EFFECTS OF CERTAIN SILICATE DUSTS ON THE LUNGS*

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SILICATES, in comparison with silica (SiO_2), have been considered rather innocuous when inhaled as dust. It is silica itself, especially in the form of quartz, which is the classical dust producing serious pulmonary fibrosis; silicosis has far overshadowed other pneumoconioses, though the importance of asbestosis, which is due to a silicate, has recently been recognized. Other silicates also are implicated in the production of pulmonary fibrosis. Badham (1) in Australia has even considered that from a purely mechanical point of view the finer fibrosis produced by silicates might be at least as damaging as the more obvious and coarse ones produced by quartz (silica). Others also have described the fibrosis induced by these dusts as being of a finer type than that induced by dust which contains free silica in the form of quartz. To present briefly the results of recent observations conducted by the Public Health Service in industrial environments containing two classes of silicate dusts is the purpose of this paper.[1]

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[1] These observations were part of the dust studies of the Office of Industrial Hygiene and Sanitation of the United States Public Health Service. The field studies were under the direct charge of Surgeon Albert E. Russell, and the occupational and dust surveys were made by Sanitary Engineer J. J. Bloomfield, to both of whom the author is greatly indebted. The petrographic analyses were made by Prof. Adolph Knopf of Yale University, and the X-rays were made by Miss Rena A. Gianni.

One of the sources of dust was tremolite talc; slate was the other source—a greenish slate in one mill and a red slate in the other. Although these minerals had a total silicon content of about 60 per cent. (expressed as dioxide), most of this was in the form of silicates, for the tremolite talc contained no free silica in the form of quartz, the green slate only a trace, and the red slate 3 per cent. Tremolite is a hydrous calcium-magnesium silicate, $H_2Ca_2Mg_5(SiO_3)8$, which occurs in several forms; pure talc (or soapstone) has the formula $H_2Mg_3\ (SiO_3)4$. These two silicates, talc and tremolite, occur in about equal proportions (45 per cent.) in the stone dust of the first industry. In the slate mills, the dust was largely composed of silicates of aluminium, iron, magnesium, and potassium.

In both industries the plants were engaged in the crushing and milling of stone. In the case of tremolite talc a single mine supplied the raw stone for two separate mills, and the slate plant comprised two mills and their associated quarries which yielded a greenish and a red slate respectively.

The general principle of manufacture was very similar in each trade, for the loose stone obtained by blasting in quarry or mine was conveyed to the crushers and mills where it was gradually reduced in size to yield the final product of pulverized tremolite talc or of slate granules and flour. This ground stone was not a by-product, but rather the sole object of manufacture in each trade. Attention is called to this point because many plants, particularly of the older machined slate or structural slate trades, have installed such crushing and milling machinery for the utilization of waste stone.

The slate granules, which are used in coating manufactured composition roofing, will pass through a 10 and over a 26 mesh screen; they are thus about 1 mm. in diameter. The more finely pulverized slate flour is virtually a by-product as it is obtained by means of exhaust ventilation from the finishing mills. The tremolite talc is milled to a point which will allow 99 per cent. of the finished product to pass through a 325 mesh screen; the particles are thus less than 40 microns in diameter.

Since stone dust is the sole product of manufacture, the quantities produced are greater than if it were a by-product, and it is conceivable that the concentrations in the air from the crushing and milling machinery might

TABLE 1

CHEMICAL ANALYSIS OF TREMOLITE TALC AND SLATES

Chemical analysis of tremolite talc

CONSTITUENT	PERCENTAGE
Silicon dioxide*	56.54
Iron and aluminium oxide	1.04
Manganous oxide	trace
Magnesium oxide	30.74
Calcium oxide	6.25
Carbon dioxide	0.83
Loss on ignition	4.60
Insoluble (ignited)	84.92
Water—110°C	0.50
Specific gravity	2.8–3.1

Chemical analysis of slates

CONSTITUENT	PERCENTAGE	
	Green	Red
Silicon dioxide*	59.27	67.61
Titanium dioxide	0.99	0.56
Aluminium oxide	18.81	13.20
Ferric oxide	1.12	5.36
Ferrous oxide	6.58	1.20
Manganous oxide	0.13	0.10
Calcium oxide	0.42	0.11
Barium oxide	0.05	0.04
Magnesium oxide	2.21	3.20
Potassium oxide	3.75	4.45
Sodium oxide	1.88	0.67
Water below 110°C	0.32	0.45
Water above 110°C	3.98	2.97
Phosphoric oxide	0.11	0.05
Carbon dioxide	0.21	None
Ferric sulphide	0.15	0.03
Specific gravity	2.795	2.796

* The silicon found, though expressed in the chemical analysis as silicon dioxide, is not differentiated chemically as to the forms present in the original minerals, whether free silica or silicates.

