CHAPTER XXXI

SILICIOUS DUSTS OF UNDETERMINED PATHOLOGIC STATUS

It has long been the opinion of most investigators that only free (crystalline) silica and asbestos (a silicate) are capable of producing a disabling pulmonary fibrosis. For many years many of the silicates have been studied experimentally, and their action has been observed clinically with no evidence that these silicates are harmful to any appreciable degree. Recently, however, several of the silicates have been suspected of being capable of producing a fibrosis not unlike that due to free silica. As yet no conclusive opinions have been reached and until more investigation by capable authorities is carried out, the status of these dusts must remain undecided.

Talc

Talc is a hydrous magnesium silicate. When it is mined, talc may be accompanied by other minerals such as serpentine, dolomite, and tremolite. Occupational exposure includes, in addition to mining the mineral, the preparation of talc for fillers in paint, linoleum, paper, dusting agents, and cosmetics.

In 1933 Dreessen[1] and subsequently in 1935 Dreessen and Dalla Valle[2] studied the effects of talc mining in Georgia and Vermont and noted that x-ray pictures revealed diffuse fibrosis, but whether this constituted a disabling pneumoconiosis was debatable. Porro and co-workers[3] took the definite position that talc did cause a disabling pulmonary fibrosis and attempted to correlate the mining and milling of talc with a morbidity among these workers. In 1942 they made the following observations on fifteen cases with a history of exposure to talc:

> "The symptoms are those characteristic of disabling pneumoconiosis: dyspnea, cough, chest pain and weakness. Vital capacity was extremely low. The gross pulmonary changes in all cases are stiffening of the lungs, poorly outlined grayish bands and nodules appearing in the parenchyma and moderate enlargement of the tracheobronchial lymph nodes. Emphysema is universally present but is not grossly recognized in the mild case. In all except the least involved case, extensive intrapleural adhesions are found and in all advanced cases there is a cor pulmonale. Microscopic changes consist chiefly in irregular areas and bands of cellular fibrosis surrounding the vessels and bronchi and producing thickening of the alveolar wall. Histiocytes and fibroblasts are numerous in proportion to collagen fibers. Asbestosis bodies are frequently present in the lesions. This implies a degree of similarity between asbestosis and pneumoconiosis due to talc. While tuberculosis or other complications may be present, pneumoconiosis in itself is a reaction of living tissue to injury and therefore an inflammatory disease resembling other chronic inflammation. Diffuse haziness is the most constant roentgen abnormality and is probably the

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earliest detectable change. The general background of the pulmonary field may have a fine indefinite reticulation of lines. The appearance suggests that the haziness due to interstitial fibrosis has been modified by a fine emphysema. Another manifestation is usually general nodulation. Confluence of lesions and haziness usually begin in the areas of distribution of the lower lobe trunks. The diagnosis is made on the history of an adequate exposure and on the roentgen signs. If disability is present the characteristic symptoms are significant. If uncomplicated, the symptoms of talc pneumoconiosis are so unlike those of pulmonary tuberculosis that a differential diagnosis is comparatively easy. In uncomplicated talc pneumoconiosis the onset of symptoms marks the beginning of a disability from which recovery appears to be impossible. It is desirable to withdraw the worker from exposure prior to this time. There are roentgen changes before the onset of dyspnea or other subjective symptoms. The determination of vital capacity may be an effectual routine procedure in selecting workers that should be more thoroughly studied as potential subjects for withdrawal from further exposure. Standard exercise tests for the objective periodic determination of dyspnea may aid in the discovery of early pulmonary fibrosis."

In 1946, Porro and Levine[4] reported an autopsy examination of a talc worker, aged 45, who had been unable to work for three years because of difficulty in breathing. Two weeks before he had started to expectorate bloody sputum and to complain of pain in the left side of the chest. Roentgenologic observation revealed the left lung field below the level of the first interspace to be completely obscured and in the right lung field a dense reticulation. The dyspnea continued to be severe, and the patient died. The gross necroptic aspects as well as the microscopic changes were described. One section of the lung consisted largely of hemorrhagic infarct. Other sections revealed many alveoli containing fluid, erythrocytes, and macrophages containing hemosiderin. Some of the alveoli contained asbestos bodies. Localized emphysema and atelectasis were present. Many of the interlobular septa and some alveolar walls were thickened by a fibrocellular reaction consisting of histiocytes, scattered lymphocytes, fibroblasts, collagen fibers, and amorphous brown pigment. No tubercles or silicotic nodules were found.

