OCCUPATIONAL EXPOSURES TO NON-ASBESTIFORM TALC IN VERMONT

Maryanne G. Boundy, Karen Gold, Kenneth P. Martin, Jr., William A. Burgess, John M. Dement

Department of Environmental Health Sciences, Harvard School of Public Health, Boston, Massachusetts 02115

INTRODUCTION

An environmental study of the Vermont talc mines and mills was undertaken in support of a concurrent epidemiological study of talc workers. Since geological studies dating from the early 1900's have shown that the Vermont talc deposits contain no asbestos and little quartz this population represents a group of talc workers employed in mining and milling operations who have no association with these two fibrosis producing minerals (Jacobs, 1914, 1918; Weiss and Boettner, 1967). Therefore, the intent of this study was to verify these geological reports by quantitating the personal dust exposures of these talc workers, and by identifying the mineral content of this "clean" talc ore.

MINERALOGY

Pure talc mineral is a hydrous magnesium silicate (Table 1) and consists of a brucite sheet containing magnesium ions sandwiched between two weakly held silica sheets (Hildick-Smith, 1976). This mineral is extremely soft and slippery, and has a hardness of 1 on the Mohs scale. However, as used industrially, the term "talc" refers to a mixture of minerals that meet certain physical requirements rather than one which has a fixed chemical composition (Brown, 1973). Industrial grades of talc (Table 2) usually contain chlorites which are sheet silicate minerals containing magnesium, iron, and aluminum, and carbonates which include magnesite, dolomite, and calcite. Quartz, iron oxides, serpentine (one of the minerals from which talc evolved) and tremolite may also be present. Since the constituents of industrial talc

TABLE 1. Some Chemical and Physical Properties of Talc

Talc: $3MgO \cdot 4SiO_2 \cdot H_2O$
Refractive indices: 1.54 - 1.6
Specific gravity: 2.6 - 2.8
Hardness (Mohs Scale): 1
Color: White or gray to apple green
Morphological varieties: Laminated and Fibrous

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vary in their mineral and fiber content, the ensuing product has a considerable range in hardness and particle shape which contributes to its versatility.

TABLE 2. Some Minerals Found in Industrial Talc

Chlorite	$(MgFe)_5Al(AlSi_3)O_{10}(OH)_8$
Magnesite	$MgCO_3$
Dolomite	$CaMg(CO_3)_2$
Calcite	$CaCO_3$
Serpentine	$Mg_6(Si_4O_{10})(OH)_8$
Quartz	SiO_2
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$

FIELD STUDY

The three major Vermont talc companies were surveyed in the summer of 1975 and the winter of 1976. Bulk samples from representative milling and mining operations were collected and were analyzed qualitatively for their mineral constituents A total of 312 personal respirable mass samples (118 in mines and 194 in mills) were taken using nylon, 10 mm cyclones at a flow rate of 1.7 lpm. Seventy percent of these samples were analyzed for free silica content by infrared spectrophotometry or x-ray diffraction (Cares *et al.*, 1973). Fifty-seven parallel filter samples were taken for fiber determinations on 0.8 μm Millipore filters using phase contrast microscopy at X437 magnification and on 0.4 μm Nuclepore filters using scanning electron microscopy at X5000 magnification.

BULK SAMPLES

Bulk samples from the mines and mineral mixtures or products from the mills were obtained from each company. Each sample was ground, dried, and scanned qualitatively by x-ray diffraction (Table 3). For all the samples, talc and magnesite are found in major amounts, chlorite and/or dolomite are minor constituents, and dolomite, calcite, quartz, biotite, ankerite, chromite, oligoclase, or phlogopite may be found in trace quantities.

Quartz was present in trace amounts in 15% of these samples. Further analysis by NIOSH, which included petrographic microscope analysis, transmission electron microscopy, and x-ray diffraction with step-scanning, revealed no asbestos in these samples.