TABLE 2

DUST COUNT AVERAGES IN VARIOUS DEPARTMENTS OF SLATE AND TREMOLITE TALC MILLING PLANTS

OCCUPATIONS	AVERAGE DUST COUNT IN MILLIONS OF PARTICLES PER CUBIC FOOT	
	Slate	Tremolite talc
Miners (jackhammer drillers)	—	1,440
Millers	710	52
Others	15	4

reach high values. Dust samples were taken at various breathing levels in the plants with the impinger apparatus (2) and dust counts determined from these.

Averages of these dust counts indicated that the users of the jackhammer pneumatic drills in the tremolite talc mines had the highest exposure of any group; the dust count for this group averaged 1,440 million particles less than 10 microns in diameter per cubic foot, and the millers in the slate crushing and milling plants were next with 710 million. The millers in tremolite talc, however, were exposed to an average of only about 52 million. Outside the mill proper the workers in slate (quarriers and yardmen) were exposed to an average of 15 million; a similar group in tremolite talc was exposed to only 4 million particles per cubic foot. These counts indicate that very dusty

PLATE 1.—First stage pneumoconiosis.

Tremolite talc miller (aged 54 years) for 22 years. Past medical history indicated he had had pleurisy at 20 years of age; pneumonia, 22 years of age. Examination of the lungs and heart was essentially negative.

Note the moderate bilateral increase in the size and density of the hilus shadows and the fine, diffuse reticular fibrosis in each lung field.

conditions prevailed around slate millers (screenmen, floormen, and other employees within the mill proper) and around the miners using drills in the case of tremolite talc. In a previous study in the cement industry, (3) in which the crushing and milling are not very dissimilar in principle to that here observed, the highest count was only 105 million particles per cubic foot.

In addition to these dust counts, other samples of dust were obtained with the Owens Jet apparatus, (4) and the size of the individual dust particles was measured by a filar micrometer. Sixty-eight per cent. of the tremolite talc and 60 per cent. of the slate particles were less than 2 microns in diameter. None of the particles for either dust exceeded 6 microns in diameter.

