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THE DUST HAZARD IN TREMOLITE TALC MINING, INCLUDING ROENTGENOLOGICAL FINDINGS IN TALC WORKERS

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FROM time to time the attention of the Division of Industrial Hygiene has been drawn, through compensation claims, to incapacitating fibrosis in talc workers. Since silicate dusts, of which talc is one, have been considered relatively innocuous in the opinion of most authorities (the single exception being asbestos), the occurrence of these cases has naturally raised several questions—the obvious question as to whether this incapacity has resulted from talc exposure alone, and the second more interesting question as to whether industrial hygienists, with few exceptions, have erred in considering asbestos to be the only injurious silicate dust.

In an attempt to answer these questions, the study here reported was undertaken. It consisted of an investigation of the talc industry and an examination of talc miners and mill workers in northern New York State (St. Lawrence County) made, in 1940-1941, as a joint enterprise of the Division of Industrial Hygiene of the State Department of Labor and the Division of Tuberculosis of the State Department of Health.

NATURE OF TALC

Talc is a hydrous magnesium silicate with the formula $H_2Mg_3(SiO_3)_4$, composed, according to Ladoo¹² of about 63 per cent SiO_2 , 32 per cent MgO , and 5 per cent H_2O . It is usually a secondary mineral resulting from the alteration of other magnesium silicates or carbonates. While its own silica is present in the combined form, most talcs mined commercially contain varying amounts of such impurities as quartz, calcite, dolomite, iron oxide, etc.

Talc has a characteristic soapy feeling and a pearly lustre. It may be pure white, silvery white, gray or green and, when impure, yellow, brown or reddish. The most common commercial variety is a massive, foliated, or granular type, but it may also occur in a micaceous, or in a fibrous form.

Soapstone is a closely related substance, being essentially an impure talc, and when pulverized it may be used for the same purposes. Tremolite, which is a calcium magnesium silicate, changes over to talc. It may be mined with it and subsequently ground and sold as talc.

GEOGRAPHICAL DISTRIBUTION

The United States produces about 65 per cent of the world's supply of talc, the leading states in its production being Vermont, New York, California, North Carolina and Georgia.

THE INDUSTRIAL USES OF TALC

According to the Minerals Year Book (1938) of the United States Bureau of Mines, the use of talc and soapstone is steadily increasing. Ladoo¹² states that at least 60 different uses for talc have been noted, though most of them are of minor importance. Its value depends chiefly on its usefulness as a filler, inert extender, dusting powder and absorbent. In 1921, according to Ladoo, the marketed, ground talc production in this country was industrially distributed as follows: paper 38 per cent, paint 23 per cent, prepared roofing 18 per cent, rubber 9.5 per cent, textiles 4 per cent, toilet powder 2.5 per cent, other uses 5 per cent.

The other uses for which ground talc is adapted are: as a filler in soap; in foundry facings; in wire-insulating compounds; in dry lubricants; as a filler in cotton textiles; in the dressing and manufacture of leather; as a cleaning and polishing agent for rice, peas, coffee beans, peanuts, etc.; in making colored crayons; as a filler in windowshade cloth; as a dusting agent in making candy, chewing gum, etc.; and as an ingredient of concrete, plastics and insecticides.

Since 1921 there has been a marked increase in its use in the ceramic industry. Fourteen thousand more tons of talc and related materials were sold in 1937 than in 1936 and about 10,000 tons of this increased amount went to the ceramic industry where talc is chiefly used as constituent of glazed wall tile.

REVIEW OF LITERATURE ON THE EFFECTS OF TALC DUST

Experimental Studies. During the last ten years a certain amount of experimental work with talc dust has been reported, but on reviewing this literature most of the inhalation experiments are found to have been of insufficient duration to be helpful in regard to the probable effect of long continued industrial exposure.

In 1931, Haynes¹⁰ included talc in a series of dusts studied for their reactions on guinea pigs. Twelve pigs were dusted two hours daily, except Sunday, for a fortnight. The author saw no sign of pulmonary damage, but found that bronchial and lymphatic removal occurred unusually briskly. He concludes that the substances dissolved from talc are of a low degree of toxicity but sufficiently obnoxious to neighboring tissues to cause the removal of cells containing them.

Stüber,¹¹ in 1934, studying the cellular response of lymph nodes to various dust suspensions introduced into the lymphatics, found that talc caused no apparent cellular proliferation within the lymph nodes after five days. After 108 days the nodes were still normal and showed no increase in connective tissue.

Fossel,¹² in 1935, reported experiments in which guinea pigs were exposed to the inhalation of talc for one hour daily over a period of

eight weeks. No significant tissue changes were seen.

Bethune,¹³ in 1935, was able to produce pleural adhesions in cats and dogs by blowing commercial talc into the pleural cavity. Miller and Sayers, quoted below, found that adhesions were produced by injecting various dusts into the peritoneal cavity, but that such adhesions were not related to the subsequent behavior of the dust.

Fienberg,¹⁴ in 1937, having observed granulomas from the surgical use of talc, experimented with the injection of this substance in mice and obtained subcutaneous granulomas in these animals.

