PLAINTIFF'S EXHIBIT WRG-73

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CAMBRIDGE

TO: O. F. Stewart, Enoree, S.C. DATE: August 31, 1973

FROM: Julie C. Yang SUBJECT: Tremolite Determination in South Carolina Vermiculite Ores

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FILE: 150 - Asbestos Determination in Vermiculite Ores

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OBJECTIVE:

To determine the tremolite content in S.C. vermiculite ores at various locations.

SUMMARY:

Instrumental means were employed to determine the asbestos content in S.C. ores. The findings are listed as follows:

1. There are asbestiform fibers present in S.C. ores, but mostly very fine and small. All the identifiable fibers are hornblende, an aluminum-rich amphibole. So far no information has been published to indicate whether this material is detrimental to health or not, as of other types of amphiboles (tremolite, crocidolite and amosite) and chrysotile asbestos.

2. The only detectable difference between Allen and Waldrup type specimens from the same location (Poole #7) is that the Allen type has relatively higher talc and hornblende contents than the Waldrup sample.

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MATERIALS RECEIVED:

The following samples were submitted from O. F. Stewart, Enoree, S.C. at R. M. Vinning's request for tremolite analysis:

Sample No.	Deposit	Type
22210-1	Poole #7	Allen
2	Poole #7	Waldrup
3	Allen	Allen
4	Poole #3	
5	Burns	Waldrup
6	Meadows	Waldrup
7	Yarborough	Waldrup
8	Lanford	Waldrup

EXPERIMENTAL WORK:

Instrumental Methods Employed

X-Ray Diffraction	A rapid, non destructive method to identify crystalline materials such as mineral species
Scanning Electron Microscope (SEM)	To study the morphology of particules
Optical Microscopy	To identify individual particules by its optical properties
Electron Probe Analysis (EPA)	To analyze the elements present and the relative quantities of them

DISCUSSION OF RESULTS:

The instrumental analyses were done at Arthur D. Little, Inc. by Dr. E. Peters and his colleagues, the interpretations were made by J. C. Yang in collaboration with E. Peters.

1. X-Ray Diffraction Data

The ore samples as received showed an intense x-ray diffraction peak at 20-28.5°. The position employed for our previous quantitative measurement of tremolite in Monokote® and expanded vermiculite from Libby mine. Attempts were made to expand the vermiculite 1) chemically with conc. hydrogen peroxide and 2) thermally for 3 minutes at 1400°F, but in the expanded samples the unwanted peak at 28.5° persisted. It

was then decided to perform the x-ray diffraction analysis to provide identification and quantitative estimates of the mineral species present, and to examine the fibers in several samples by scanning electronmicroscope. If fibers were present, they would be identified by the optical properties and electron probe analysis for its elemental ratio.

The mineral species in the samples were analyzed and tabulated in Table 1.

All the samples were found to have x-ray diffraction peaks that correspond to hornblende or tremolite. Based upon the diffraction peak at 8.40 A hornblende line, the quantity of hornblende in various samples were estimated and corporated with other results in Table 1. The distinction between hornblende and tremolite, as well as whether they are in platy or fibrous form was then determined by SEM and EPA.

2. Scanning Electron Microscopic (SEM) Examination and Electron Probe Analysis (EPA)

A few representative photographs and profiles for the elements present are shown in Figs. 1 to 5.

Elements corresponding to various peak position are:

Mg	1.25	K	3.30	Ti	4.55
Al	1.47	Ca	3.70	Fe	6.40
Si	1.75	Ca	4.05	Fe	7.05

Several fibrous particles were observed in each sample by SEM. The chemical composition by the probe analysis showed that the elemental ratio of 5Mg-1Al-16Si-4Ca, whereas the tremolite standard from Libby yielded a relative ratio of 5Mg-20Si-1K-3Ca. It thus appeared the analyzed fibers were hornblende instead of tremolite as we suspected. Other non-fibrous particles showed the typical ratio of 2Mg-1Al-5Si (Vermiculite) with occasional replacement of some or all of the Mg by K (hydrobiotite).