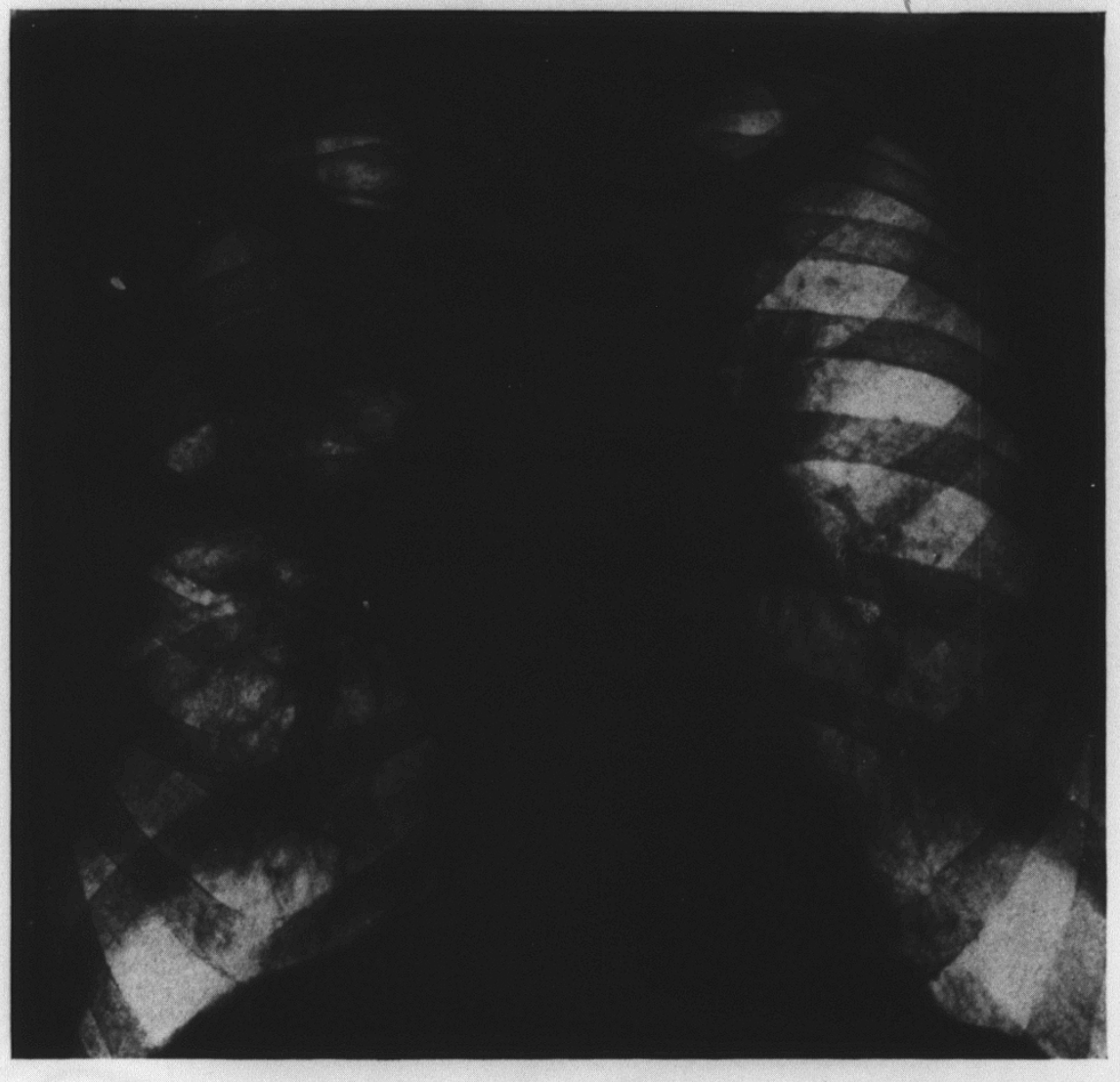

PLATE 2.—Second stage pneumoconiosis (with dormant tuberculous infection). Tremolite talc miller (aged 68 years) for 42½ years. Had severe influenza in 1918. Respiratory and cardiac physical findings were essentially negative.

Note the accentuation of the "soft" linear fibrosis and the appearance of flakelike, dappled areas of increased density. The fibrotic remains of an interlobar pleurisy on the right appear to have caused traction on the mediastinal structures. Diaphragmatic irregularities are present on both sides.

Clinico-roentgenographic study.—Sixty-one men were employed in tremolite talc and 80 in the slate plants at the time of the study. This small number suggests that caution should

be observed in making definite deductions from the clinical data. The endeavor was made to examine as large a proportion as possible of the workmen, and in fact 93 per cent. of the tremolite talc workers (57 men) and 99 per cent. of the slate workers (79 men) were given careful clinical examinations supplemented by roentgenograms of their chests.

In the clinical examination of the tremolite talc group no cases were encountered that presented symptoms or signs of active pulmonary tuberculosis; and in the slate group only one case had clinically active pulmonary tuberculosis. Bronchitis was present in only 5 per cent. of each group. No cases of cardiac decompensation were found. Upper respiratory conditions such as chronic pharyngitis, enlarged tonsils, etc., were present in about the same proportion as is observed in the industrial population generally.

PLATE 3.—First stage pneumoconiosis.

Slate miller (aged 37 years) who had worked as such for 14 years (slate trimmer and sawyer previously for 4 years). He had influenza in 1919 with an illness of three weeks duration. Physical examination of the lungs was essentially negative.

Note increase in size and density of hilar shadows and the soft, fine reticulated fibrosis converging toward the hilus from periphery of the lung fields. The bilateral symmetry of these features and their confinement mainly to the lower two-thirds of each lung field is shown.

Symptoms and signs which might point to pneumoconiosis were very infrequent. Dyspnoea, which is such a striking finding in advanced late stages of silicosis, was not observed among the tremolite talc workers and was present only to a mild degree in the two advanced cases of pneumoconiosis observed in the slate workers.

Interpretation of the radiograms was independent of the clinical history. In recording the findings observed in these X-rays the designation of first, second, or third stage of pneumoconiosis is made, similar to the designation commonly applied in the United States to silicosis. While it is true, no doubt, that the same criteria used in the X-ray diagnosis of silicosis cannot be directly transposed and used to in-