In 1942, following the publication of the author's book on *Occupational Diseases*, a communication was received from Dr. Daniel F. Levy, of New Haven, Connecticut, in which he questioned the statement that talc produces no undue pulmonary fibrosis. In this communication (April 21, 1942) Levy stated:

"I have had occasion to be concerned rather recently with a case in which there was a long history of inhalation of soapstone or talc used for coating rubber wires. The patient developed fibrosis and tuberculosis and died. At autopsy (the findings of which I was permitted to observe) it was most interesting to observe that there was fibrosis, fibrous pleural adhesions, and fibroulcerative pulmonary tuberculosis. Microscopically, typical asbestosis bodies were seen in addition to other findings such as are present with the diagnoses just enumerated. This man had never been exposed to asbestos.

"In connection with the subject, I have examined a considerable amount of literature which would indicate that talc dust is not innocuous. I have in mind

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such matters as the report of Dreessen, W. C., and DallaValle, T. M.: Effects of Exposure to Dust in Two Georgia Talc Mills and Mines, Pub. Health Rep. **50**: 131, 1935. I should furthermore like to state that Dr. Zimmerman, pathologist at Yale University, has told me that he has met this same picture of asbestosis bodies following talc inhalation in other autopsies performed by him."

Bauxite

Inhalation of aluminum powder or dust has been considered harmless to the lungs. In fact, as pointed out in the chapter on Silicosis, aluminum inhalations have been considered effective in the prevention of silicosis. Studies made of a large group of workers at the plant of the Aluminum Company of America at New Kensington, Pa., revealed that inhalation of aluminum powder even in large amounts and over a period of many years had caused no lung damage.

In the spring of 1946, while attending the annual meeting of the Ramazzinians, Dr. J. G. Cunningham, Director of Industrial Hygiene of the Department of Health of Ontario, Canada, told the writer of some unusual pulmonary disturbances that were occurring among the furnace workers processing bauxite. At that time, he and Dr. A. B. Riddell, his associate, were working on the problem. But before relating their subsequent report it is best that the composition of bauxite be explained.

Most of the aluminum found in the earth's crust is locked up in soluble crystalline silicates, such as feldspar and mica, which make up a large part of granite and other igneous rocks. As these rocks slowly weather and are leached by running water during the lapse of centuries, they may leave a residue of kaolin. Further weathering of kaolin gradually removes the silica, leaving behind bauxite, the chief ore of aluminum. Chemically it is hydrous aluminum oxide. It contains considerable amounts of soluble impurities such as silica, oxides of iron, and titanium. Emery is an anhydrous, impure, aluminum oxide. A purer form of aluminum oxide, more definite crystalline, is corundum.

When this book was nearing its final stages of preparation the author wrote to Dr. Cunningham and Dr. Riddell, seeking some information as to their conclusions regarding the cause of the illness existing among the bauxite furnace workers. In a letter of January 29, 1947, Dr. Riddell replied as follows:

"*History.* The condition first came to attention in February, 1942, when a young man, aged 33, was referred for examination by Dr. C. G. Shaver, of the Niagara Peninsula Sanatorium, St. Catharines. Dr. Shaver noted the history of exposure, but thought little of it at the time. Two similar cases were seen by him in August, 1942. These men had worked in the same plant as the original case at the same type of work, and the clinical picture presented was so unusual that he felt he was dealing with a condition of occupational origin.

"Over some months several other cases were seen. Dr. Shaver appealed to this department. He stated that he was sure that he was dealing with an unusual disease of occupational origin. At first his contention was received with some scepticism but he finally convinced me, and I convinced Dr. Cunningham and

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the others concerned. An investigation into the process was commenced and is proceeding. An additional group of cases have come to our attention. We have obtained a number of autopsies which are quite convincing.

"The process concerned was carried on in four plants in the neighborhood of Niagara Falls, Ontario. It is the manufacture of corundum and artificial abrasives. In the process, bauxite, to which is added small quantities of iron and coal or coke, is subjected in metal pots to a temperature of approximately 2,000° C. The pots are approximately 6' by 6'. Into these large carbon electrodes are lowered and the necessary heat is produced by the electric arc. The mixed material is added to the pots prior to the lowering of the electrodes and from time to time during the process. It is added to the pots by workmen who shovel the mixture.

"During the process dense white fumes are evolved. These are largely carried upward by the heat draft from the pots to openings in the roofs of the furnace rooms, where they escape. There is, however, considerable contamination of the atmosphere in the neighborhood of the furnace tenders. Crane operators and certain other workers also are exposed to large quantities of this fume.

"Analysis of the fume shows that it consists of extremely fine particles of alumina (Al_2O_3) and silica, the proportions being approximately alumina 60 per cent and silica 25 per cent. In addition to these substances small quantities of many other materials are present in the fumes.