TABLE 3. Qualitative Analysis of Bulk Samples by X-Ray Diffraction

Source	Major (20-100%)	Minor (5-20%)	Trace (<5%)
Mine (37)	Talc Magnesite	Chlorite (Dolomite)	Dolomite Calcite Quartz Biotite Ankerite Chromite Phlogopite Oligoclase
Mill (20)	Talc Magnesite	Chlorite (Dolomite)	Calcite Quartz Phlogopite Biotite Dolomite

RESPIRABLE MASS SAMPLES

The personal respirable mass concentrations of the miners for the two sampling surveys are presented in Table 4. Companies A and B were working one mine, while Company C had three mines in operation in the summer and two mines during the

TABLE 4. Respirable Mass Concentrations of Vermont Miners

Company		Summer 1975			Winter 1976		
		(N)	GM	GSD	(N)	GM	GSD
			(mg/m^3)			(mg/mg^3)	
A	Underground Mine	(18)	0.6	2.1	(16)	0.5	2.1
B	Underground Mine	(15)	1.5	1.6	(23)	0.9	1.9
C	Underground Mine	(12)	0.5	1.9	(19)	0.7	1.8
	Walk-in Mine	(7)	1.2	2.2			
	Walk-in Mine				(6)	1.7	3.3
	Open Pit Mine	(2)	5.1	1.4			

GM - Geometric mean
GSD - Geometric standard deviation
N - Number of samples

winter survey. Table 4 shows that the highest dust concentrations in the underground mines occur at Company B. The ore in this mine is relatively hard, and the extensive drilling operations required to break apart the large boulders may account for the higher dust levels. There is no statistical difference between the dust exposures of the summer and winter surveys for the mines.

The respirable mass data of the millers for the summer and winter surveys are presented in Table 5. With the exception of Mill #1 at Company C, all the Vermont talc mills are large, barn-like, drafty structures heated by space-heaters. Despite the

TABLE 5. Respirable Mass Concentrations of Vermont Millers

Company		Summer 1975			Winter 1976		
	Shift	(N)	GM	GSD	(N)	GM	GSD
				(mg/m^3)			
Company A	1st	(4)	1.7	1.6	(13)	1.7	1.9
	2nd	(6)	0.5	2.0	(3)	1.5	2.2
Company B	1st	(22)	1.8	1.8	(42)	1.8	1.6
	2nd	(12)	2.9	1.7	(16)	1.9	1.6[1]
Company C							
Mill #1	1st	(12)	0.9	2.4	(20)	1.1	2.8
	3rd	(3)	0.8	2.0	(4)	1.4	1.9
Mill #2	1st	(11)	1.0	1.4	(8)	0.5	1.7[2]
	2nd	(13)	0.8	1.5	(3)	1.1	1.5

[1] $p<0.5$
[2] $p<0.2$
GM - Geometric mean
GSD - Geometric standard deviation
N - Number of samples.

winter closed-door policy, Table 5 shows that the dust concentrations were statistically different for only two shifts during the winter study. At Company B, the lower winter respirable dust exposures for the second shift may be caused by the severe weather conditions which forced the milling area employees to stay inside their acoustical booths whenever possible.

Of the three companies, the millers at Company C have the lowest respirable dust exposures. The bagging area at Mill #1 was not operational in the summer, since most of the product is shipped in bulk. However, this area was sampled during the winter survey and may partially account for the slight increase in the mean dust exposures. Since only the bagging area at Mill #2 was operational during the winter survey, the mean exposures are lower than the summer data.

FIBER COUNTS

The carcinogenic potential and the hazards of asbestos exposures have been well documented. Also, several types of asbestos are known to be geological contaminants in talc ore. Since the accepted best index of exposure to asbestos requires counting the respirable fibers in the worker's breathing zone, a problem arises in the methodology of distinguishing asbestos fibers from talc. Charcteristically, talc has a tendency to curl and stand on its edge which may result in many erroneous counts by optical microscopy.

The latest USPHS/NIOSH method for counting asbestos fibers requires phase contrast microscopy at X400-500 magnification, and arbitrarily defines a fiber as a particulate with a length to width ratio of 3:1 or greater, and a maximum width and minimum length of 5 micrometers (Leidel *et al.*, in press). This method is a crude determination of total fiber exposure because of the resolution limitations of optical microscopy. Most airborne asbestos fibers are less than 5 μm in length, and those that are longer may have diameters too small to be resolved by phase contrast microscopy.