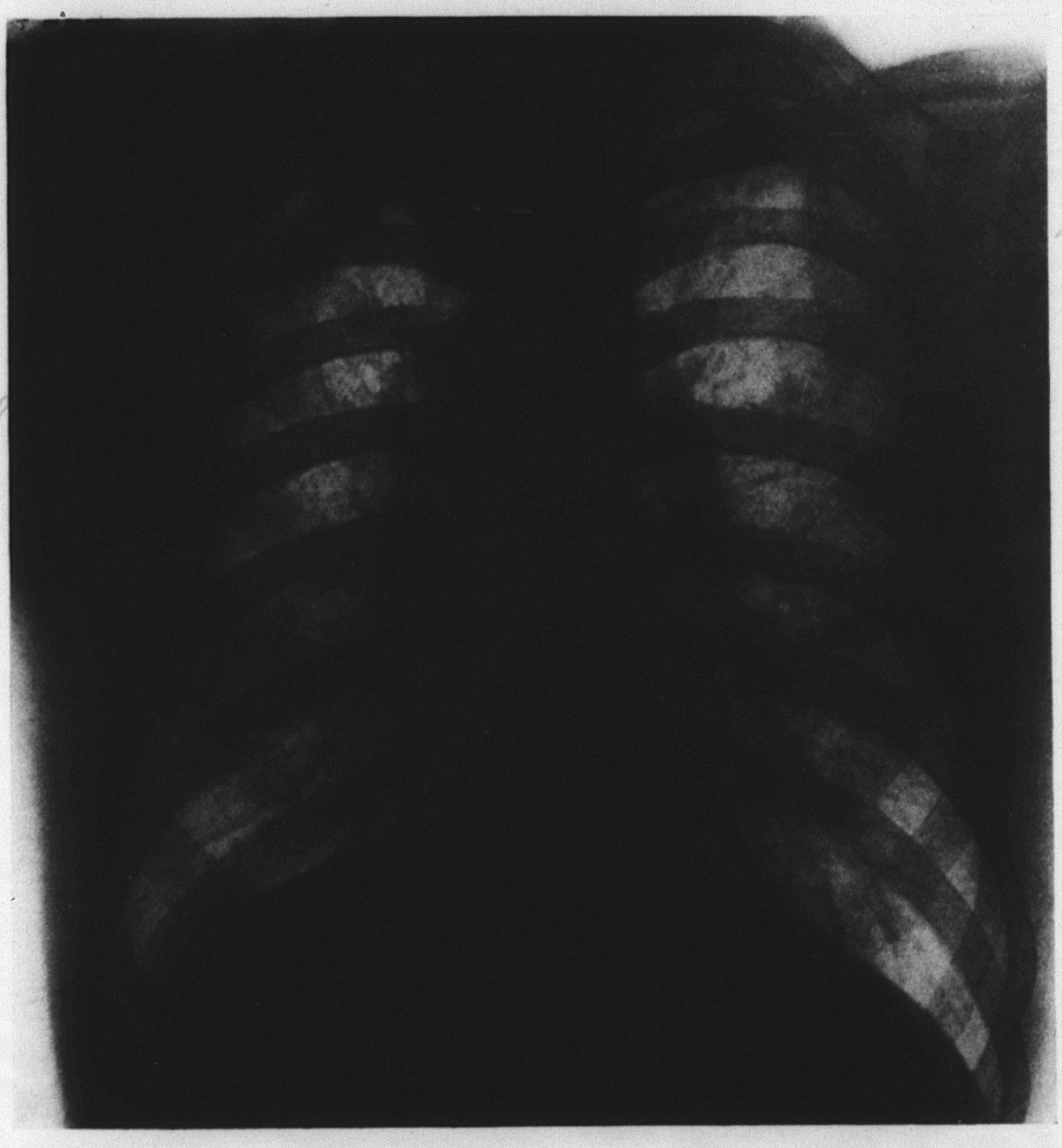

PLATE 4.—First stage pneumoconiosis (with dormant tuberculous infection).

Slate miller (aged 36 years) who had worked in slate mill 12 years and previously as slate quarrier for 3 years. He had pneumonia in 1918 complicated with pleurisy of left chest. Physical examination of the lungs elicited no definite findings.

Note the vertical or "drop" heart. Here the fine fibrosis has same general characteristics of Plate 3. In addition, however, an infra-clavicular clouded area of increased density is seen on the right side, between 1st and 2nd ribs anteriorly.

terpret the fibrosis incited by this less fibro-genetic dust, it was felt that making the interpretations along these general lines would offer fewer difficulties than attempting to use an altogether different classification.

PLATE 5.—Third stage pneumoconiosis (with dormant tuberculous infection).
Slate miller (aged 53 years) who had worked as crusherman for 18 years. Respiratory diseases were denied. Physical examination revealed a bilateral limitation of expansion and decreased breath sounds at the bases of the lungs posteriorly.
Note the dappled areas of increased density which are becoming conglomerate in middle of the lung fields particularly on the left side.

Of the 48 cases of pneumoconiosis observed, all were in the first stage except 5 cases. In general, the pneumoconiosis observed in the early or first stage cases resembled that induced by cement dust. The bronchial striations, however, were somewhat more prominent. There was always a moderate bilateral increase in the size and density of the hilar shadows with accentuations of bronchial striations which extended well out into each lung field. The linear striations seemed "softer" in appearance and lacked some of the sharpness of detail which is usually observed in

the X-rays of individuals who have inhaled silica dust. This diffuse, fine, generalized fibrosis was chiefly confined to the lower two-thirds of the lung fields.

In the second stage an increased prominence of the above-mentioned characteristics was present with the appearance of flakelike, dappled areas of increased density in both lung fields. In the third stage these dappled areas seemed to conglomerate, and in this manner gave way to massive, clouded areas of increased density.