"This process has been carried on for many years, but no cases such as those to be described had previously come to our attention, nor as far as can be determined had any similar case been seen by other persons. The processes were carefully canvassed to see whether any recent change in procedure or in materials had been instituted in any of the plants. No change had apparently been made, except that during the period when these cases occurred production was increased. This increase was in the dimensions of about ten times. There was no corresponding increase in the working staffs. Exposure of those working during the period of increased activity would therefore be materially greater than previously.

"An x-ray survey, supplemented by clinical examination when this was considered necessary, was made of the working staffs of the four plants involved. Some 1,913 workers were examined. Three hundred forty-four were furnace tenders or worked in the neighborhood of the furnaces. From this group of furnace men upwards of 35 persons have been found whose chest films show shadowing which we consider to be characteristic, and in addition there are a number of others with x-ray changes which we have labelled as doubtful. It is of interest that some of this doubtful group have progressed since they were first seen and we can now consider them definite. In one case in particular special comment might be made. A young man aged 32, who had been employed as a furnace tender for two years, joined the armed forces in September, 1943. He served in England and on the Western Front. He returned to Canada in the Fall of 1945 and was discharged in July, 1946. While on service he had what was diagnosed as pneumonitis in February, 1945. His case was investigated in a military hospital and was labelled as pulmonary tuberculosis. It is evident that the clinicians were somewhat puzzled because they had re-x-rayed him very frequently. While under observation he developed a spontaneous pneumothorax and was admitted to the Niagara Peninsula Sanatorium, under Dr. Shaver, at his request. On reviewing this man's enlistment film, it is evident that some slight changes are present. These were evidently not considered sufficient to bar him

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from military service. Films prepared during the period when he was under observation in the Military Hospital show quite characteristic shadowing.

"I know of no condition in which the chest film corresponds so closely to the changes found on pathologic examination. We, in our Survey, divided the cases into 'early' and 'well established.'

"In early cases an increase is seen in the subapical area in the upper lung fields. This is bilateral and the shadowing is of a somewhat lacelike or granular character. As the condition extends the shadowing becomes more widespread. In very marked cases practically the whole lung field may be involved.

"Advanced cases show less of the lacelike character in the shadowing. The appearance in these is somewhat like that seen in irregular types of silicotic fibrosis. In addition, however, the mediastinum is widened, sometimes markedly so, and the diaphragm is very markedly distorted. In contradistinction to what is seen in ordinary dust fibrosis, the general trunk and linear shadowing is not unduly prominent and the shadows of the hili are not marked. Spontaneous pneumothorax characterizes the more advanced cases. The collapse is often bilateral. Where unilateral collapse occurs there is a marked shift of the mediastinum away from the side of the collapse. Also, as a rule the diaphragm returns to its normal position following a collapse.

"Symptoms. In early cases, symptoms are slight or entirely absent. Not uncommonly, those affected gave a history of some cough and expectoration over a period of time. The sputum was generally frothy in character. Not infrequently the case sought medical advice because of the sudden occurrence of severe dyspnea. Sometimes, but not invariably, this was associated with pain. Most of those seen complained of a tightness in the chest, which had been present for indefinite periods. Most of those with severe symptoms had lost considerable weight and many complained of loss of appetite and sleeplessness. The well-established cases all complained of moderate dyspnea on exertion. Of course, in severe cases this was very marked and sometimes it was present even while the patient was at rest.

"No special findings were elicited in clinical examination. As a rule, in the early cases, the examination was essentially negative. In the presence of spontaneous pneumothorax, hyper-resonance occurred with increasingly diminished breath sounds. In several cases adventitious sounds, rales, and rhonchi were present. Not infrequently, areas of impairment of resonance were made out. These often occurred toward the lung bases and in several instances could be ascribed to the marked elevation of the diaphragm on the side concerned.

"I mentioned that we have had upwards of 35 cases from an over-all population of some 344 persons in exposure. I have no doubt that this finding is on the low side. From among these there have been 7 deaths and at the present time at least another half dozen individuals with serious disability.

"This condition is receiving our concentrated attention. Investigations are proceeding at the plants from which these cases have come and also some work is in progress in the laboratory. We are not yet prepared to state with any assurance what the specific causative agent is, except insofar as to say that it is occasioned by inhalation of the furnace fume. Whether any specific part of the fume is particularly responsible we do not yet know.

"Incidentally these cases appear from the descriptions to be quite similar to certain cases which occurred in Germany during the war years. In Germany, these workers were exposed to the dust of aluminum which is apparently pure. The condition here occurred also during war years. Unfortunately, we have no

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back films on our cases, except in one instance. It may be significant that a film on one of these men which was prepared in 1936 shows some shadowing of the type which we associate with this disease. This man is not, however, seriously disabled.

"For the most part the cases occurred in persons who were exposed after 1939. Many of those seriously affected were young, 25 to 35 years of age. The shortest exposure was 22 months. We have had exposures of approximately 32 to 36 months."