To compensate for the many controversies, our sampling protocol involved taking parallel fiber samples on Millipore (0.8 μm) and Nuclepore (0.4 μm) filters and quantitating the fibers by phase contrast microscopy and scanning electron microscopy. The fiber samplers were placed in the immediate vicinity of the worker, and a breathing zone sample was obtained without having the man wear the pumps. The Millipore filters were counted using the latest USPHS/NIOSH method at X437 magnification.

The evaluation of the corresponding Nuclepore filter by scanning electron microscopy at X5000 magnification allows one to morphologically distinguish rolled talc particles and talc shards from actual fibers. Fibers less than five micrometers in length may be counted by the higher magnification of this instrument, and the sample stage may be rotated to view a specific particle at various angles. Figures 1 through 7 represent scanning electron micrographs (SEM) of some Nuclepore filter samples showing rolled talc and elongated talc particles. Phase contrast magnifications cannot resolve the detailed morphology of these particles, and hence they would be erroneously counted as fibers.

Table 6 represents a partial list of fiber samples, and shows that by phase contrast microscopy the counts range from 0 to 60 fibers/cc. The parallel filters counted by SEM are greatly reduced and range from 0 to 0.8 fibers/cc. These concentrations are below the present time-weighted average (TWA) of asbestos which is 2 fibers/cc greater than five micrometers in length based on the phase contrast method. If the minimum length restriction is released, then the total fiber concentration for some of these samples changes slightly and ranges from 0 to 2.0 fibers/cc. Thus this SEM method provides a more realistic approach to fiber counting in the talc industry.

FIGURE 1. Scanning electron micrograph of a Nuclepore filter showing a counting field at X400 which is the magnification recommended for fiber counting by phase contrast microscopy. Notice the number of elongated particles that fit the definition of a fiber.

