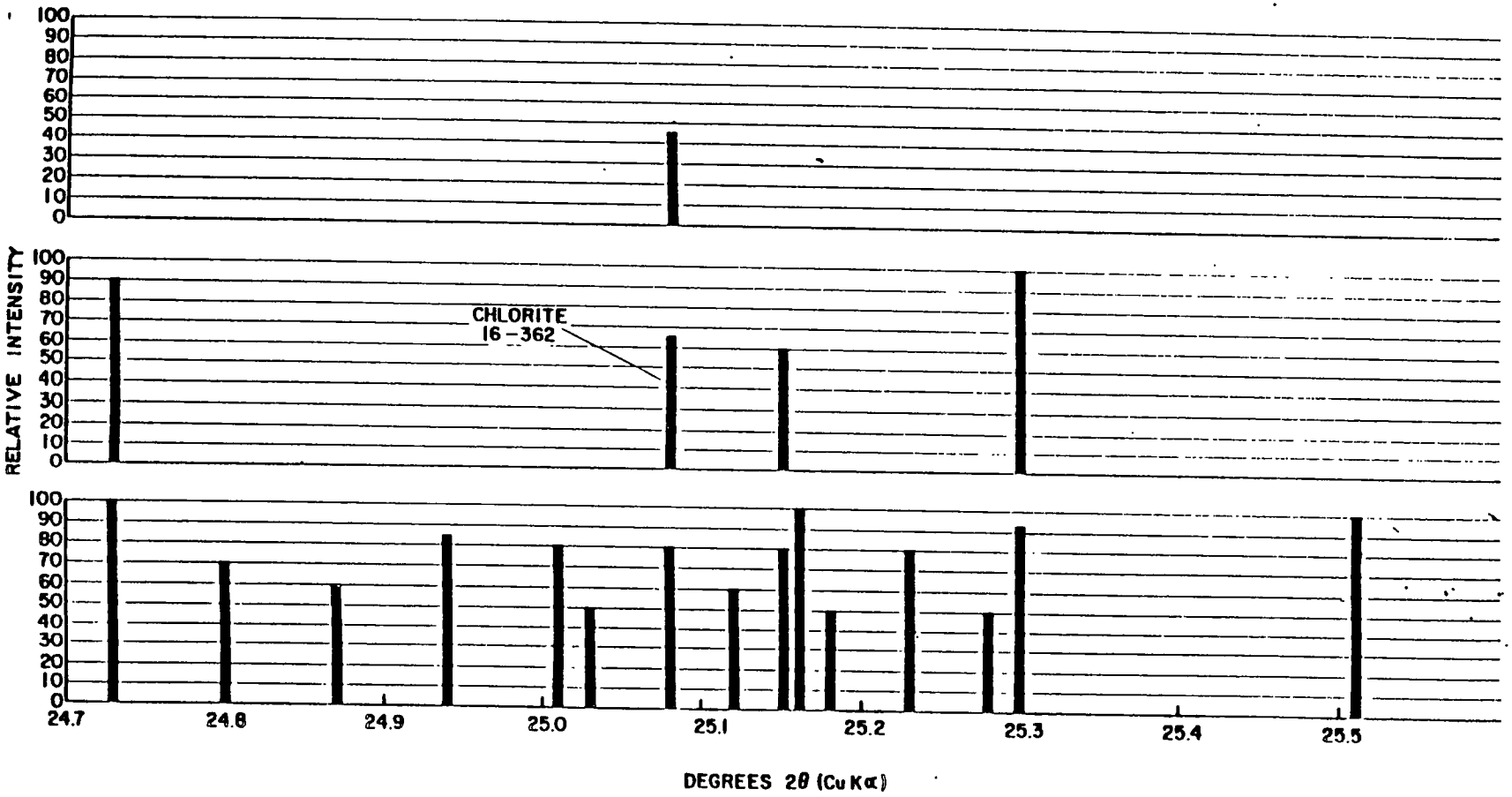

Figure 2. Chlorite $d_{(004)}$ – peak positions and relative intensity. The data of Table 2 are presented in graphical form showing the variation in position of the $d_{(004)}$ XRD peaks for different chlorites. Selection of JCPDS card 16-362 as diagnostic for chlorite can obviously result in misidentification.