Miller and Sayers,¹⁵ in 1936, reported studies in which talc was included among the dusts whose intraperitoneal reaction in guinea pigs was studied. They found that it produced an "inert reaction." That is to say, the injected dust was not absorbed; neither did it initiate a cellular proliferation. In interpreting the significance of "inert reactions" the authors conclude that such dusts should be considered as potentially harmful.

Gardner,¹⁶ summarizing experimental work on silicate dusts at the Saranac Laboratory said, at the Fourth Saranac Laboratory Symposium on Silicosis (1939), "a few silicates like true talc . . . and some of the clay minerals have provoked chronic inflammation (of the lungs) but this reaction has tended to retrogress after several months. No progression to a stage of true fibrosis has been observed within periods of one to two years and there is no indication that the progression will occur."

Polcard,¹⁷ in 1939, reported an experiment in which he dusted white rats with foliated, industrial talc three hours a day for twelve days. The intensity of the exposure was high. He found that the dust was irritating to the upper respiratory tract and produced a marked dyspnea. In the lungs of animals sacrificed two and six days after inhalation began, he found dilatation of bronchi, acute emphysema, and exudative alveolitis. Many animals died spontaneously with pulmonary congestion and foci of bronchopneumonia. The short duration of the experiments did not permit any conclusion concerning the possibility of pulmonary fibrosis.

McCormick and Ramsey,¹⁸ in 1941, reported postoperative, peritoneal granulomatous inflammation caused by talc in 2 cases.

Schulz and Williams,¹⁹ in 1942, injected intra-

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tionally in guinea pigs a series of seven commercial talcs with different silicate-carbonate ratios. Animals were sacrificed at intervals ranging from ten days to fifteen months. In all cases, the pathological histology showed the holding of talc particles in a local area by phagocytic cells of the macrophage and giant cell type. Progressive fibrosis was not found. The fibrosis which occurred was only enough to hold and limit the space for storing the foreign material. The greatest amount of fibrous tissue developed in the presence of the two talcs which contained the least carbonate and the most talc and tremolite respectively.

Clinical Reports. Talc fibrosis as an occupational disease has received attention in this country only within the past ten years, and until the studies of Dreessen and DallaValle, discussed later, extremely few talc workers had been studied anywhere.*

Policard¹⁸ says that it was in 1896 that the question of the action of industrial talc dust on the human lung was first considered. At that time a pathologist of Nuremberg, Thorel, published the results of the pathological examination of the lung of a tuberculous woman patient of forty-four years, who had worked for many years in soapstone dust. According to Policard, Thorel demonstrated the presence of cells containing soapstone dust in the cavity and walls of certain alveoli and the existence of formations, more or less nodular, resulting from the accumulation of cells filled with talc. Other nodular formations of a tuberculous nature were present, and Thorel pointed out a combination of tuberculous and pneumoconiotic lesions.

In 1915, according to Policard,²⁰ Hayburst stated that work in talc dust favored and exaggerated tuberculosis, but the basis for this opinion is not known.

Zanelli, in 1931, quoted by Teleky,²¹ came to the conclusion that talc dust, though belonging to the family of silicates, ought to be considered dangerous and likely to produce typical pneumoconiotic lesions.

Merewether¹ in 1933, reported the cases of 11 rubber tire workers, exposed from ten to thirty-two years to French chalk, a fine granular

variety of talc dust, who showed diffuse interstitial fibrosis by roentgen examination without clinical evidence of anything more than a peribronchial increase in fibrous tissue. Thirteen additional workers, with exposures of from four and one-half months to forty-eight years, were examined and reported upon the following year¹ confirming the original findings.

In 1933 a report was made by Dreessen² of examinations of a number of workers in silicate dusts, including 57 men exposed to tremolite, a hydrous calcium magnesium silicate containing no free silica.

The findings in this group were as follows: more fibrosis than usual 67 per cent, first stage pneumoconiosis 26 per cent, second stage pneumoconiosis 2 per cent, normal lungs 5 per cent.

Dreessen described the first stage pneumoconiosis as similar to that produced by cement dust; "softer" than that resulting from silica dust, a "diffuse, fine, generalized fibrosis . . . chiefly confined to the lower two-thirds of the lung fields."

In 1935 the same author, together with DallaValle,⁴ reported on the effect of exposure to dust in two Georgia talc mills and mines. The dust involved was, again, a calcium magnesium silicate containing no free silica. It was present in excessive amounts, over one and one-half billion particles per cubic foot in some operations, the particle size averaging less than 1 micron. Sixty-six workers were examined. Among these, 22 (33 per cent) showed pneumoconiosis, 8 in stages two or three. The conclusion was reached that exposure to talc dust was either "too severe" in the Georgia study, or that this talc was a more dangerous dust than that previously studied. No particular relationship between talc exposure and tuberculosis was demonstrated.

Middleton,¹⁶ in 1936, referred to an unpublished case of Cunningham's in which pneumoconiosis was found in a talc grinder who had been employed for nine years. He also mentioned an autopsy by Sand in 1910 on a woman exposed to talc dust in which "not much reaction" was found.

In 1938, Nuck and Szczepanski¹⁹ reviewed the literature on talc fibrosis and added several cases of their own. They concluded that this type of pneumoconiosis resembled asbestosis more than silicosis.