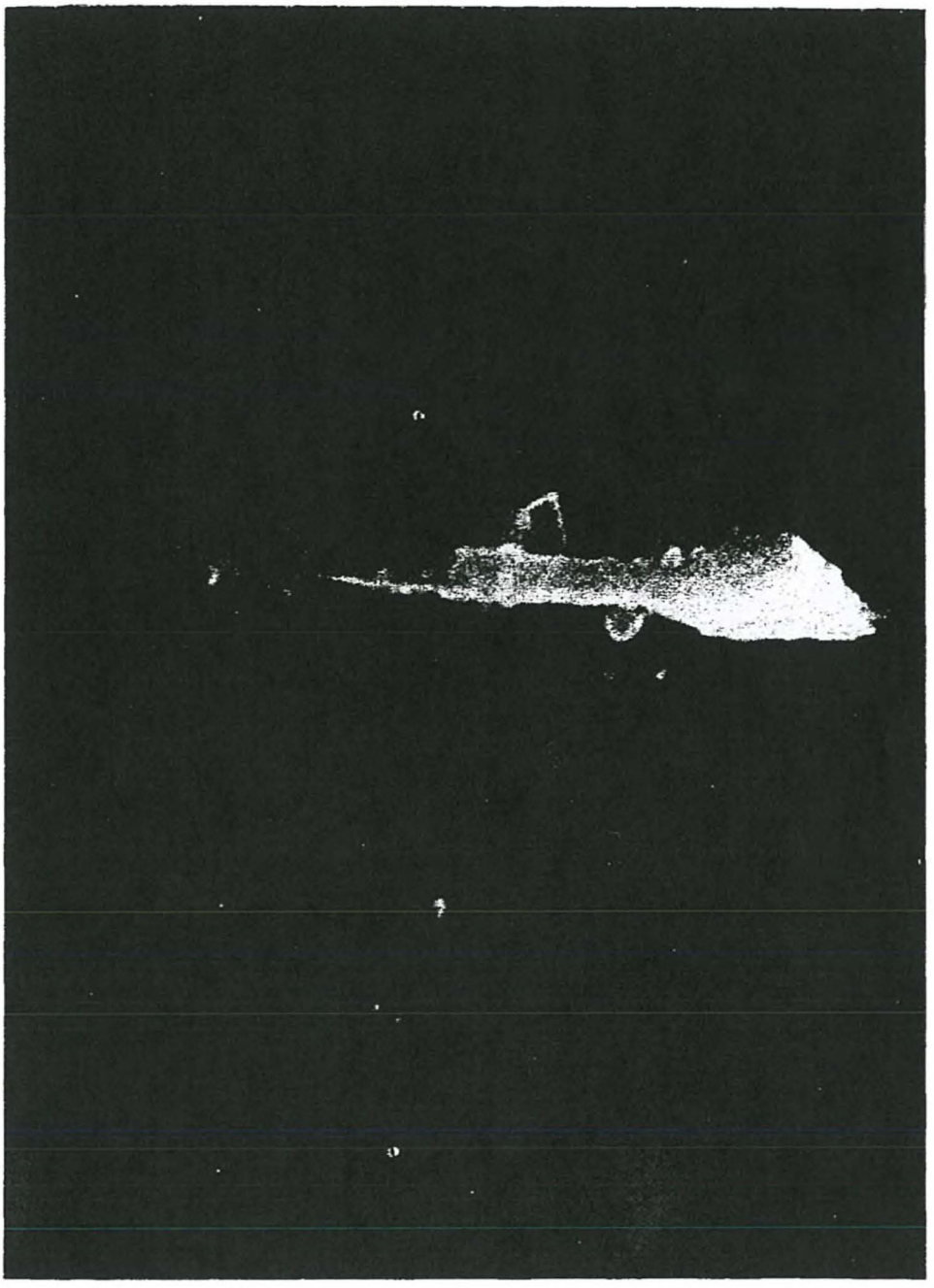

FIGURE 2. Scanning electron micrograph at X7000 magnification showing that the elongated particle located in the center of Figure 1 is morphologically not a fiber.

FIGURE 3. Scanning electron micrograph of one rolled talc particle at X12,000 which has curled on both sides to form a tube. At a lower magnification this particle would be counted as a fiber.

