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CAMBRIDGE

TO: E. S. Wood

DATE: May 16, 1977

FROM: J. C. Yang

SUBJECT: Tremolite & Vermiculite Content in Libby & Kearney Ore Deposits and Expanded Vermiculites

CC: R. M. Vining, H. C. Duecker, B. R. Williams, H. A. Eschenbach, J. W. Wolter, B. A. Blessington, W. R. Hanlon, C. C. Ou, D. M. Kirven, F. W. Eaton, R. C. Ericson, O. M. Favorito, R. H. Locke, S. C. Vaughan

File: 71-048/049

PLAINTIFF'S EXHIBIT WRG-1580

OBJECTIVE

The objective of this study is to determine the vermiculite and tremolite content in ore concentrate and expanded vermiculite from the Libby and Kearney mills. A sample of the head feed from the Libby mills, from which all the Libby ore samples were derived, is also analyzed as a check for the effectiveness in fiber removal of the Libby operation.

The samples analyzed below are single samples of concentrate or expanded product, selected at random. We do not know how accurately these samples represent the average with respect to tremolite (or amphibole mineral) content. Further sampling will be required to better establish more typical or average values.

The reported tremolite content may include other amphibole minerals, particularly hornblende, which cannot be distinguished from tremolite.

SAMPLE DESCRIPTION

All the analyses made in this report were single sample analyses. From the materials submitted in 5-10 lb. quantities, they were quartered very carefully and repeatedly until the desired sample sizes (200-300 grams) were obtained, which were expected to be fairly representative. However, the range of variations in field sampling and in the geological formations were not established, so that the results observed may only indicate a ballpark figure with ±10% of accuracy.

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ID No.	Description	Date and Source
99952-31	Ore Concentrate L-1	3/10/77 - R. L. Oliverio
99952-32	Ore Concentrate L-2	
99952-33	Ore Concentrate L-3	
99952-34	Ore Concentrate L-4	
99952-35	Ore Concentrate L-5	3/1/77 - E. D. Lovick
99952-36	Ore Concentrate K-3	3/7/77 - O. F. Stewart
99952-37	Ore Concentrate K-4	
99952-38	Ore Concentrate K-5	
99952-39	Expanded Vermiculite L-1	3/21/77 - F. W. Eaton
99952-40	Expanded Vermiculite L-2	
99952-48	Expanded Vermiculite L-3 (Terra-Lite)	3/9/77 - F. W. Eaton
99952-41	Expanded Vermiculite K-3	3/3/77 - O. F. Stewart
99952-42	Expanded Vermiculite K-4	
99952-43	Expanded Vermiculite K-5	
99952-46	Libby Head Feed - a composite of 3 shifts	3/9/77 - R. L. Oliverio

METHOD

1. Tremolite Analysis of Libby #1 and #2 Concentrate:

Since the fiber bundles and the rock aggregates are unusually large, tremolite fiber bundles and rocks were first separated by hand-picking of a carefully quartered sample. The vermiculite was then separated from the rock by screening. Rocks and fines in the -50 mesh fraction were x-rayed for quantitative determination of tremolite. The total tremolite was obtained as the sum of factored portions from hand-picked and the fine portions. The scheme of analysis is shown in Figure 1.

2. Tremolite Analysis of #3 Ore Concentrate:

The concentration of rock fines and tremolite fiber fractions are shown in Figure 2. Vermiculite was separated by chemical exfoliation with 30% H_2O_2, followed by water flotation.

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3. Tremolite Analysis of #4 and #5 Ore Concentrate:

A set of finer screens than the ones used in analyzing #3 ore was selected for this separation. A diagram of the procedure is shown in Figure 3.

4. Tremolite Analysis of Expanded Vermiculite (size #2 to #5)

The expanded vermiculites are easier to work with since they were expanded already and the percentage of rocks and fines were lower than those of the corresponding ore concentrates.

The procedure for analyses is shown in Figures 4 and 5, respectively.

5. Tremolite Analysis of the Head Feed:

The head feed sample from the Libby mill was obtained one day before the ore composite collection from the screening plant, and is the starting material from which the ore composites were obtained. The analysis was more complicated than the others since the size varied over a wide range and the non-vermiculite portion was very high. The tremolite concentration procedure is shown in Figure 6.