Table 3. Serpentine, Kaolinite, Halloysite, and Dickite JCPDS Card Nos., peak position, miller index (hkl), and relative intensity.

JCPDS Card #	Å	2θ(Cu)	I	(hkl)	Serpentines
18-779	3.67	24.25	80	(002)	lizardite, 1M
9-444	3.66	24.32	100	(0012)	antigorite, 60
21-543	3.65	24.39	70	(004)	chrysotile, 2M
7-417	3.63	24.52	300	(102)	antigorite, 6M
11-386	3.62	24.59	60	(002)	lizardite, 10, aluminian
21-963	3.61	24.66	80	(002)	antigorite, 6M
12-583	3.56	25.01	80	(0012)	antigorite, 60, aluminian
13-4	3.56	25.01	70	(0012)	antigorite, 60, aluminian
7-339	3.55	25.08	100	(002)	berthierine
11-388	3.55	25.08	100	(0012)	antigorite, 60, syn
7-315	3.52	25.30	100	(002)	berthierine
9-493	3.52	25.30	100	(004)	amesite
					Kaolinites
6-221	3.58	24.87	100+	(002)	kaolinite, 1Md
14-164	3.579	24.88	80	(002)	kaolinite, 1T
12-447	3.56	25.01	50	(002)	kaolinite, 1T
					Halloysite
9-453	3.63	24.52	90	(002)	halloysite, dehydrated
					Dickite
10-446	3.58	24.87	100+	(004)	dickite $2M_1$

Chlorite 2θ Range: 24.73 - 25.52

Table 3 illustrates variation in position of XRD peaks of serpentine, kaolinite, halloysite, and dickite. The XRD patterns of these minerals interfere with each other and with chlorite (see Table 2).