At the International Conference on Silicosis

* Since this report was written, Porto, F. W., Patton, J. R. and Hobbs, A. A., Jr. (Pneumoconiosis in the talc industry. *AM. J. ROENTGENOL. & RAD. THERAPY*, April, 1942, 47, 507-524) have described pneumoconiosis in 15 tremolite talc workers with a fatal termination in five.

at Geneva in 1938,¹² Riddell reported the results of the examination of 37 workers engaged in grinding talc ore. Thirteen showed fibrosis resembling silicosis.

Gardner on the same occasion¹³ said that of 300 films of talc workers which he had examined about 50 showed some evidence of pulmonary reaction which in 17 suggested nodulation.

From a survey of the literature it appears that while experimental studies have hitherto been inconclusive, clinical studies have tended to indicate that talc dust is capable of producing injurious pulmonary changes.

COMPENSATION CLAIMS FOR DISABILITY DUE TO TALC DUST IN NEW YORK STATE

The cases which originally drew the attention of the Division of Industrial Hygiene to disability resulting from exposure to talc dust are summarized below. Six such cases have occurred during the past few years. One originated in the manufacture of talcum powder; one in the shoe industry, and 4 of them in talc mining and milling. In one case (Case v) there had been significant previous exposure to dust probably containing free silica. Five of the 6 cases were fatal. In 5 cases, summaries are available as follows:

CASE I. Aged sixty-three. The claimant had worked for twelve years operating a talcum powder mixing machine not provided with exhaust ventilation for dust control. The talc used was found by the Division of Industrial Hygiene to contain less than 0.5 per cent of free silica. The dust concentrations at this work ranged from 13.9 to 34.8 million particles per cubic foot.

For three or four years before quitting the job, the claimant had complained of cough with expectoration. Examination of the lungs showed moist râles at the bases. The vital capacity was 2,500 (normal estimated as 4,000).

Röntgen examination of the lungs showed an increase of bronchial markings in the lower and middle fields with areas of increased density resembling lipiodol or calcific deposits in both midlung fields.

A diagnosis was made in hospital of emphysema and chronic bronchitis with acute exacerbation.

CASE II. Aged forty-four. For twenty-two years the claimant had worked as a "bed laster" in a shoe factory. White shoes were manufactured during about five months of the year and at these times he used talc freely, dusting it on the shoes to prevent soiling of the white leather. The powder used was analyzed by the Division of Industrial Hygiene and found to contain no free silica.

For seven years before quitting work he complained of cough, dyspnea and increasing weakness. His condition finally necessitated hospital treatment.

Physical examination showed the presence of dyspnea, cyanosis and clubbing of the fingers. Examination of the lungs revealed dullness on both sides with diminished fremitus and breath sounds.

Röntgen examination of the chest showed marked, confluent, hazy mottling with nodular densities uniformly distributed. The right ventricle was hypertrophied (cor pulmonale).

The diagnosis was chronic pulmonary fibrosis and emphysema. The case terminated fatally nine months after admission to the hospital.

CASE III. Aged forty-nine. The claimant had worked as a talc miner for fifteen years with eight months' exposure in other mines ten years previous to his talc exposure. His illness began five years before death with shortness of breath and a productive cough. He quit work two years after the onset of symptoms because of increasing weakness, and was admitted to a sanatorium.

Physical examination showed an emaciated individual who looked chronically ill. The vital capacity was 1,800 (normal estimated as 3,000). The lungs showed dullness over the middle and thirds, râles above second rib anteriorly, and posteriorly throughout. Five specimens of sputum were negative for the tubercle bacillus. The temperature was normal.

Röntgen examination showed extensive, bilateral fibrosis with infection, probably tuberculous, and this was the diagnosis.

CASE IV. Aged thirty-seven. For twenty-one years the claimant had worked in talc mines as mucker, driller and foreman. For two years before quitting work he had noticed cough, shortness of breath and pain in chest. He was easily fatigued. These symptoms caused him to enter a hospital for treatment.

Physical examination revealed no lung abnormalities but showed cardiac hypertrophy, hypertension and evidence of nephrosis.

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Roentgen examination of the chest showed consolidation through both lung fields below the fifth posterior rib, more marked in the right lung field, an increase in hilum shadows and cardiac hypertrophy.

The clinical diagnosis was early silicosis with probable infection, hypertensive disease and pyelonephrosis.

The case terminated fatally.

Case v. Aged fifty-two. The claimant had worked in talc mines for seventeen years with a previous exposure of ten years in zinc and iron mines. Illness began six years before death with cough and dyspnea. Following the initial symptoms he developed pain in chest and hemoptysis and sought hospital treatment.

Physical examination showed an emaciated individual, appearing chronically ill. The fingers were slightly clubbed. The chest expansion was limited. Examination of the lungs showed dullness on the right below the seventh spine with rales and diminished breath sounds. The sputum was positive.

Roentgen examination showed a fine miliary type of increased density on the left, a mass of increased density in the right middle lung field with evidence of excavation, and heavy fibrosis at the right base.

The clinical diagnosis was probable silicosis, complicated by tuberculosis.

Death occurred twenty-one months after admission to the hospital.