6. Vermiculite Analysis of Ore Concentrates:

To cross-check the vermiculite analysis from the scheme shown in Figures 2 and 3, for ore composites #3 and #5, a 100 g ore sample was taken and expanded in a furnace for 5 minutes at 1500°F., then allowed to cool at ambient conditions for half an hour. In general, a weight loss of about 7% resulted from heat expansion. By previous experience, a higher vermiculite yield will result from chemical expansion since some of the poorly weathered vermiculite will not readily respond to heat expansion but will expand in H_2O_2. The complete analyses of the Libby and Kearney vermiculites are shown in Tables 1 and 2.

7. Evaluation of Fine Fiber Content:

In Table 1, a breakdown of the tremolite fiber in ore concentrate by size fraction is also shown. The fines (-50M for size L-1 to L-3; -100M for size L-4 and L-5) can be considered to be the maximum limit of the respirable fiber portion (provided no further vigorous mechanical degradation of the material takes place in handling).

We have also hand-picked the fiber bundles from two L-2 ore concentrate samples and run them through the air-elutriation column built in the laboratory. We then collected the airborne particulate through a series of screens and then on a wet filter under vacuum. The screens used were graded to eliminate the blockage of the filter by large dust aggregates and long fibers. This experiment indicated the fiber bundles were fairly stable. At the end of 30 minutes of the air elutriation, the results are as follows:

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Sample Description	% wt. on 325 mesh screen	% wt. on wet filter	Respirable Dust
Tremolite, hand-picked from SL-2	0.29	0.05	0.34
Tremolite, hand-picked from CL-2	0.21	0.04	0.25
Observation:	mostly fiber some larger than 30 μ	fiber and vermiculite dust	

The fine sized dust content average for the two samples was approximately 0.3%, corresponding to .0076% of the total sample. Thus, it is concluded that the amount of respirable size tremolite fiber present in the L-2 ore composite must be less than 0.01%.

No attempt was made to determine the respirable size fiber content from the Kearney ore since most of the Kearney tremolite is massive and difficult to be distinguished from hornblendes present.

In the expanded product, the tremolite fiber contents found in the Libby vermiculites as shown in Table 2 were primarily fine sized. Very few small bundles were observed which demonstrates the effectiveness of fiber removal by the stoner.

COMMENTS

1. The tremolite content of L-1 and L-2 were reduced to about half the amount of those analyzed in 1976 (see Research Report on Libby Ore Evaluation - J. C. Yang to H. C. Duecker, 2/23/76). The tremolite content of L-3 and L-4 has apparently not improved since early 1976. However, the vermiculite platlets were much cleaner presently with less dust particles adhered to the surface than those of 1976.

2. This is the first time that Kearney ores and expanded vermiculites of all sizes were analyzed for their total tremolite content by the x-ray diffraction method. Unfortunately, the x-ray diffraction patterns of the fibrous and massive forms of tremolite are identical and in fact cannot be distinguished from other amphibole minerals, particularly hornblende. More sophisticated analytical methods using electronmicroscopic techniques and related structural and elemental analysis such as TEM, SEM, SAED and EDAX are needed to pinpoint the exact nature of the amphibole minerals present.

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Tremolite & Vermiculite Contents in Libby & Kearney Ore Deposits and Expanded Vermiculite

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TABLE 1

Tremolite Content of Ore Concentrate

ID No.	Description	Date	% Vm.	% Tremolite		% Total Tremolite*
-31	L-1	3/10/77	91.7	(+50M) (-50M)	1.2 .005	1.2
-32	L-2	3/10/77	91.2	(+50M) (-50M)	2.5 .018	2.5
-33	L-3	3/10/77	78.1	(+50M) (-50M)	.653 .013	0.7
-34	L-4	3/1/77	70.1	(+70M) (-70 +100M) (-100M)	1.495 .232 .009	1.7
-35	L-5	3/1/77	63.9	(+70M) (-70 +100M)	.119 1.016 1.913	3.0
-36	K-3	3/1/77	72.0	(+50M) (-50M)	1.60 .158	1.8
-37	K-4	3/1/77	75.1	(+70M) (-70 +100M) (-100M)	8.903 .554 .492	10.0
-38	K-5	3/1/77	76.6	(+70M) (-70 +100M) (-100M)	0.874 2.070 13.034	15.9
-46	Head Feed, Libby	3/9/77	7.0**	(+6M) (-6 +20M) (-20 +70M) (-70M)	1.302 .684 1.235 .609	3.8

*Includes all amphibole minerals.