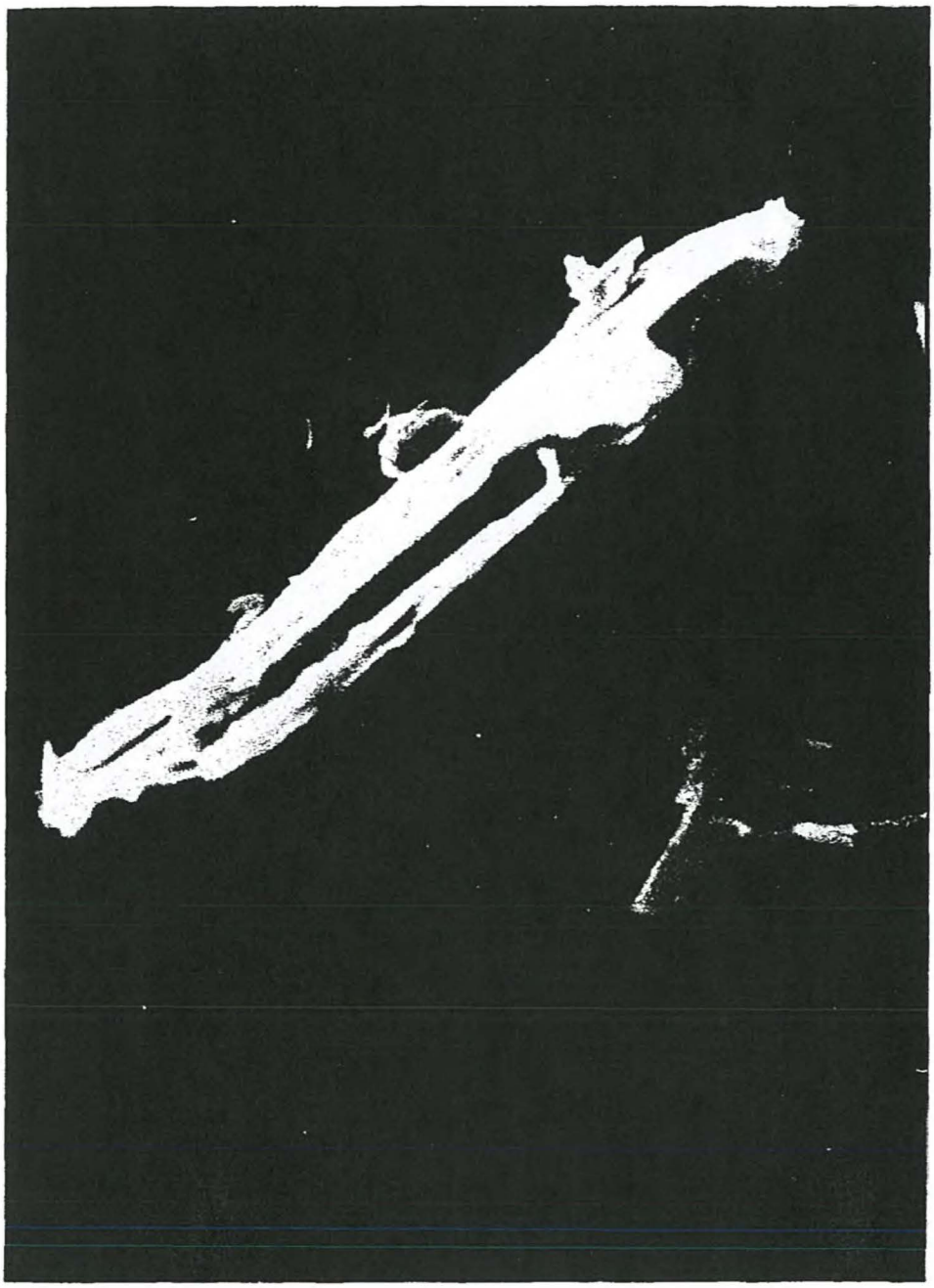

FIGURE 4. Scanning electron micrograph of an elongated particle standing on edge at X3500 magnification which might be considered as a fiber. By rotating the sample stage 60° (Figure 5), the laminated features of this talc particle can be seen.

FIGURE 5. (see Fig. 4 for legend).

FIGURES 6. Scanning electron micrographs showing that even some "fibers" are not immune from closer scrutiny. When the sample stage of the "fiber" in Figure 6 is rotated 50°, this "fiber" has the appearance as shown in Figure 7. These magnifications are X5000 and X15,000 respectively.