In certain cases which did not come within the scope of these three stages, the South African term "more fibrosis than usual" (5) was used to signify a condition observed in a chest roentgenogram midway between that of one

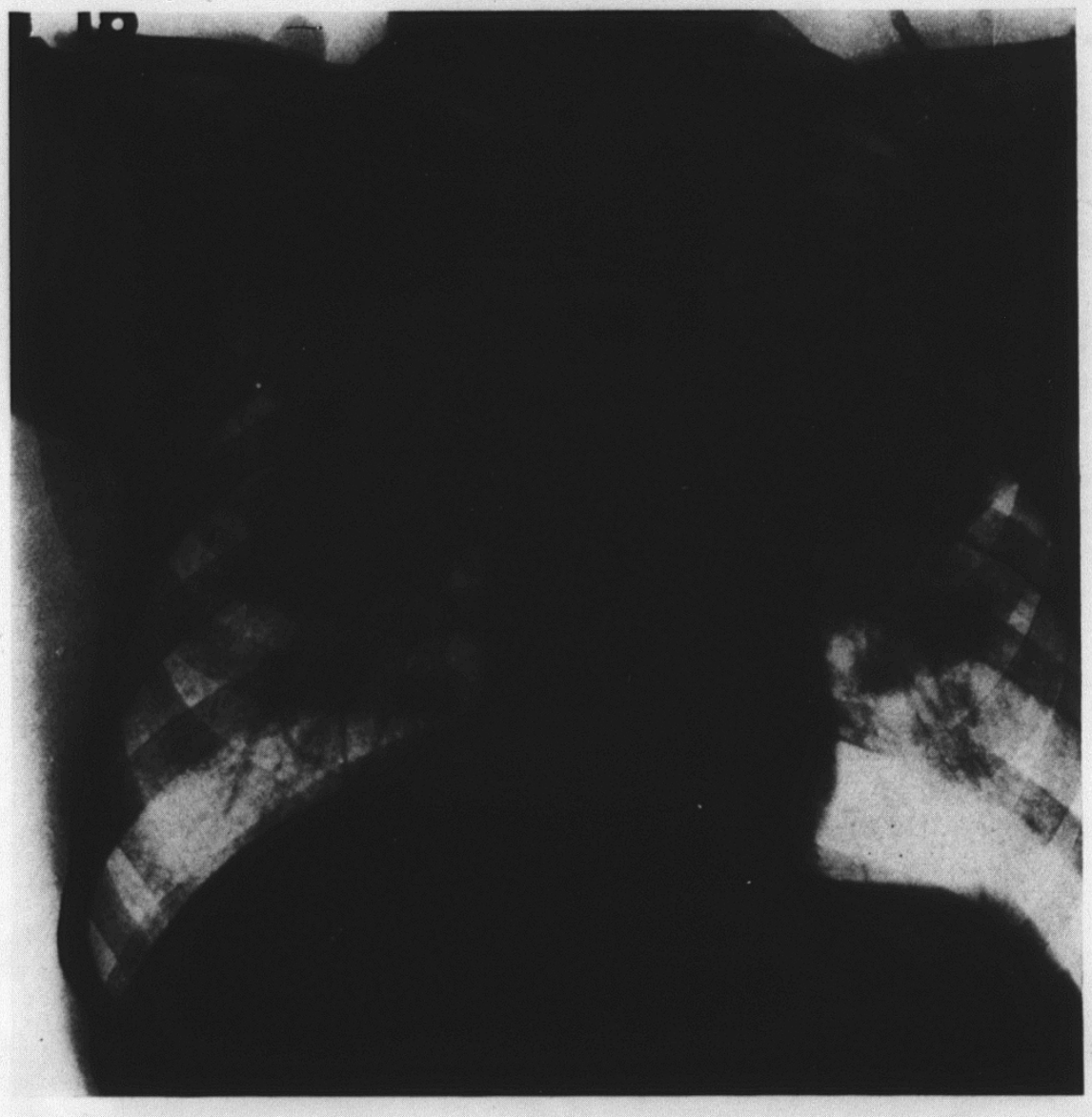

PLATE 6.—Third stage pneumoconiosis with active pulmonary tuberculosis.

Slate miller (aged 39 years) for 9½ years. His previous industrial employment was limited to 8 months as a metal worker (machinist) and 2 years as truck driver. Had symptoms of active pulmonary tuberculosis (such as anorexia, loss in weight and strength, cough, hemoptysis and dyspnoea) for three months preceding examination. Physical examination of lungs revealed definite infiltrative processes in upper portions of each lung.