3. Optical Examinations

Two of the samples 22210-2, Poole #7 (Waldrup) and 22210-6, Meadows (Waldrup) were examined by optical microscope, utilizing the Montana tremolite sample as a standard. Observed fibers were found to have the refractive indices in the range of those of hornblende (measure γ_a = 1.623, 1.648) which are considerably higher than the values for tremolite (γ_a = 1.599, 1.625).

4. Chemistry of Hornblende

Hornblende series is a family in the amphibole asbestos group which shows a considerable variation in composition. The principle features of the composition are the presence of both Ca and Na or K, the former dominating, the Al is partially substituted for Mg and Si, and most of the members are deficient in silica. The composition of the series may be expressed by the two end members:

$Ca_4Na_2Mg_{10}Al_2Si_{14}O_{44}(OH, F)_4$ edenite

$Ca_4Na_2(Mg, Fe)_8Al_6Si_{12}O_{44}(OH, F)_4$ hastingsite

Compared with tremolite $Ca_2Mg_5Si_8O_{22}(OH)_2$.

Fluroine commonly enters into the composition to replace OH in part, Mg by Fe^{II}, Al by Fe^{III}, as do Ti and Mu for cations.

Such as Pargasite (Na,K) $Ca_2Mg_4Al_3Si_6O_{22}(OH)_2$

and Barroisite $(Ca,Na)_{2.26}(Mg,Fe,Al)_{5.15}(Si,Al)_8O_{22}(OH)_2$

are the intermediate members.

These minerals are monoclinic in crystal structure, and have fiber-like appearance but usually very chunky (low aspect ratio). These are soft and easily pulverizable like clay minerals, and quite different from either the harsh Mg-amphibole, tremolite; Fe-amphibole, crocidolite and Fe-Mg amphibole, amosite or from the silky, flexible chrysotile asbestos fibers.

No known literature published to date has been found discussing the effect of hornblende to health.

CONCLUSIONS:

1. All the S.C. ore samples analyzed are very similar in mineral compositions. All of them are rich in vermiculite and hydrobiotite with minor amounts of hornblende, talc and quartz.

2. All samples examined contain asbestiform fibers that have been identified as hornblende, an Al-rich amphobile, which are fiber-like under light and electron microscope. This material is, at this time, an unknown health hazard.

3. The difference of Allen & Waldrup type specimens from the same location is the relative talc and hornblende content. Allen type seems to be richer in both.

4. The SEM preparation procedure tends to emphasize the smallest size particles, so that the method is not quantitative. Of all these samples examined, 22210-2, Poole #7 (Waldrup) appeared to contain the largest fraction of fibers.

RECOMMENDATIONS FOR ADDED STUDY:

Since hornblende is a fibrous amphibole, the carcinogenic potential of this material has not yet been found in any literature, but it may be questioned in the future because of composition and structure closely associated with tremolite and other amphiboles. It is suggested to contact outside agencies to have an animal study made on the potential carcinogenic effects of horblende, compared with tremolite and chrysolite fibers. Usually, the test will take one to two years, but by then we will know for sure whether this material exhibits any cancer-inducing potential.

Agencies and Institutions equipped to do this type of work:

1. Huntingdon Research Center
   Huntingdon, England

   - where the carcinogenic screening of vermiculite (S.A.) was done in 1970-1972.

2. Dr. Lewis J. Cralley
   Occupational Health Program
   National Center for Urban and Industrial Health
   Public Health Serivce
   1014 Broadway
   Cincinnati, Ohio 45202

   - previous contact, had studied amphiboles and chrysotile of various length, pure synthetic chrysotile and chrysotile with added Ni, Fe, Co, etc. in the structure.