REPORT OF A STUDY OF TALC MINERS AND MILLERS IN ST. LAWRENCE COUNTY, NEW YORK

Scope of Study. In the course of this investigation studies of operations and dust concentrations were made by engineers of the Division of Industrial Hygiene in three talc mines and five talc mills. Two hundred and twenty-one men from seven plants received an initial roentgen examination. In the case of 28 of these individuals, who showed positive lung findings, a follow-up examination was made at the end of ten months which included a second roentgenogram, a medical history and physical examination of the chest, and a detailed occupational history.

The roentgen examinations were made with a 200 milliamper machine mounted on a truck belonging to the Division of In-

dustrial Hygiene.¹¹ Patterson high speed screens were used, and exposures were made at a 60 inch distance and with an exposure time of one-tenth of a second.

Type of Talc Involved. The type of talc produced in St. Lawrence County is of the fibrous variety known as asbestine. It is noted for its clear whiteness and is used chiefly as an ingredient in the manufacture of paint and tile. With it is found tremolite—calcium magnesium silicate ($\text{CaMg}_3(\text{SiO}_3)_4$)—a similar appearing mineral occurring in a fibrous or asbestiform state which in the course of time changes over to talc. Gardner¹² reports that anthophyllite, another fibrous silicate, is also present in the talc deposits of the St. Lawrence County region.

Analysis of representative samples of talc from two of the mines in the region, submitted by one of the mining companies, shows the following composition:

Analysis	Sample A	Sample B
Total silica*	68.24	57.50
Calcium oxide	2.72	5.24
Aluminum oxide	—	.27
Iron oxide	—	.17
Manganese oxide	—	.16
Carbon dioxide	—	.38
Magnesium oxide	24.51	30.20
Calcium carbonate	0.23	—
Sulfur trioxide	trace	—
Ignition loss	3.65	5.13
	99.35	99.05

Free silica content. The free silica content of commercial talc as found in industrial use is very low. Schulz and Williams¹³ report that of 51 samples analyzed quartz was not found in 25; traces of quartz only were present in 25; while one sample showed a quartz concentration of 3 per cent. The free silica content of the talc in the mills and mines included in this study was likewise found to be low. Six samples from two talc mines, taken and analyzed by chemists of the Division of Industrial Hygiene, showed 1 per cent or less of free silica. Two of these samples were taken from long standing accumulations of waste rock; two were

* Includes both free and combined silica.



FIG. 1. Tremolite talc. Note bundle-like arrangement of fibers. (Magnification 2,500 $\times$. 1 inch = 10 microns.)

from recent three- and four-day-run waste accumulations; and two were from collections of rock destined for the mills. Six samples of ground talc from several mills were also analyzed and in each case the silica content was found to be less than 1 per cent. Dreessen² also reported little or no free silica in the composition of the talc in this region.

Gardner,⁸ on the other hand, found

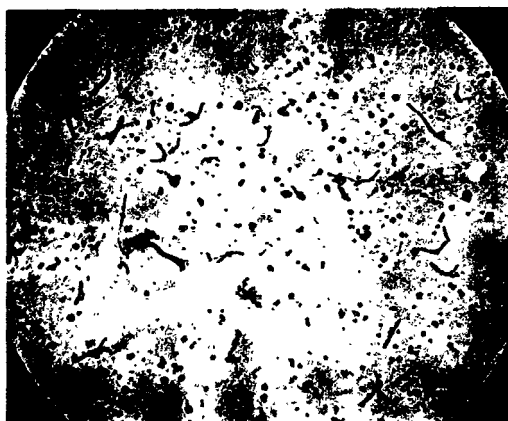
amounts of quartz ranging from 12 to 20 per cent in mineral samples from two mines in this area. It is difficult to explain the marked difference between Gardner's findings and those of Dreessen² and ourselves, except upon the supposition that Gardner's samples included some of the quartz-bearing stratum overlying the talc deposit proper. That such high percentages are not representative, however, is shown by the



FIG. 2. Tremolite talc. Note straight needle-like fibers. (Magnification 2,500 $\times$.)

talc. Note bundle-like of fibers. (Magnification inch = 10 microns.)

Fig. 3. Asbestos. Note curving and tendril-like fibers. (Magnification 2,500X.)



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fact that material from the mills where all rock is mixed and crushed showed low quartz percentages both in Gardner's studies and our own.

Microscopic appearance. Photomicrographs of talc dust from St. Lawrence County show that it tends to occur in oblong or squarish particles made up of parallel fibers (Fig. 1) which splinter off into sharp spicules (Fig. 2). Its microscopic appearance differs from that of asbestos (Fig.

3) in that asbestos fibers tend to be curved and tendril-like in form, whereas those of talc appear straighter and needle-like in structure. Tremolite talc fibers are also much shorter than those of asbestos. In this study their maximum length was approximately 15 microns. Asbestos fibers, on the other hand, may attain a macroscopic length. In interesting contrast to both tremolite talc and asbestos are the flake-like particles of mica dust (Fig. 4), another

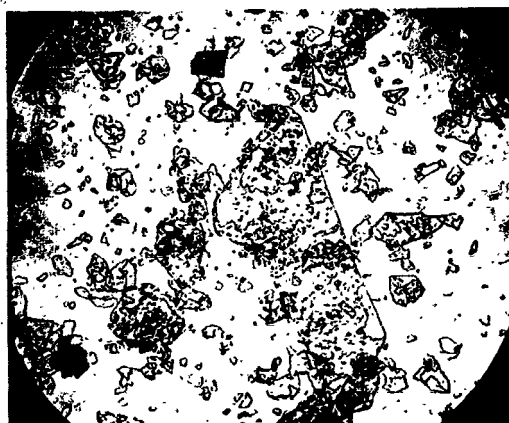


FIG. 4. Mica. Typical mica particles, showing the very thin plate-like structure. (Magnification 2,500X.)

magnesium silicate, and the granular particles of granite dust (Fig. 5), a combination essentially of quartz and feldspar.