Note the massive clouded areas of increased density in the upper two-thirds of each lung field; linear fibrosis and emphysema are noted in the lower thirds of each lung field, with slight diaphragmatic irregularities on each side.

which was radiographically negative or within the limits of normal, and that of a chest which showed definite first stage changes. In these, an increase of fibrosis above that usually seen in the X-rays of an adult was present, yet the extent of the involvement was not sufficient to warrant the diagnosis from its significance. In certain cases where the type of fibrosis, its distribution, and other radiographic characteristics pointed to such an inactive pulmonary tuberculosis, the term "dormant tuberculous infection" was added to the other diagnoses. This probably tuberculous condition appeared non-

TABLE 3

RELATION OF YEARS OF EXPOSURE TO ROENTGENOGRAPHIC DIAGNOSIS. TREMOLITE TALC MINE AND MILL WORKERS

(A, without; B, with dormant tuberculous infection)

ROENTGENOGRAPHIC DIAGNOSIS*	YEARS OF EXPOSURE							NUMBER	PERCENTAGE
	Up to 5	5–9	10–14	15–19	20–24	25–34	35–44		
Negative:									
A	1							3	5
B	1	1							
More fibrosis than usual:									
A	10	10	2	1		2		38	67
B	4	6	1	2					
Early pneumoconiosis:									
A	1	6	3	3	1			15	26
B						1			
Pneumoconiosis II:									
B							1	1	2
Total number men	17	23	6	6	1	3	1	57	100
Percentage distribution according to length of exposure	30	41	10	10	2	5	2		100

* No cases of active pulmonary tuberculosis.

of pneumoconiosis. The distribution of this fibrosis was usually bilateral and in most instances had characteristics which were consistent with exposure to dust, but it was not definitely indicative of dust exposure, for other contions in an adult X-ray may present a similar appearance. The presence of an apparently arrested or healed tuberculosis, for instance, would detract progressive at the time of X-ray and is therefore to be distinguished from active tuberculous disease. When the X-ray findings were within the limits of normal, the term "negative" was used. By using the above classification, the findings for the tremolite talc workers in summary showed that in only 3 cases (5 per cent.) were the X-ray findings within the limits of normal;

thirty-eight (67 per cent.) showed more lung fibrosis than usual; fifteen (26 per cent.) showed evidence of an early or first stage pneumoconiosis. In only one case—that of an individual who had been in the tremolite talc milling trade over 40 years—had the fibrosis advanced beyond the first stage. This individual showed second stage findings. No advanced or third stage cases were encountered.

In Table 4 similar findings were recorded for slate quarry and mill workers, and it was found that nine of these (12 per cent.) had X-ray findings of entirely negative chests as regards pneumoconiotic tendencies; thirty-eight (48 per cent.) showed more fibrosis than usual; and twenty-eight (35 per cent.) showed first stage or early pneumoconiosis. Two showed second stage and two third stage changes. One of the latter had clinically active pulmonary tuberculosis.

Discussion of findings in light of actual dust exposure.—By using dust count values which were observed in the dust survey of the plant, and taking cognizance of the worker's trade life, an attempt was made to show whether any relationship existed between the concentration of dust which the men might inhale and the clinico-roentgenographic findings. This is presented

TABLE 4

RELATION OF YEARS OF EXPOSURE OF SLATE WORKERS TO ROENTGENOGRAPHIC DIAGNOSIS

(A, without; B, with dormant tuberculous infection)

ROENTGENOGRAPHIC DIAGNOSIS	YEARS OF EXPOSURE						NUMBER MEN	PERCENTAGE
	Up to 5	5–9	10–14	15–19	20–24	25–34		
Negative:								
A	2	2	1	1			9	12
B		2	1					
More fibrosis than usual:								
A	5	6	7	1	1	1	38	48
B	4	5	6	1	1			
Early pneumoconiosis:								
A	3	5	5	2	1		28	35
B	3	2	3	4				
Pneumoconiosis II:								
B		2					2	2.5
Pneumoconiosis III:								
B		1*		1			2	2.5
Total number men	17	25	23	10	3	1	79	
Percentage distribution according to length of exposure	21	32	29	13	4	1		100

* Active pulmonary tuberculosis.

for tremolite talc workers in the graphic representation of Figure 1. Here, each individual worker is indicated as a square and placed according

It is seen that all the cases of pneumoconiosis were observed in Groups 1 and 2. The small number of workers, as well as the short occupational life,