3. Dr. Paul Gross M.D.
   Industrial Hygiene Research Unit
   Dept. of Occupational Health
   Graduate School of Public Health
   University of Pittsburgh
   Pittsburgh, Pa. 15213

   - previous contact, did similar studies as Dr. Cralley.

Julie C. Yang

TABLE 1

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DETERMINATION OF MINERAL COMPONENTS PRESENT
IN SOUTH CAROLINA VERMICULITE ORE
(BY X-RAY DIFFRACTION METHOD)

SAMPLE NO.	DESCRIPTION	VERMI-CULITE	HYDRO-BIOTITE	HORNBLENDE TREMOLITE	TALC	QUARTZ
22210-1	Poole #7 (Allen)	+++	+++	++ (10-20%)*	++	+
2	Poole #7 (Waldrup)	++	+++	+ (2-5%)	?	Trace
3	Allen (Allen)	+++	+++	+ (5-10%)	+++	-
4	Poole #3	+++	+++	+ (2-5%)	++	+
6	Meadows (Waldrup)	++	+++	++ (10-20%)	-	Trace

Legend:

+++	Major	(>50%)
++	Intermediate	(10-40%)
+	Minor	(1-9%)
?	Doubtful	(<1%)
-	None	

* The percentage of hornblende in the parenthesis was determined by the intensity of $2\theta = 8.40$ A°.

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Figure 1. SEM AND ELECTRON PROBE ANALYSIS OF SAMPLE 22210-1

Poole #7, S.C. (Allen)



(1000 X)

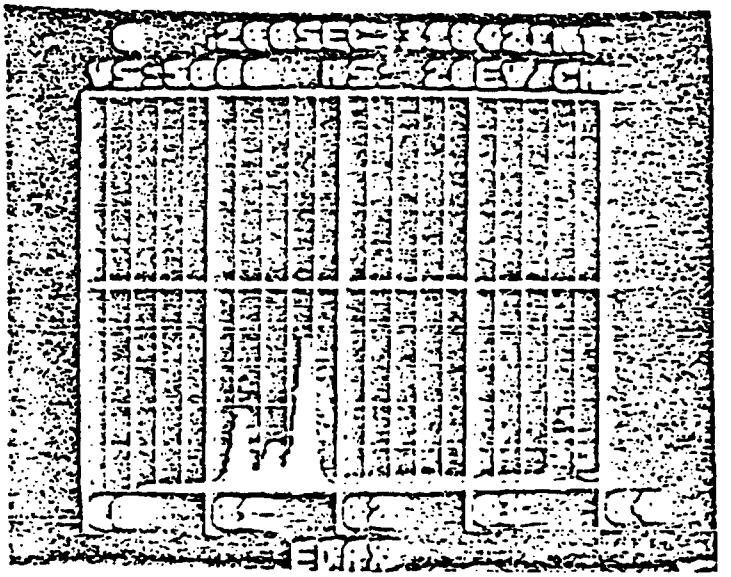
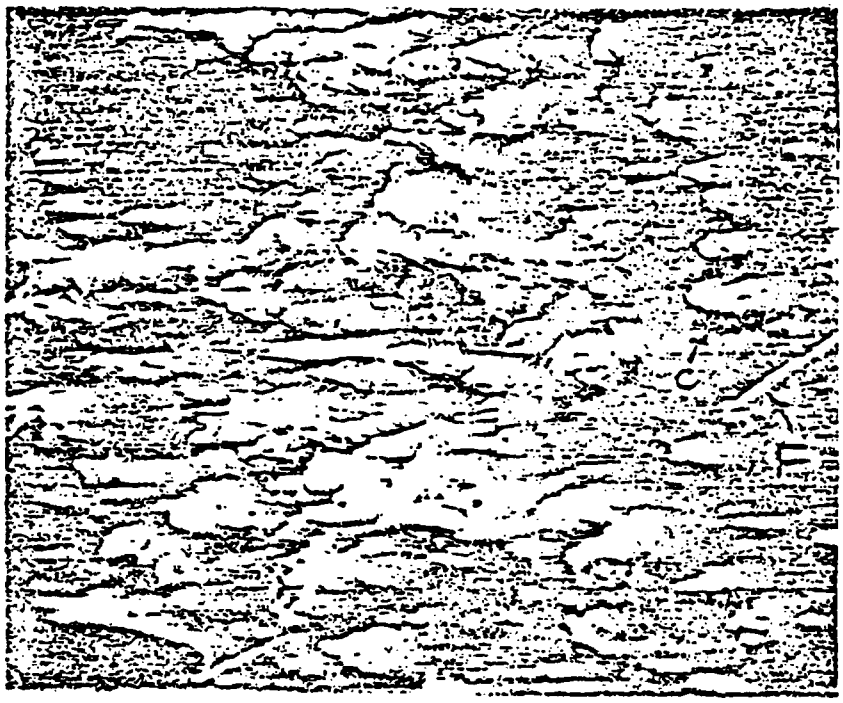