**The material floated after expanded with 30% H_2O_2.

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Tremolite & Vermiculite Content in Libby & Kearney Ore Deposits and Expanded Vermiculite

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TABLE 2

Tremolite Content of Expanded Vermiculite

ID No.	Description	Date Collected	% Vermiculite	% Tremolite
99952-39	L-1	3/18/77	97.7	0.074
99952-40	L-2	3/18/77	97.1	0.028
99952-48	L-3	3/9/77	97.7	0.049
99952-41	K-3	3/3/77	91.0	1.6*
99952-42	K-4	3/3/77	79.4	7.9*
99952-43	K-5	3/3/77	48.7	interference

*Includes all amphibole minerals.

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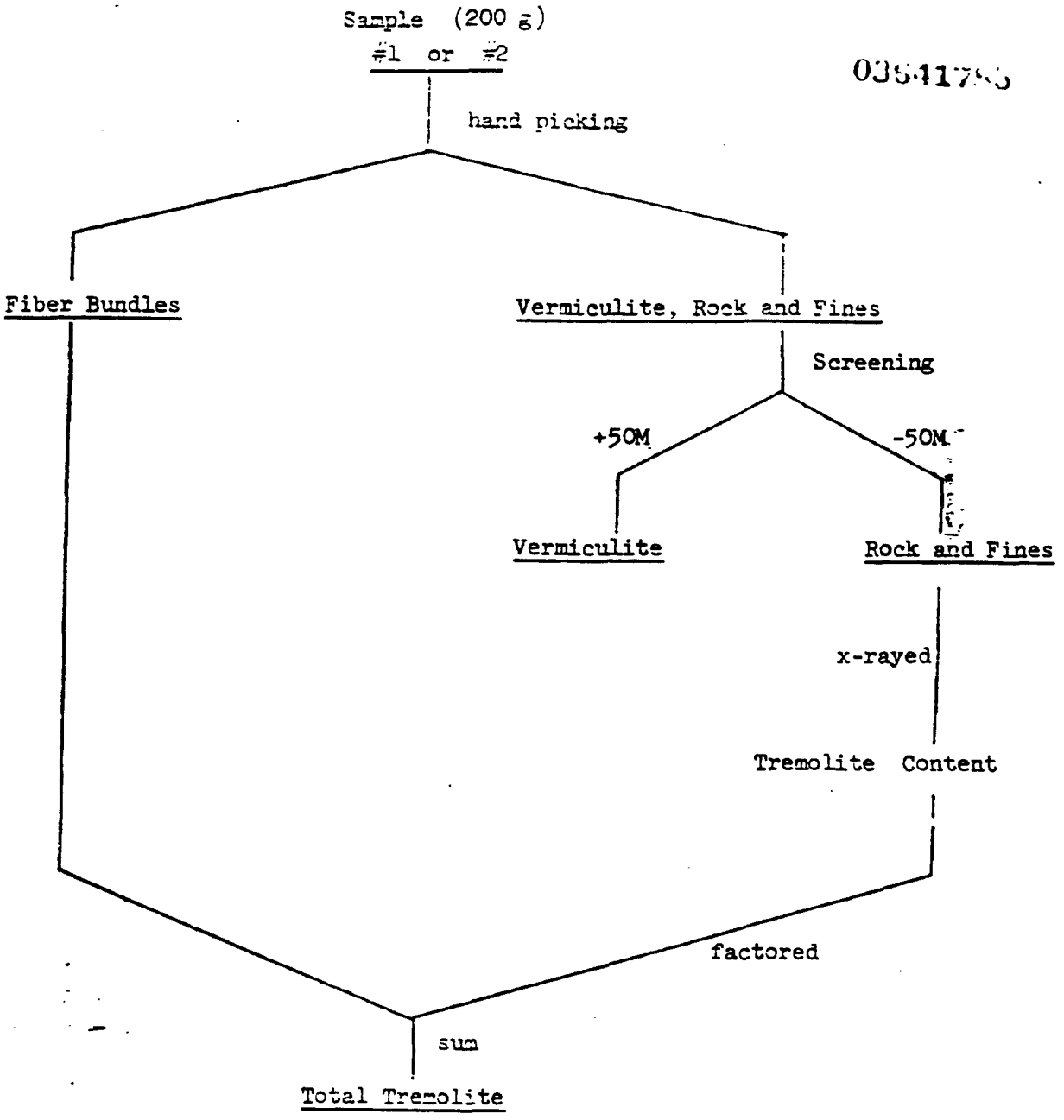
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EXHIBIT