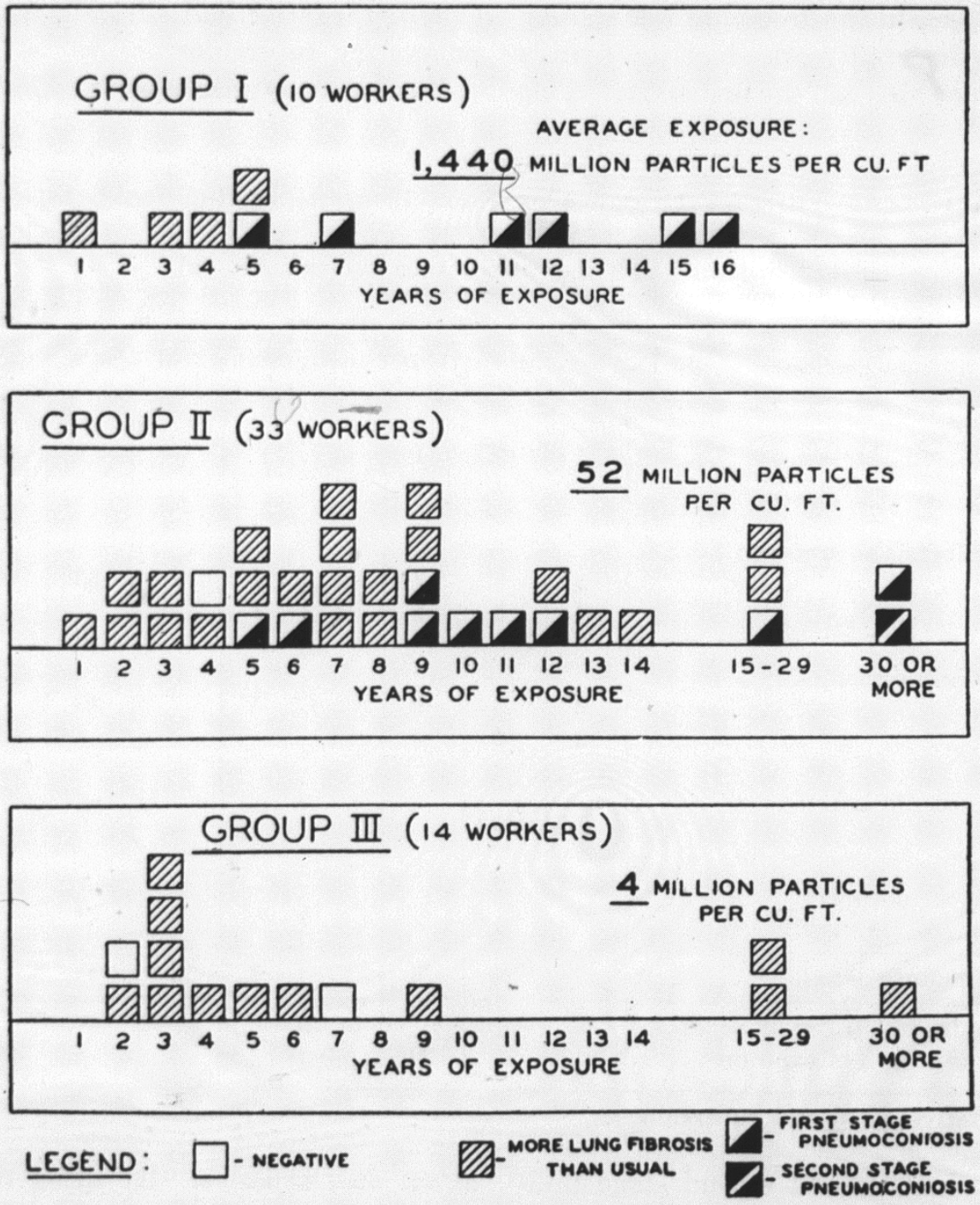

FIG. 1.—The occurrence of pneumoconiosis at various degrees of dustiness among tremolite talc mine and mill workers.

to the concentration of dust to which he has been exposed and the length of time he has worked in this exposure. The shading indicates the degree of pulmonary fibrosis or pneumoconiosis.

is probably the explanation for the absence of more advanced cases in Group 1, especially since these men were exposed to such a high concentration of dust. It is felt, however, that

some indication of the amount of pneumoconiosis likely to occur at this concentration may be obtained, as all of the cases in this group who had worked more than 6 years showed definite evidence of pneumoconiosis. This constage pneumoconiosis, which was observed in the man who had worked in talc for over 40 years. In Group 3 no definite cases of pneumoconiosis were observed.