Figure 2 SEM AND ELECTRON PROBE ANALYSIS OF SAMPLE 22210-2

Poole #7, S.C. (Waldrup)



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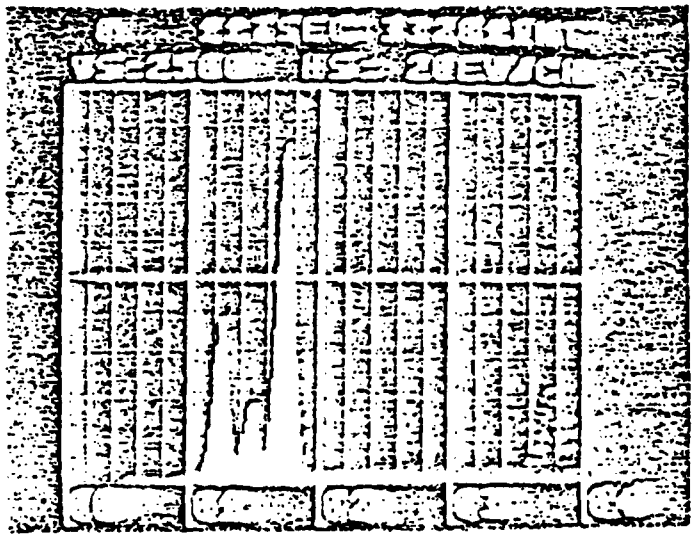
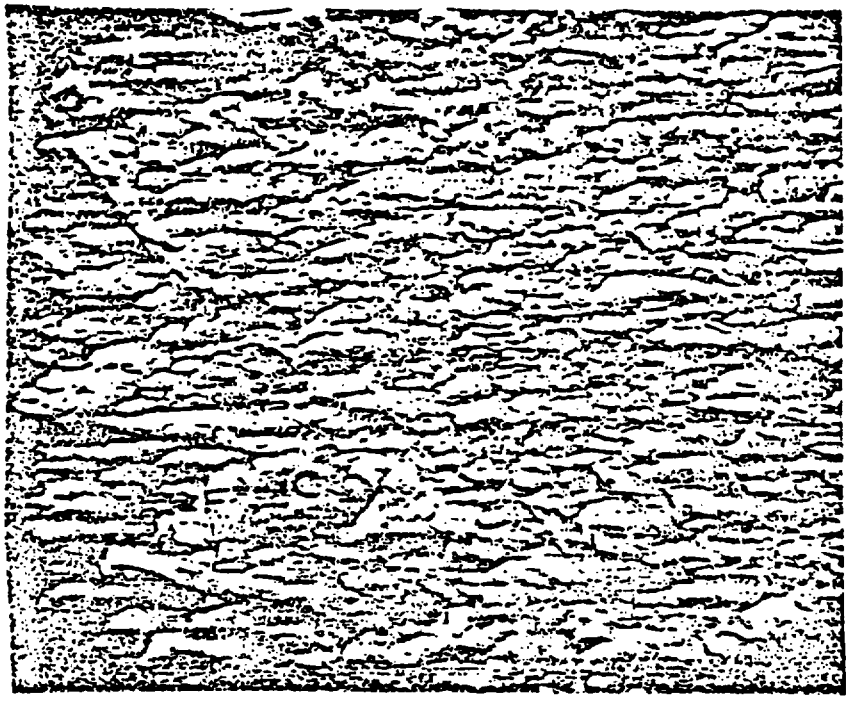