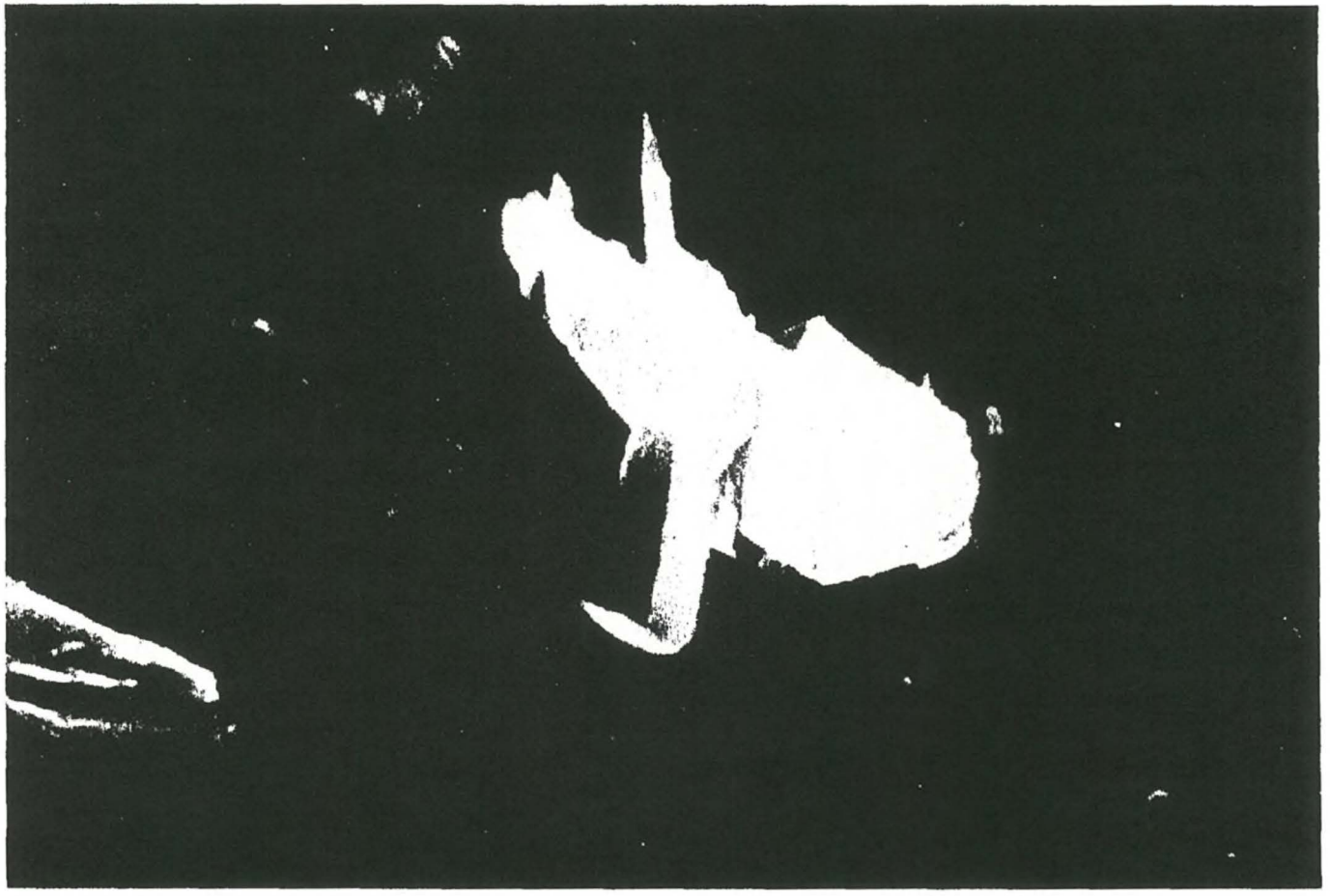

FIGURE 7. (see Fig. 6 for legend).

TABLE 6. Fiber Counts

Company		Location	Phase Contrast (fibers/cm³ > 5 μm length)	SEM	SEM fibers/cm³
A	Mine	Bobcat area	3.8	0	0.3
		Drilling area	4.1	0	
	Mill	Crushing area	4.7	0	
		Bagger	63.5	0	
		Palletizer	7.9	0.7	
B	Mine	Driller	0.8	0	
		Scraper	16.1	0.7	2.0
	Mill	Crusher	1.6	0	
		Bagger	6.0	0.8	
		Palletizer	4.6	0.3	
C	Underground mine	Driller	0.6	0.3	
		Mucker	0	0.3	0.6
	Walk-in Mine	Automatic Miner	7.5	0	
	Mill #2	Bagging Area	0.6	0.1	
		Palletizing area	1.7	0	

CONCLUSIONS

The Vermont talc industry was selected by NIOSH for both epidemiological and environmental surveys to establish a TWA dust exposure because this talc was believed to contain minimum amounts of quartz and asbestos. This environmental study characterized bulk samples from the three companies, and quantitated the talc workers' dust exposures. X-ray diffraction studies showed that the bulk samples contained major amounts of talc, and only trace amounts of quartz were found in 15% of these samples. Petrographic microscopy analyses, analytical transmission electron microscopy, and x-ray diffraction with step-scanning revealed no asbestos in the bulk samples.

The study further showed that SEM should be considered as an adjunct to the USPHS/NIOSH method when counting fibers in a dust environment. Phase contrast microscopy may suffice in an asbestos environment, but the resolution limitations of optical microscopy and the inability to distinguish rolled talc particles and talc "shards" from actual asbestos fibers will allow only a crude determination of the total fiber exposure.

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JOHN M. DEMENT
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