The slate workers have similarly been

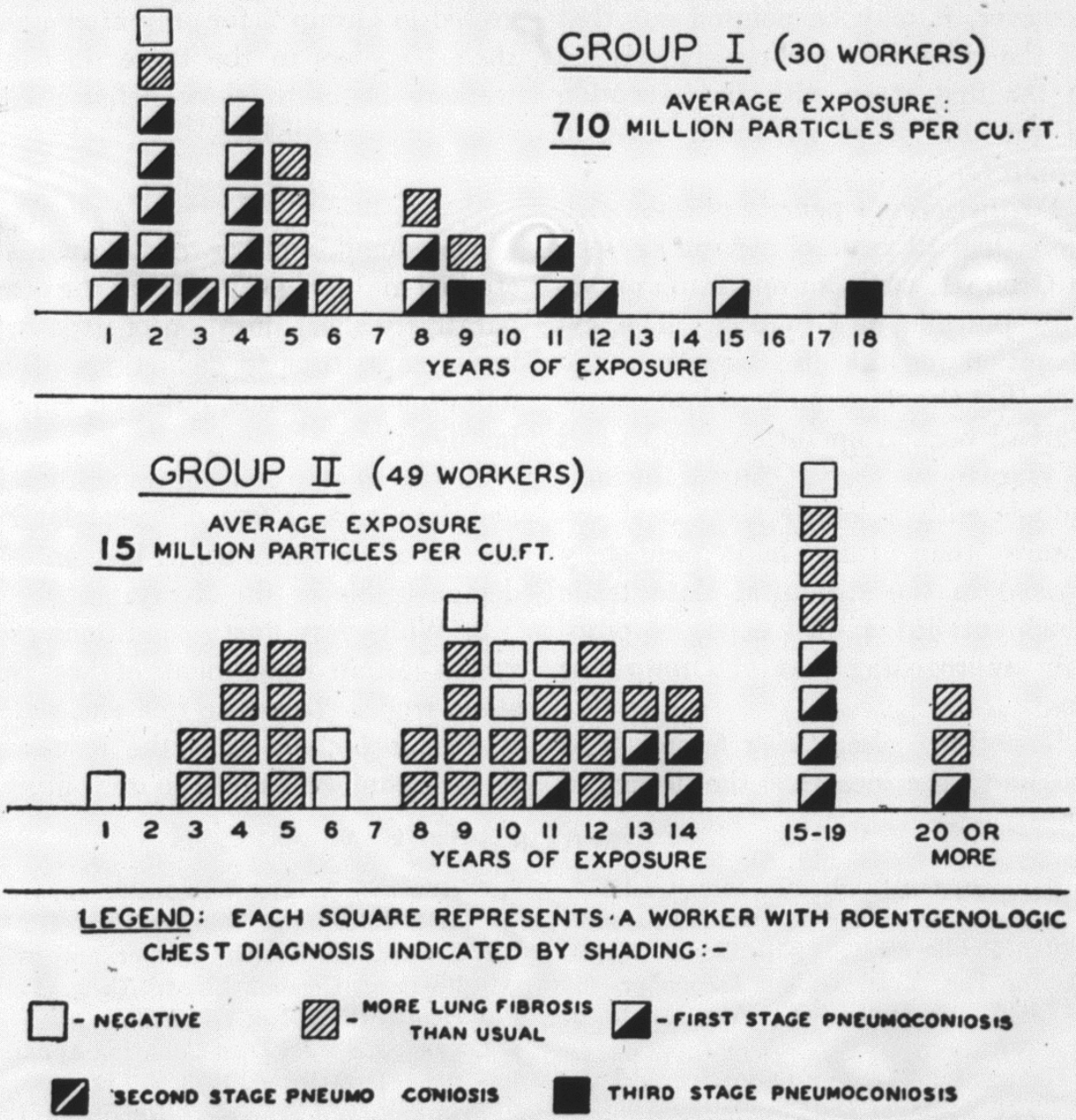

FIG. 2.—The occurrence of pneumoconiosis at different degrees of dustiness among slate quarry and mill workers.

sistent appearance of pneumoconiosis makes one wonder what picture these individuals might present after 30 or 40 years of such exposure. In Group 2 pneumoconiosis is also encountered but somewhat more irregularly. This group shows the single case of second

divided into two groups as regards exposure. Three striking differences are shown in Figure 2 with respect to pneumoconiosis as seen in the two groups, namely: (1) 74 per cent. of Group 1 show pneumoconiosis compared with the 20 per cent. of Group 2; (2) pneu-

moconiosis is noted within the first few years of trade life in Group 1; and (3) advanced stages (second and third) are observed only in those with the highest exposure. Lest the figure create a false impression of severity, however, it may be pointed out that all the cases with pneumoconiosis are in the first stage with the exception of the four more advanced cases in Group 1.

Furthermore, a paucity of cases with more than 10 years of exposure is seen in Group 1, while an opposite appearance prevails in Group 2. The explanation for this lies largely in the fact that the slate milling plants studied had been in operation only 13 and 18 years respectively. Any of the individuals with a longer slate dust exposure than this, had previously worked in the structural slate trade which entailed a dust exposure probably approaching that of Group 2 or less.

If nothing else, these figures lend weight to the idea that the dosage of dust expressed in the concentrations which the workers might inhale cannot be overemphasized, as a definite relationship seems to exist with regard to this factor. The effect of years in the trade (length of exposure) is suggested in Group 2, for only after more than 10 years in the trade do these workers begin to show definite first stage pneumoconiosis.

Summary

The small number of individuals studied and for most of them the comparatively short duration of exposure, invite caution as to deductions. The following conclusions, however, appear justified:

1. The silicate dusts of tremolite talc and slate induce a fine, diffuse, bilateral fibrosis of the lungs which is definitely demonstrable in the X-ray.

2. While very dusty conditions prevail in certain departments of these two stone trades (tremolite talc and slate) it cannot be said that the resultant pneumoconiosis has led to disability.

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