Figure 3 SEM AND ELECTRON PROBE ANALYSIS OF SAMPLE 22210-3

Allen, S.C. (Allen)



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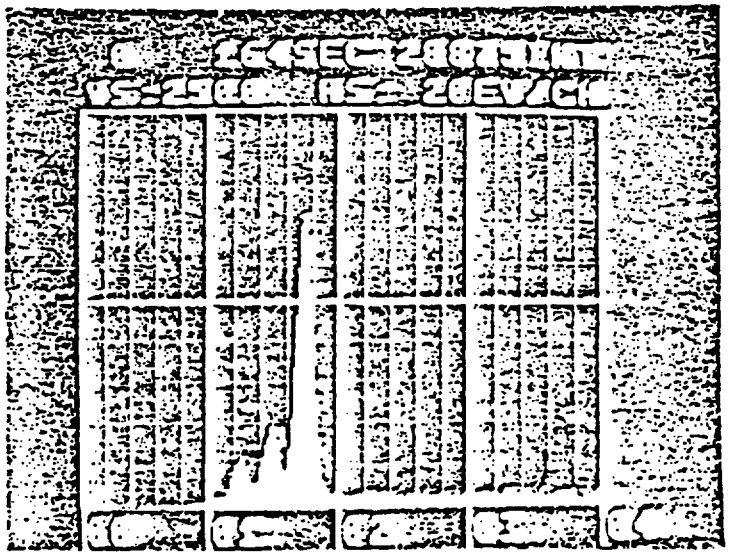
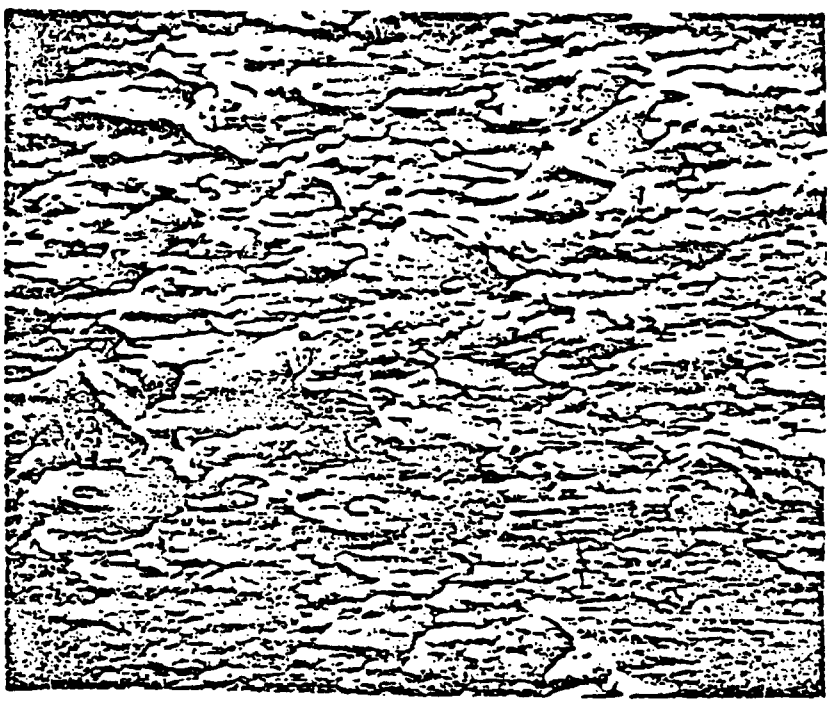


Figure 4 SEM AND ELECTRON PROBE ANALYSIS OF SAMPLE 22210-6

Meadows, S.C.