1. TREMOLITE ANALYSIS OF #1 and #2 BEE COMPOSITES



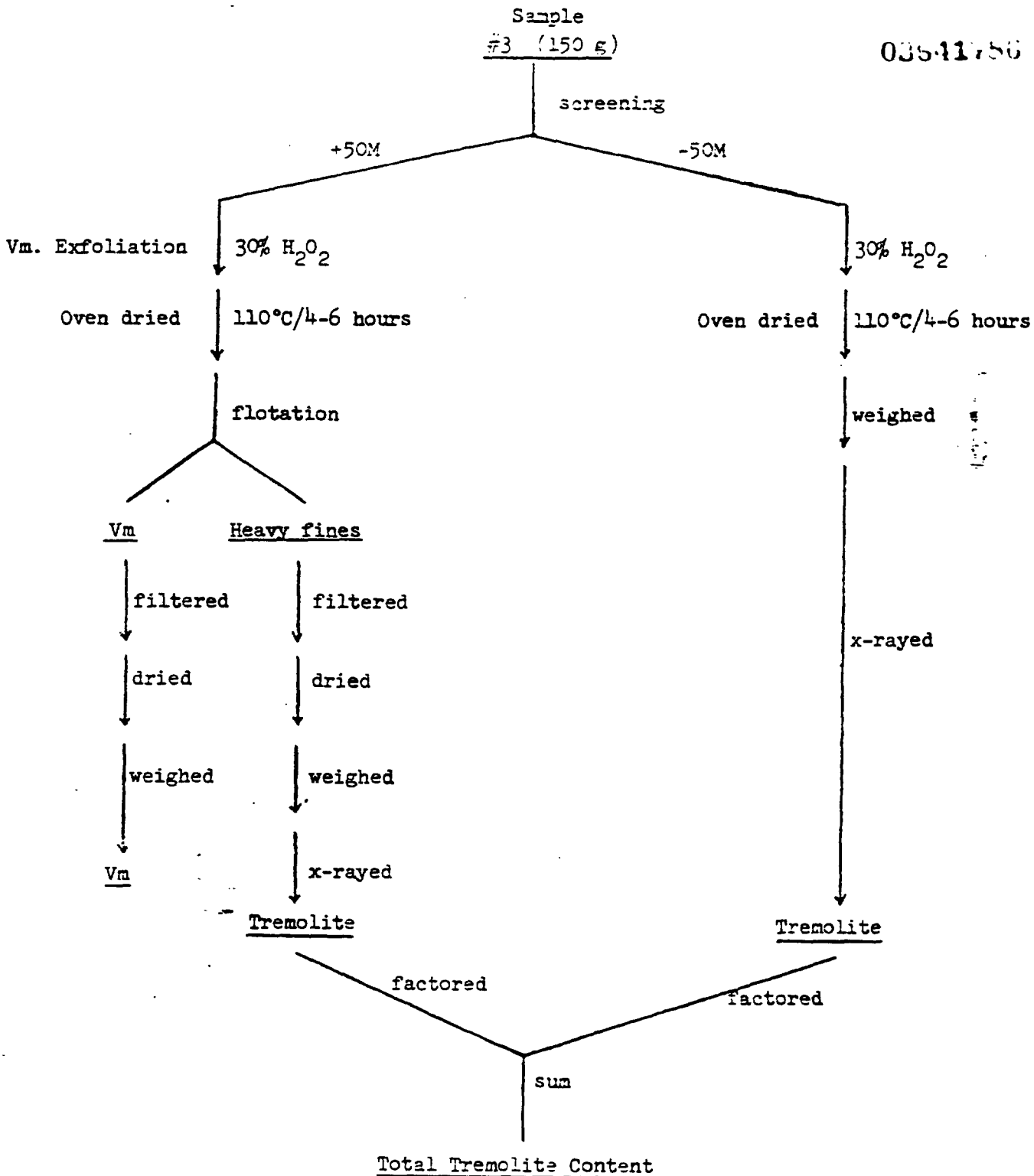
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2) TREMOLITE ANALYSIS OF #3 ORE COMPOSITE