Description of the Industry

Talc Mining

Mining operations. Talc ore is obtained by underground mining. Inclined shafts are used with headings to various depths down

muck cars and pushed along the haulage-ways to the shaft where it is dumped into a skip, hoisted to the surface, and dumped into railroad cars or trucks for shipment to the mills. Each mine employs fifteen to seventeen men underground.

Dust exposure in talc mining operations. The problem of the best method of control of the dust in talc mines is one which is re-

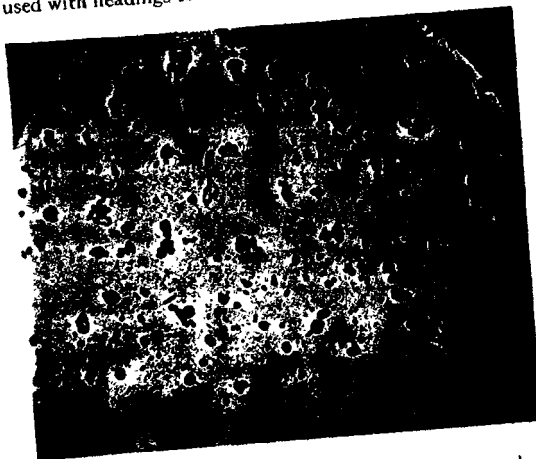


FIG. 5. Granite. Shows lack of form usually found in silicate and silica particles. (Magnification 2,500 X.)

to about 1,100 feet. The talc occurs in compact, homogeneous seams, so that contact with hard rock is limited to that incurred on entering a seam. Once a seam is entered there is no exposure to anything but talc until it becomes necessary to enter another seam. Since seams may be worked for years, the amount of drilling in hard rock is very small compared with the amount of drilling in talc.

The headings are mined by drift drilling, blasting, and hand or machine mucking. Raising and stoping are resorted to, to obtain the ore from pockets. All drilling is done dry since every precaution must be taken to avoid wet ore which cannot be milled and is wasted. Drilling crews of one or two men are used, the drillers doing their own blasting. The ore is then mucked as it is required by the mills. It is loaded into

ceiving the attention of the Division of Industrial Hygiene at the present time. Very little dust control was found in the three mines studied. Some attempts had been made to remove the dust during drift drilling by means of small, home-made, portable units, but relatively few of these were in actual use during drilling operations. The drillers wore respirators.

Twenty-two dust samples were taken with a midget impinger at various operations and situations. These were counted within ten hours of the time of sampling by means of the low power, light field technique, and gave the results shown in Table I.

The dust counts where no exhaust device was used gave average dust concentrations as follows: for drilling 1,350, for stoping 1,290, for mucking 35, and in the general air, 17 million particles per cubic foot.

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Table I

DUST CONCENTRATIONS IN TALC MINES

Milling operations. The milling processes in five mills were found to be essentially the same. The ore is shipped to the mills in rail cars or trucks and is dumped into bins leading to a jaw crusher. From the crusher the talc, in most mills, passes

TABLE I

DUST CONCENTRATIONS IN TALC MINES

Operation	Mine	Dust Count (million particles per cubic foot)	Remarks
Drilling	A	200	"Upstream" of drill. Rate 2' per minute
		300	"Downstream" of drill
		75	3' "upstream." Using exhaust
		110	Same as above. Breathing level of helper
		600	Exhaust off
	B	2700	Exhaust off. Breathing level of helper "downstream"
		5000	Exhaust of dust collector
		1500	Same as above; 3 minutes after drilling stopped
		150	General air stream
		65	"Upstream" air movement 50' per minute
Stoping	A	265	Same as above. Air turbulent
		90	Dead end drift
		300	Just off main airway
		16	Main airway
		100	Breathing level driller, top of open stope
	B	4000	Dead end stope. No air movement
		760	Top of dead end raise
Mucking	A	40	Bottom of stope, drilling at top
		50	Same as above
		6	Top of pile, mucking only operation
	B	35	"Downstream" of mucker
		24	Same as above

TABLE II

DUST CONCENTRATIONS IN TALC MILLS

Operation	Mill	Dust Counts (million particles per cubic foot)	Average Dust Concentration (million particles per cubic foot)
Crushing-jaw crusher	1	20	
	2	41.5	
	3	76.5	46
Crushing-disc or roller crushing	1	22	
	2	79	50
Pebble milling	1	32	
	2	46	61
Bagging- paper	1	141	
	2	190	
	4	160	163
Bagging- burlap	1	120	
	3	73.5	
	5	87.5	93
General air cylinder room	1	48	
	3	85	
	4	78	
	5	77	72
Separator room	4	58	
	5	67.5	62
Manual handling	1	215	

through disc or roll crushers, or both, before entering rotary or trommel screens. After passing the screens, the talc is stored in garners before the final milling operation which takes place in pebble mills. The final separation of the finely ground talc is accomplished with air separators, from which the material passes to garners which feed bagging machines.