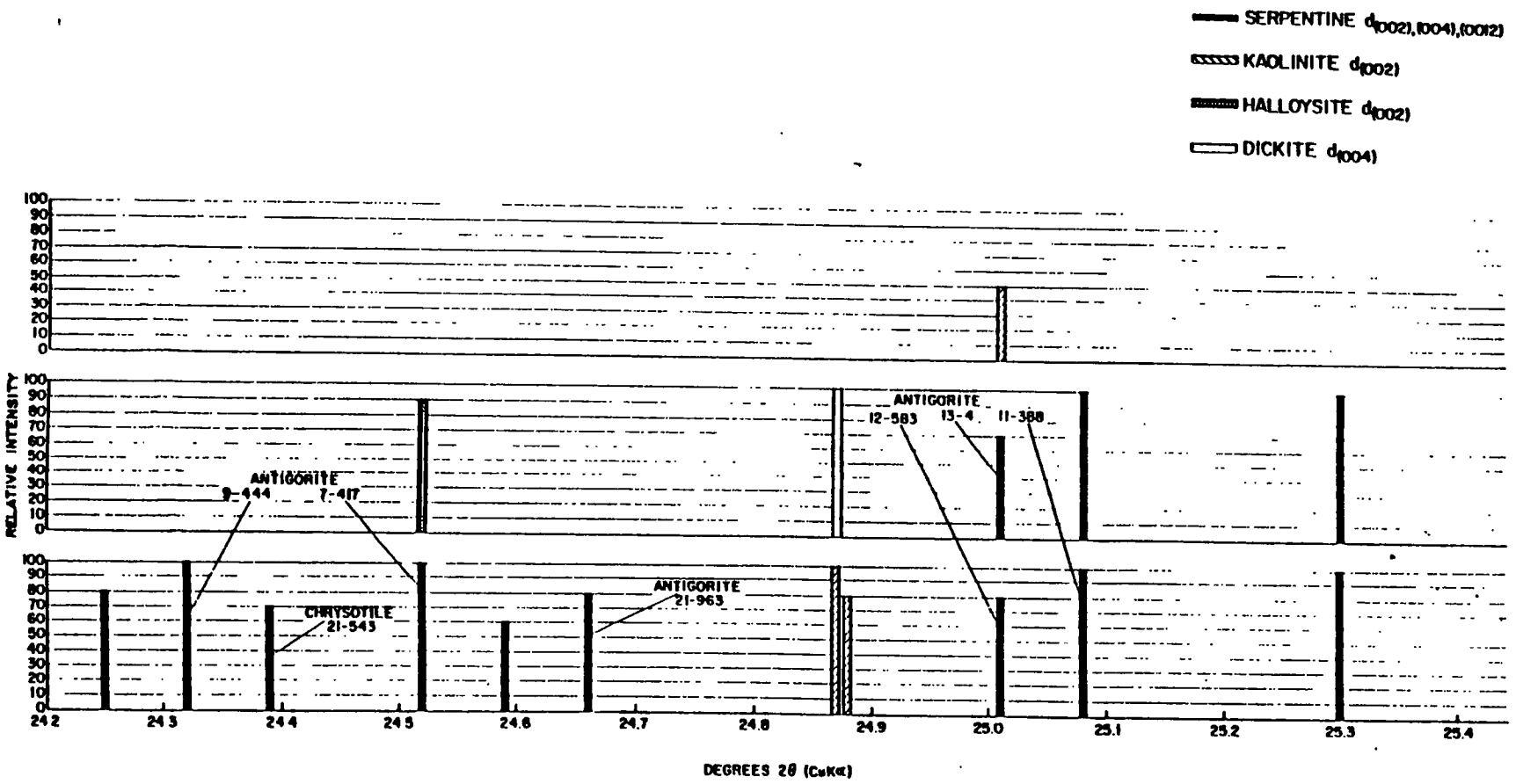

Figure 3. Peak positions and relative intensities. The data of Table 3 are presented in graphical form to illustrate the variation in position and interferring overlap of XRD peaks of serpentine, kaolinite, halloysite, and dickite.