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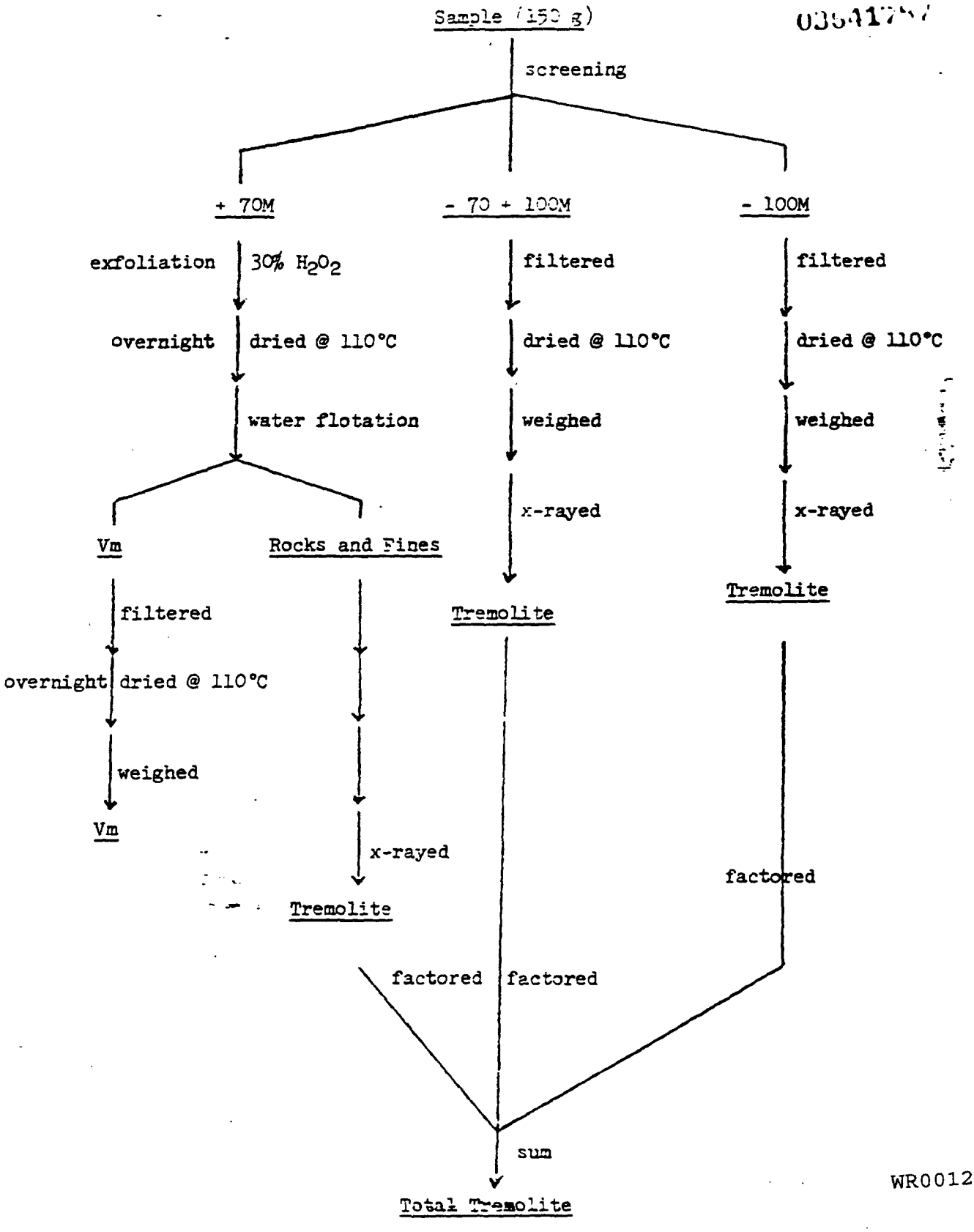
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FIGURE 1