The bagging machines utilize open top bags, or sacks, which fit loosely onto the discharge spout of the machines. Hand scoops are used to add or remove talc from the bags to obtain accurate weight. The greater percentage of material is bagged in

50 lb. paper bags, while some is shipped in larger burlap bags. The operators of the bagging machines stack the filled bags on hand trucks and wheel the loaded trucks

TABLE III
FIBROSIS IN TALC WORKERS, BY LENGTH OF EXPOSURE

Years Exposed	All Workers Examined	Cases of Fibrosis		
		Number	Total Fibrosis Cases per cent	Exposure Group per cent
5	82	—	—	—
5-9	32	—	—	—
10-14	47	8	25.0	17.0
15-19	33	13	40.6	39.4
20-24	10	2	6.3	20.0
25-29	9	3	9.4	33.3
30-39	6	5	15.6	83.3
40-49	1	—	—	—
50-59	1	1	3.1	100.0
Totals	221	32	100.0	14.5

into railroad cars or automobile trucks for shipment, or into the warehouse for storage.

Dust exposure in talc milling operations. Dust control in the various mills is confined chiefly to the bagging machines and pebble mills. Some control is also used in several mills at the crushers and material transfer points. Dust samples were taken throughout the mills using the technique already described. The samples were taken at the breathing level of the workmen in locations where men are usually stationed.

Table II shows the concentrations found at various points throughout the mills. Manual handling of the talc produces concentrations in excess of those found at other operations but, fortunately, there is little manual handling during normal procedure.

The dustiest operation, other than manual handling, is that of paper bagging where the average dust concentration for three mills was found to be 163 million particles per cubic foot.

Roentgen Findings

Fibrosis

Incidence. In recording pulmonary fibrosis among talc workers, those with slight or even moderate degrees of fibrosis were disregarded, and only those cases included in which a marked degree of this condition was present.

Upon the initial roentgen survey in 1940 fibrosis was found in 32 of the 221 men examined, giving a rate of 14.5 per cent. The distribution of these cases according to length of exposure is shown in Table III.

It will be seen that no cases occurred in workers with less than ten years' exposure. The 32 cases of fibrosis were all found among the 107 men who had worked in talc for ten years or longer, giving an incidence rate for this group with ten years or more of employment of 29.9 per cent. Of the 8 men who had worked thirty or more years in talc, 6 showed fibrosis (74 per cent).

To make clear the fact that talc is a fibrosis-producing dust the distribution of cases of fibrosis, according to age, in talc workers and in a group of carpet factory workers previously examined by the authors, is shown in Table IV.

Fibrosis was present in only 2.5 per cent of all carpet workers, and in 4.9 per cent

TABLE IV
FIBROSIS IN TALC AND CARPET WORKERS, BY AGE

Age	Talc Workers			Carpet Workers		
	Num- ber exam- ined	With fibrosis Num- ber	Per cent	Num- ber exam- ined	With fibrosis Num- ber	Per cent
Less than 20	4	—	—	6	—	—
20-29	71	1	1.4	57	1	1.6
30-39	72	7	9.7	57	1	1.7
40-49	41	7	17.0	49	4	8.1
50-59	17	9	52.9	33	—	—
60-69	13	6	46.1	3	—	—
70-79	3	2	66.6	—	—	—
Totals	221	32	14.5	266	6	2.5

of those fifty years or it was present in 5 workers in this age group.

Ten months after study, a second visit plants for follow-up cases. At this time o cal histories were tal tions were made. F histories it was poss men who had previ other types of silice group of 18 cases sh was defined in men any other dusty inc significant dust ex been to talc.

Signs and sympto showing fibrosis we 3 were miners. T workers to miners i ever, was approxim that fibrosis was re

Fig. 6. Case 200-28. 1 at age of fifteen. W worker twenty-five shortness of breath, examination: Chest 28, breath sounds d Roentgen examinati fibrosis on a diffuse edes are thickene

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fifty years of age and older; while present in 51.5 per cent of talc miners in this age group.

Two months after the original roentgen examination a second visit was made to the same men for follow-up examinations of selected cases. At this time occupational and medical histories were taken and chest examinations were made. From the occupational histories it was possible to eliminate those who had previously been exposed to other types of siliceous dust. In this way a group of 18 cases showing marked fibrosis was defined in men who had not worked in any other dusty industry and whose only significant dust exposure, therefore, had been to talc.

Signs and symptoms. Fifteen of the men showing fibrosis worked in the talc mills; 3 were miners. The proportion of mill workers to miners in the entire group, however, was approximately 2.3 to 1, showing that fibrosis was relatively more prevalent

among millers than miners. With one exception, the men with fibrosis were all forty years of age or older and had been exposed to talc dust, as noted above, for at least ten years.

Thirteen of the 18 had one or more symptoms referable to the lungs. Ten complained of dyspnea; 7 of chronic cough and 3 of pain in the chest. In addition, 5 complained of excessive fatigue.

On physical examination, all 18 showed limited chest expansion. Thirteen showed abnormal lung signs and 13 showed curving of the nails or clubbed fingers. In one case cardiac hypertrophy was observed, and in one auricular fibrillation.