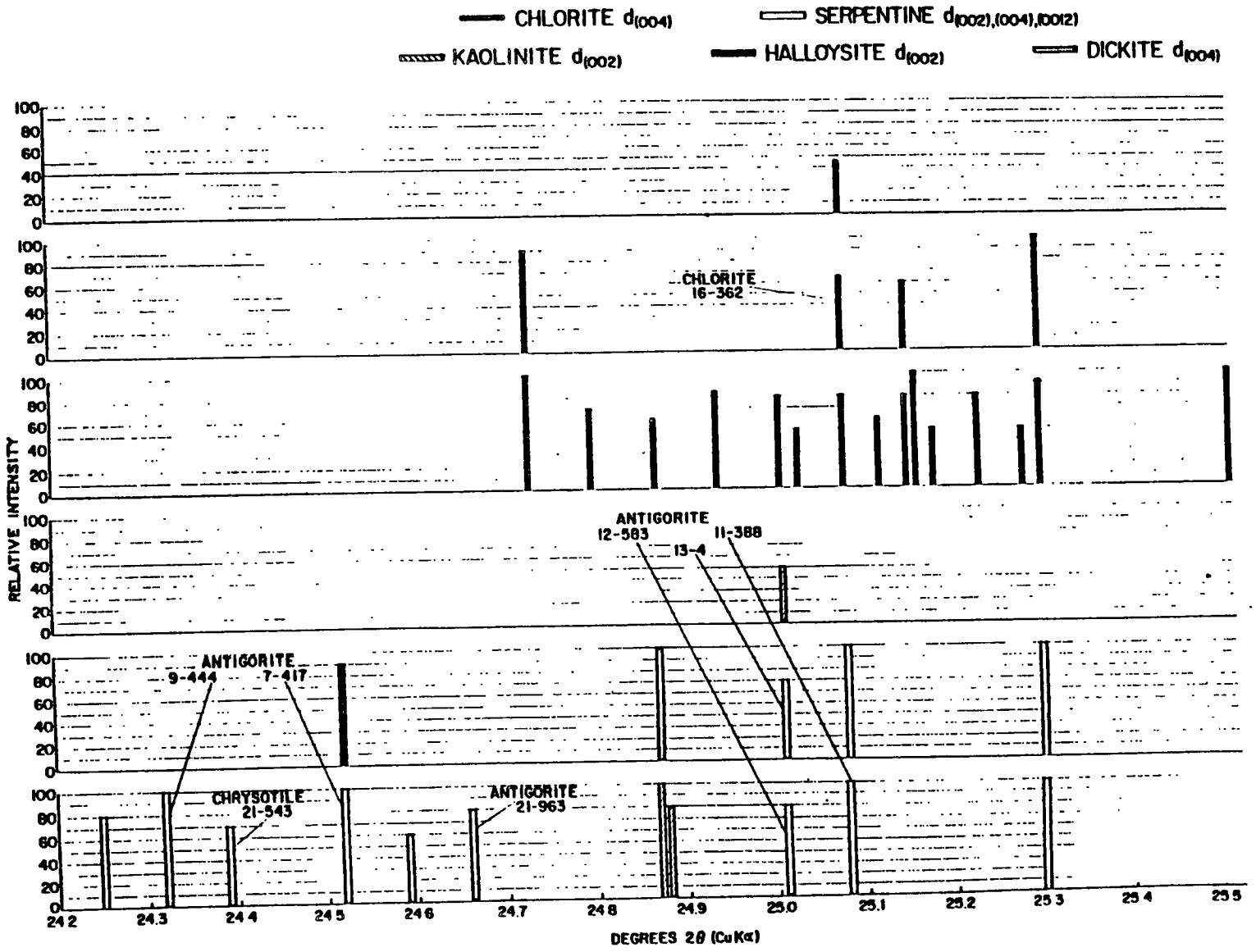

Figure 4. Peak positions and relative intensities. The data of Tables 2 and 3 are presented combined, illustrating the problems of XRD identification when chlorite and serpentine, and possibly kaolinite, halloysite, or dickite are also present.

Three essential features are demonstrated in Tables 2 and 3, and Figures 2, 3, and 4:

1. The diagnostic peaks show considerable variation in the position in which they occur ($\Delta 2\theta = 0.79°$ for chlorites and 1.05° for serpentines).

2. The chlorites and serpentines overlap and interfere with each other.

3. Basal peaks of the clay minerals kaolinite, halloysite, and dickite overlap the positions of the chlorite and serpentine peaks, and will interfere when present.

The significance of the chlorite-serpentine interference is increased by the fact that chlorite is a very common accessory mineral associated with talcs, whereas serpentine is much less commonly associated.

In spite of the chlorite-serpentine problem, numerous investigators have performed XRD identification and/or quantification of serpentine in chloritic talcs. It is obvious to us that they have misidentified asbestos as being present by overlooking the chlorite/serpentine interference and by misconcluding that a chlorite peak was serpentine.

Other Methods

Infrared Spectroscopy (IR)

The infrared absorption spectrum of a material results from vibrational and bending frequencies of various atomic bonds within the structure. For example, Si-O stretching frequencies produce similar IR peaks for all silicate minerals. As a result, IR spectra are not particularly useful for identifying the minerals present in a mixture, and the method certainly is not capable of determining whether or not a detected mineral is the asbestiform variety.

Differential Thermal Analysis (DTA)

The rearrangement or decomposition of mineral crystal structures due to thermal heating is a characteristic and reproducible reaction. It follows that DTA can identify specific minerals in a mixture but the method is not capable of determining morphology. Therefore, any DTA data which might point to the presence of a serpentine mineral could lead to misidenfying chrysotile asbestos in a talc when the mineral could well be a normally occurring platy antigorite having the same DTA pattern.

Electron Microscopy

Electron microscopic techniques of identification of asbestos have been amply covered in other presentations during this workshop. We do not intend to cover that subject again, but rather to point out some areas where asbestos can be misidentified.