3) TREMOLITE ANALYSIS OF #4 and #5 ORE COMPOSITE



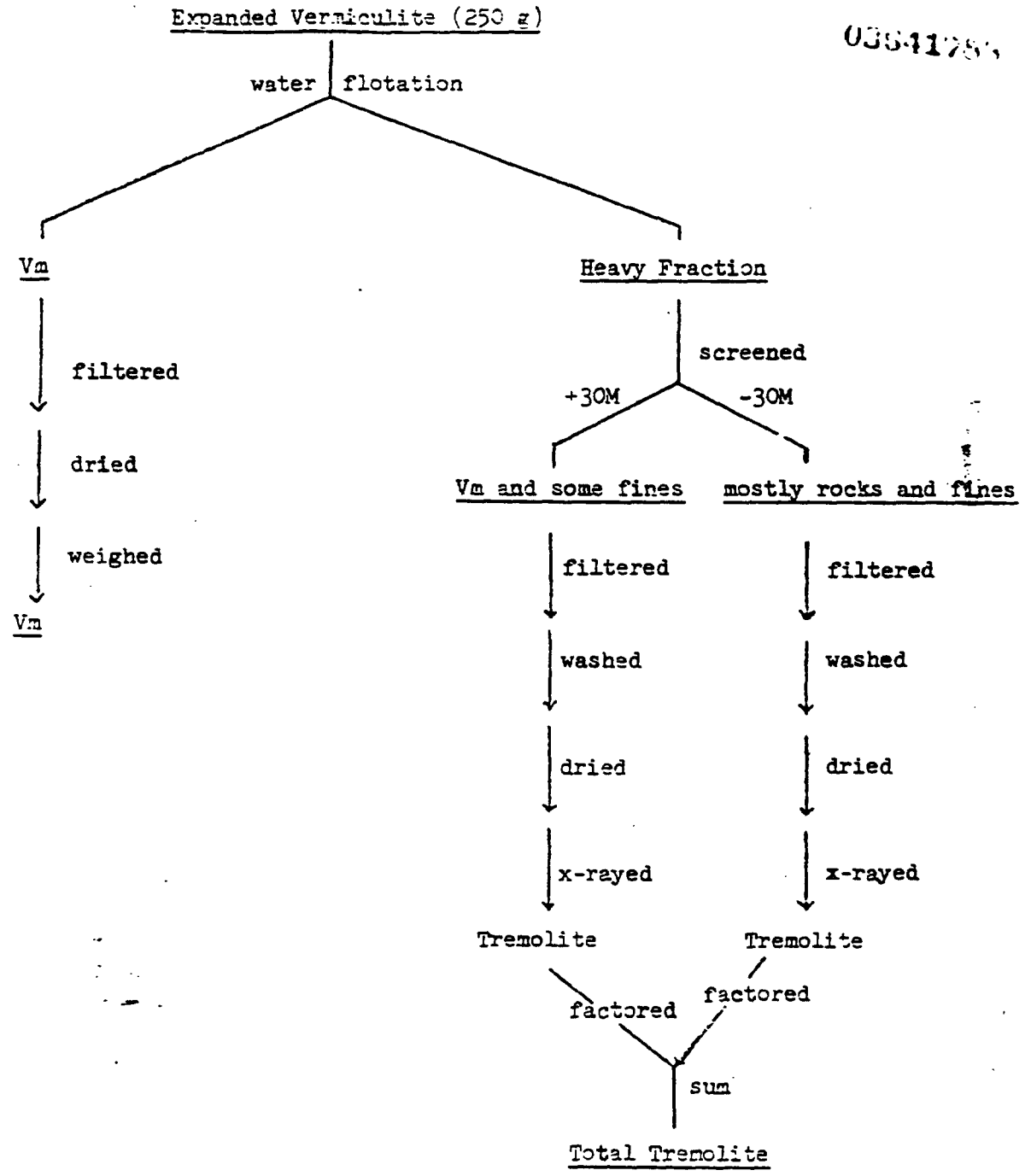
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4) TREMOLITE ANALYSIS OF #2, #3 AND #4 EXPANDED VERMICULITE