The general appearance of the group struck the examiners as being distinctly different from the appearance of the usual group of first and second stage silicotics who are still able to work. The latter usually present a robust appearance. A substantial number of individuals in such a group are

TABLE 1. BY AGE

Talc Workers	
With fibrosis	
Num.	Per cent

—	—
—	—
1	1.6
1	1.7
4	8.1
—	—
—	—
6	2.5

FIG. 6. Case 200-28. Aged forty-six. Began working at age of fifteen. Woolen mill six years; talc mill worker twenty-five years. Complaints of cough, shortness of breath, pain in chest, fatigue. *Physical examination:* Chest expansion 1 1/4 inch, respiration decreased, breath sounds diminished. Clubbing of fingers. *Roentgen examination:* Shows a very fine, granular fibrosis on a diffusely hazy background. The hilar nodes are thickened.



FIG. 7. Case 198-3. Aged fifty-four. Began work at age of fifteen. Farmer sixteen years; telephone linesman seven years; talc mining sixteen years. Complaints of productive cough and dyspnea. *Physical examination:* Chest expansion 1 inch. Nails curved. *Roentgen examination:* Shows enlargement of the hilar nodes, and exaggerated linear markings at the right base. There is also a fine, generalized, diffuse fibrosis having a granular appearance.

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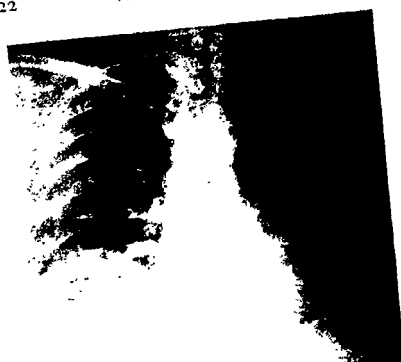


FIG. 8. Case 197-38. Aged fifty-five. Began working at age of fourteen. Talc mill laborer and foreman forty-one years. Complains of fatigue. *Physical examination:* Chest expansion $1\frac{1}{2}$ inches; clubbing of fingers. *Roentgen examination:* Shows marked elevation of right diaphragm with obliteration of the costophrenic sulcus. On the left leaf of the diaphragm is a deposit of opaque material. Both lungs show a fine, granular fibrosis.

likely to be overweight. This was not the case with the talc workers who showed fibrosis. None of them was overweight, but on the contrary they tended to present an undernourished and drawn appearance. It was the impression of the examiners, also, that dyspnea was unusually pronounced in relation to the extent of the fibrosis seen in the roentgenograms.

Roentgenographic characteristics. The type of fibrosis seen in these roentgenograms is very fine and diffuse, showing in many cases an appearance of soft haziness to which the term "ground glass," used in describing certain cases of asbestosis, can very well be applied. This is illustrated in Figures 6, 7, and 8. In a number of cases there is in addition a distinctly granular appearance (Fig. 7), and in some nodulation (Fig. 9 and 10) which might be confused with silicosis. In certain films soft conglomerations also occur (Fig. 9 and 11).

The fibrosis in these cases tends to be somewhat more marked on the right side, and in the mid-lung fields and bases as seen

in Figures 7 and 9. The hilar nodes show a slight or moderate increase in density. Evidence of obliterative pleuritis and emphysema is also present in some cases. In a few instances (Fig. 7 and 11) a blurring or "shaginess" of the cardiac outline is noticeable.

Tuberculosis. In the total group of 221 talc workers there were 29 (13.1 per cent) cases of primary healed tuberculosis; 6 (2.7 per cent) cases of healed reinfection type tuberculosis and 5 (2.2 per cent) cases which were considered, on the basis of the roentgen appearances alone, to show clinically significant tuberculosis.

The incidence of healed primary and reinfection type lesions is not remarkable in any way, being similar to that found, in general, in other industrial groups. The incidence of clinically significant tubercu-

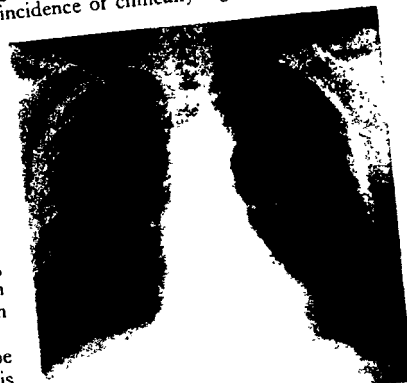


FIG. 9. Case 196-3. Aged sixty-eight. Began working at age of sixteen. Farmer twenty-three years; carpenter six months; talc mill laborer and repair man twenty-nine years. Complains of dyspnea. *Physical examination:* Chest expansion $1\frac{1}{2}$ inches, respiration 24, râles both bases. *Roentgen examination:* Shows a diffuse, finely nodular fibrosis throughout both lungs. There is emphysema at the left base. There is apparent thickening of the pleura at the right base with several horizontal shadows in this region. There is also an area of increased density extending from the second to the third interspace on the right, and shadows at both apices suggesting possible reinfection tuberculosis.