The high magnification attainable with electron microscopy is, in itself, inadequate as the sole index of mineral identity. For example, chrysotile is often identified by the presence of a hollow central core and streaked electron diffraction spots. But the clay mineral halloysite also crystallizes in that form and will produce a similar electron diffraction pattern. Therefore, in the absence of exact chemical composition, halloysite can be misidentified as asbestos. Similar care must be exercised to avoid misidentifying other fibrous clay minerals as asbestos, e.g., attapulgite and alpha sepiolite. In addition, talc ribbons can be mistaken to be asbestos, especially when some talcs have particles which roll up into spiral tubes giving the appearance of a chrysotile particle.

Selected area electron diffraction is routinely used to identify a mineral particle as amphibole. Many investigators simply observe the electron diffraction pattern in the microscope and decide on the basis of general pattern geometry whether or not the particle is an amphibole. This can lead to misidentification, since numerous other minerals can give electron diffraction patterns with amphibole pattern geometry [10,11]. Careful measurement of an electron diffraction pattern is required in order to identify the type

of mineral which produced the pattern. Chemical composition is further required in order to have a chance at identifying the particular species when the mineral is a member of a complex group such as the amphiboles. Otherwise, misidentification will result.

Cosmetic Talc Free from Asbestos

In the United States, we have a self-regulating association known as the Cosmetic Toiletry and Fragrance Association. In certifying the purity of the talcs which they use, they are aware that no single method can identify asbestos and their most recent specification for cosmetic talc [12] combines two methods (XRD and optical microscopy) for monitoring their types of talc.

The rationale is that a talc is first examined by XRD, and if even the smallest amount of amphibole is indicated, then the test proceeds into optical microscopy using a dispersion staining technique to determine whether or not the material contains asbestiform particles in the amphibole group.

Summary

This paper has categorized the main methods which have been used for detection of asbestos in talcs. The basic principles of the various methods were categorized to explain how asbestos has been and can be misidentified in talc. Generally, misidentifications arise by jumping to a conclusion from a single mineral characteristic, when, in fact, many characteristics are required to fully identify a mineral species and/or its variety.

Both optical microscopy and XRD required a more detailed review than other methods since they have received the most attention from a monitoring point of view.

This review is presented with the hope that our guidelines will enable analysts to avoid the misidentification of asbestos in talcs.

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Discussion

A. WILEY: You said that instantaneous recognition of SAD patterns is difficult. Could you give some examples as to what kind of confusions could exist in this? Can you confuse amphibole with serpentine or amphibole with talc, or is that kind of a gross mistake possible?

J. KRAUSE: Those kinds of mistakes probably would not generally happen if you are looking at pyroxenes or olivine. Electron diffraction is not one of my areas of real expertise, but I think that you could possibly get feldspars that would give confusing patterns, depending upon their orientation in the microscope.

L. MADSEN: We are using all the methods that have been talked about today for identification for asbestos materials and do not in any way limit ourselves to fiber length and aspect ratios.

J. WAGMAN: I would like to comment that it is possible by x-ray diffraction and through a special technique to identify and measure the presence of asbestos fibers even when they are in the presence of their non-fibrous counterparts. About two years ago this was demonstrated in a study which we supported at the Naval Research Laboratory in which samples were pre-treated so that fibers were first aligned and then the x-ray diffraction intensities measured at two different orientations with respect to the x-ray beam and in this way the intensity due to the non-fibrous counterparts could be subtracted from the total diffraction intensities.

KRAUSE: You were putting the fibers in some specific preferred orientation in the sample and then looking for those orientations by XRD.

WAGMAN: That is correct, and this had the advantage of not only making possible corrections, that is correcting for the non-fibrous material present, but also it greatly enhances the detectability for the fibers themselves.

KRAUSE: Is this method being currently used?

WAGMAN: This is a method whose feasibility was demonstrated and there are two publications on this in the literature. Actually our objective was to apply this method to airborne samples, which is a much more difficult application incidently, I should think than in the case of talc. The problem here is a preparative problem in that an air sample usually has a lot of organic material, sticky material present which interferes with the ability to orient the fibers. This is a preparative problem which will have to be overcome. But I should think that in the case of talc samples you probably would not have that problem.