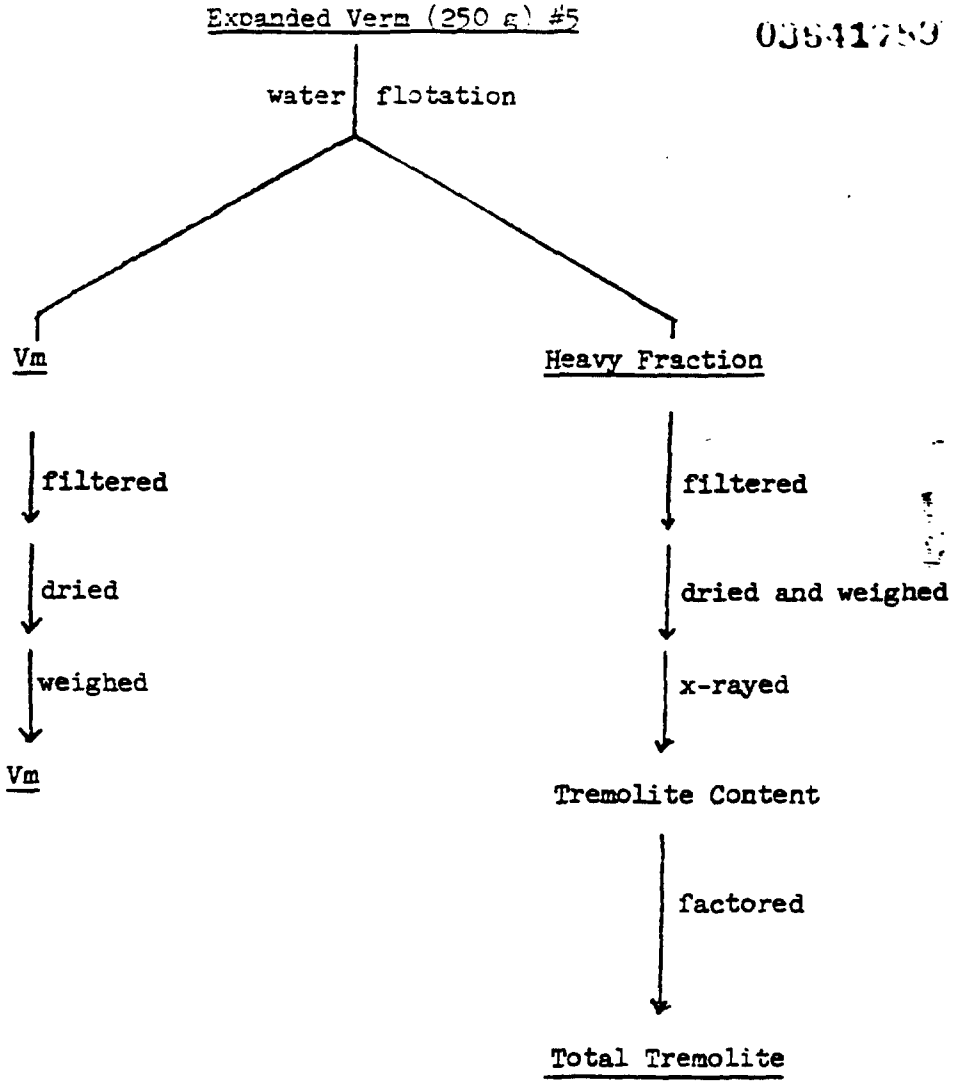


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FIGURE 5

5) TREMOLITE ANALYSIS OF #5 EXPANDED VERMICULITE



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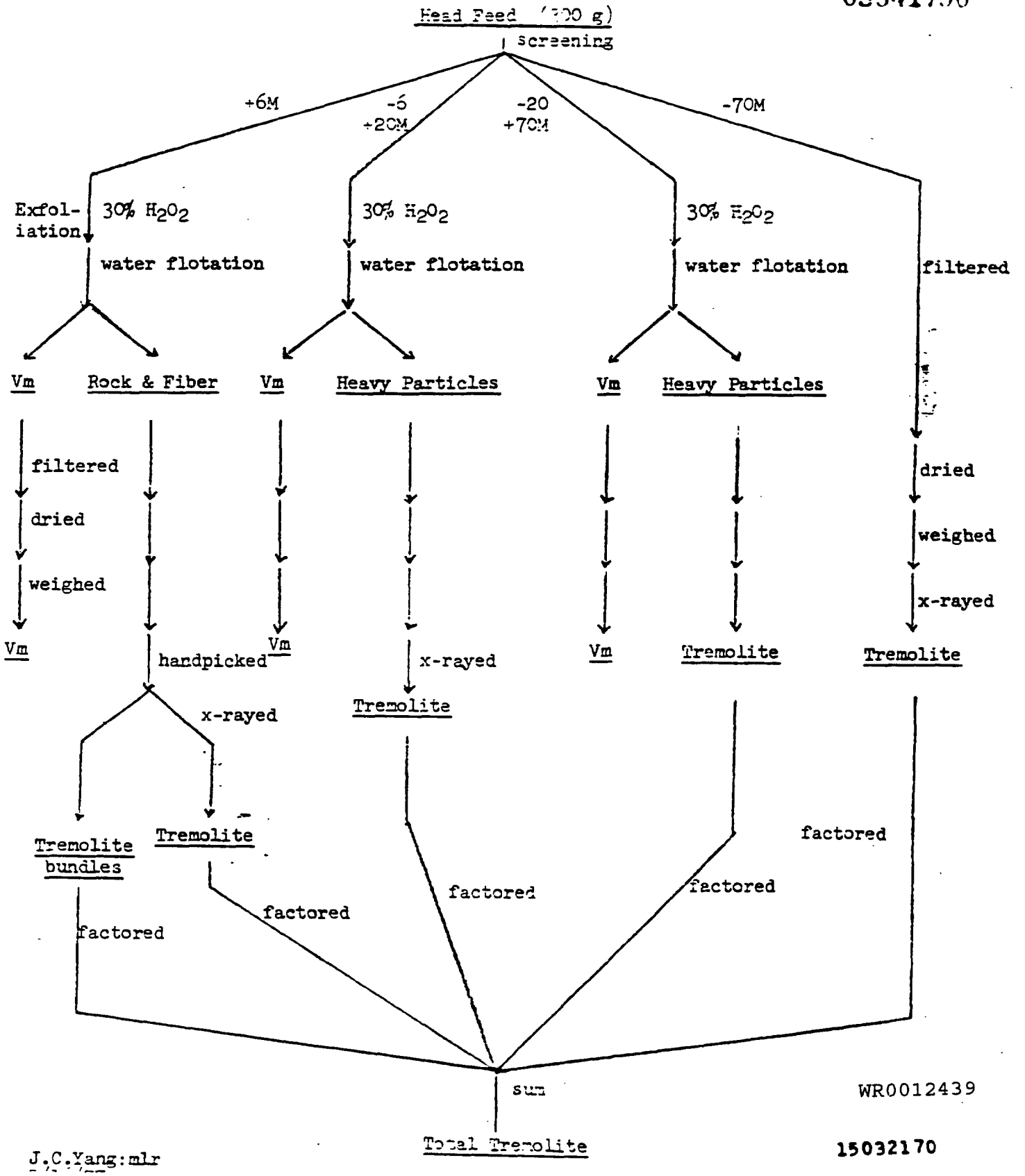
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6) TREMOLITE ANALYSIS OF THE HEAD FEED

A-head feed from Libby was analyzed from which the ore composite L-1, L-2, L-3 and L-4 were obtained.



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