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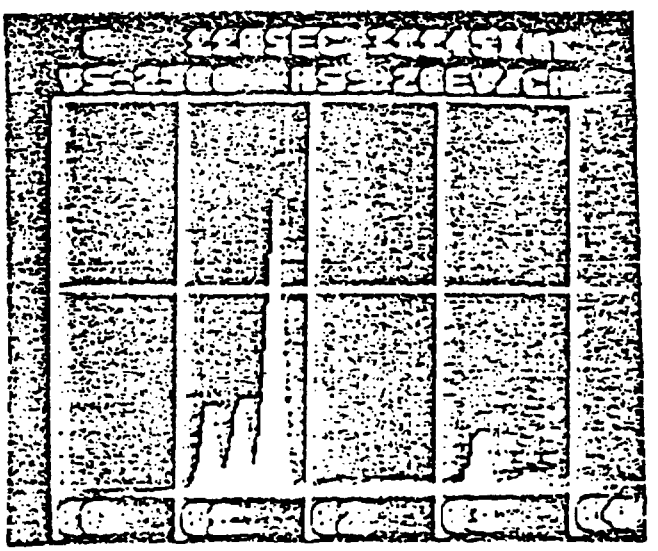
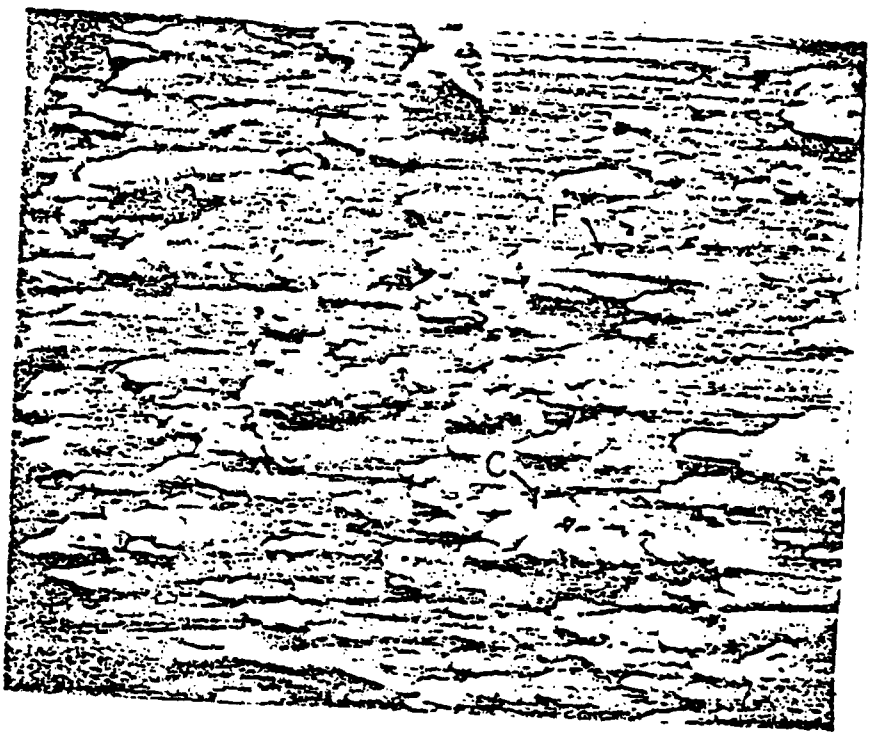


Figure 5 SEM AND ELECTRON PROBE ANALYSIS OF SAMPLE 22210-8

Lanford, S.C. (Waldrup)



(1000 X)