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2.2 per cent) is slightly higher than is found in most industrial groups, the average for this condition being about 1.5 per cent. Among the 5 individuals with clinically significant tuberculosis 3, between the ages of thirty and fifty, showed minimal lesions; one, forty-five years of age, showed moderately advanced lesions and one, sixty-four years of age, showed what is interpreted to be far advanced atypical tuberculosis. Among the 18 cases of fibrosis in men exposed only to talc clinically significant tuberculosis appeared to be a complicating feature in 3 cases (16.6 per cent).

Talc plaques. A most interesting finding in this group of talc workers—interesting because, to these investigators, it was new—was the presence in 14 instances (6.3 per cent of the 221 talc workers originally roentgenographed) of what appeared to be deposits of opaque material on various pleural surfaces. These deposits, or plaques, are seen on the visceral pleura, including the region of the diaphragm, and occasion-



FIG. 10. Case 197-8. Aged forty-nine. Began working at age of fourteen. Talc mill laborer thirty-five years. Complaints of dyspnea, pain in chest, fatigue. *Physical examination:* Chest expansion 1½ inches. Nails curved. *Roentgen examination:* Shows diffuse finely nodular fibrosis with soft shadows suggesting bilateral, clinically significant, apical tuberculosis.



FIG. 11. Case 201-10. Aged forty-nine. Began working at age of sixteen. Farmer seven years; talc mill laborer and foreman twenty-six years. Complaints of productive cough, dyspnea and fatigue. *Physical examination:* Chest flat, expansion limited, dullness at apices, otherwise hyperresonant. Râles throughout, most marked at bases. Respiration 22; pulse 116. Heart negative. Clubbing of fingers. *Roentgen examination:* Shows a fine, soft mottling over both lung fields, more pronounced at the bases. In addition, in the third left interspace near the periphery is a round homogeneous area of increased density about 2 cm. in diameter.

ally the pericardium (Fig. 8, and 13 to 17). Lateral and oblique views indicate that their location is definitely at the periphery of the lung, not involving the parenchyma (Fig. 17).

In size the plaques vary from a single, linear-appearing deposit of a few centimeters in length in the region of the diaphragm (Fig. 8 and 12) to massive deposits bizarre in shape, extending over a large part of the lung fields (Fig. 14, 15, 16 and 17). They are characterized not only by irregularity of shape, but by marked irregularities in degree of density also, and by the sharpness of their borders. In this series of films the development of these plaques can be traced from small, light, scarcely noticeable deposits to the extensive opacities described.



FIG. 12. Case 200-20. Aged sixty-three. Began working at age sixteen. Fireman three years; farmer eight years; talc mill laborer and repairman thirty-nine years. Complaints of dyspnea and fatigue. *Physical examination:* Lungs hyperresonant. Heart slightly enlarged to left, rate irregular. Clubbing of fingers. *Roentgen examination:* Shows deposits of opaque material on the left diaphragmatic dome; marked emphysema at the left base. Both lungs show diffuse, granular fibrosis with irregular patchy shadows at right base and left mid-lung field.

It should be noted that roentgen appearances similar to the plaques herein described were apparently seen in Case 1 where mention is made of areas of increased density resembling lipiodol or calcific deposits in mid-lung fields. Similar appearances have also been noted in another group of workers who were exposed to talc dust in the making of material for electrical insulation.

So far as can be ascertained, these deposits bear no relation to any history of previous infection since they occur both with and without such a history. Nor are they necessarily associated with other pulmonary pathology. The underlying lung tissue may or may not show fibrosis. There is no associated enlargement of the hilar nodes in cases showing plaques without fibrosis.

An analysis of the group of 14 talc workers who showed these deposits revealed the following facts: Their ages ranged from thirty-five to seventy-seven years and their exposure in the talc industry from four to fifty-two years. Ten were mill workers; 4 were miners. Only one individual gave a history of having had pleurisy. None had had empyema. In 5 instances no lung pathology other than the plaques was noted. A marked degree of fibrosis coexisted in 7 cases. Evidence of clinically significant tuberculosis was seen in one case and of primary healed tuberculosis in another case. No symptoms or physical signs attributable to these deposits could be identified,



FIG. 13. Case 201-5. Aged fifty. Began working at age of fifteen. Farmer seventeen years; repairman in talc mill eighteen years. Complaints of cough. *Physical examination:* Lungs show diminished breath sounds throughout, especially on right. Heart: systolic murmur at apex, Pulse 120. Clubbing of fingers. *Roentgen examination:* Shows a soft, diffuse, very finely nodular fibrosis throughout both lungs. In addition, there are irregular, sharply defined deposits of opaque material in both middle and lower lung fields. (Lateral and oblique views show that these plaques are located near the periphery.) There are similar deposits on both diaphragms and in the region of the right spinal gutter.

since in the group signs only occur in whom there was apparently the pleural process responsive symptomless.

Fibrosis. The study was characterized, by a granular or nodular, more marked bases. Densities somewhat of tremolite talcographical area, reported was m



FIG. 14. Case 196-1. Aged fifteen. Railroad four years. No complaints. Expansion 1 1/2 inc. Curved. *Roentgen examination:* Shows a soft, diffuse, very finely nodular fibrosis throughout both lungs. In addition, there are irregular, sharply defined deposits of opaque material in both middle and lower lung fields. (Lateral and oblique views show that these plaques are located near the periphery.) There are similar deposits on both diaphragms and in the region of the right spinal gutter.