In a separate communication Dr. Cunningham wrote: "I do not think that tuberculosis has been present in any of these cases. The x-rays present a wide shadow in the aortic area with an interlacing fibrosis in the upper zones. The picture presents a fibrosis which is not characteristic, that is, there is no whorl formation as encountered in silicosis."

The following series of films (Figs. 54 to 60) illustrate the case of L. R., a 43-year old bauxite worker, who was first seen on July 20, 1943, when he complained of loss of weight and difficulty in swallowing. An x-ray film taken on that date revealed a fine type of shadowing which is now considered as characteristic of the early stages of this condition.

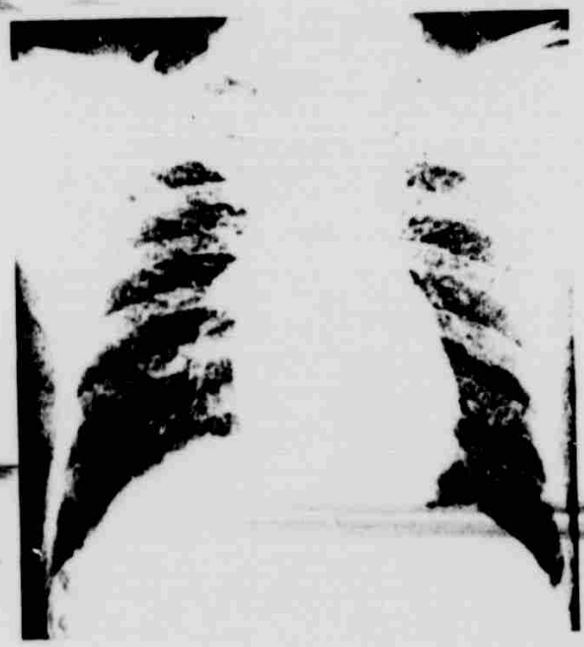


Fig. 54. Film of bauxite worker taken July 20, 1943, shows "fine shadowing" of upper portion of lungs.

His previous occupation had been that of a blacksmith and also a construction worker. In June of 1941 he began his work in processing bauxite, being engaged as a furnace feeder, shoveling the mix into the electric furnace, until December, 1943. In December, 1943, he developed discomfort in the chest with considerable dyspnea. Early in 1944 he developed a sudden, severe pain in the right chest again associated with marked dyspnea.

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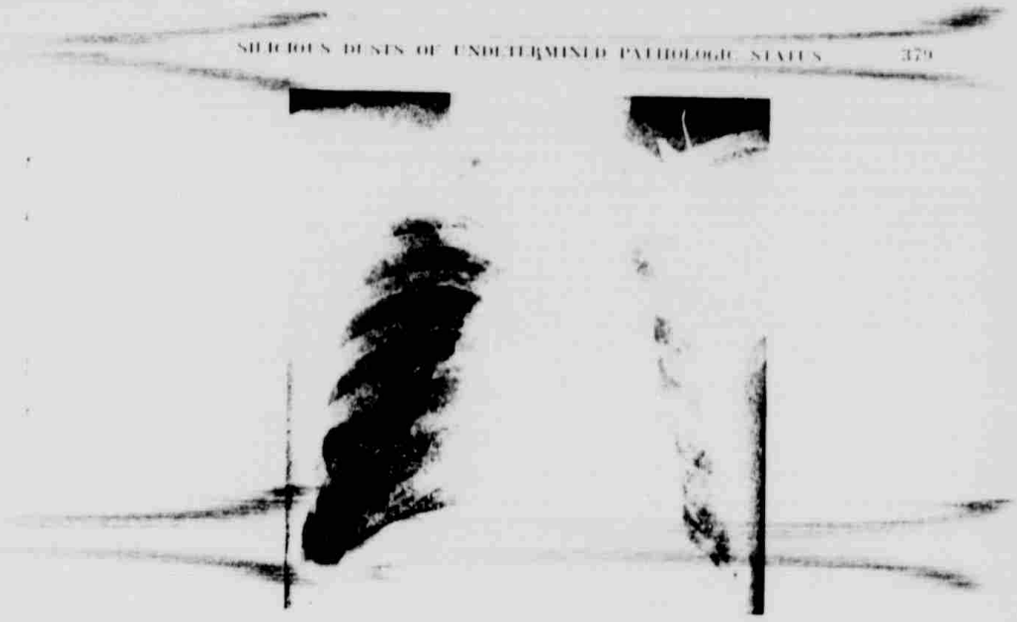


Fig. 55. Film of worker shown in Fig. 54 taken Dec. 11, 1943, shows collapse of right lung.

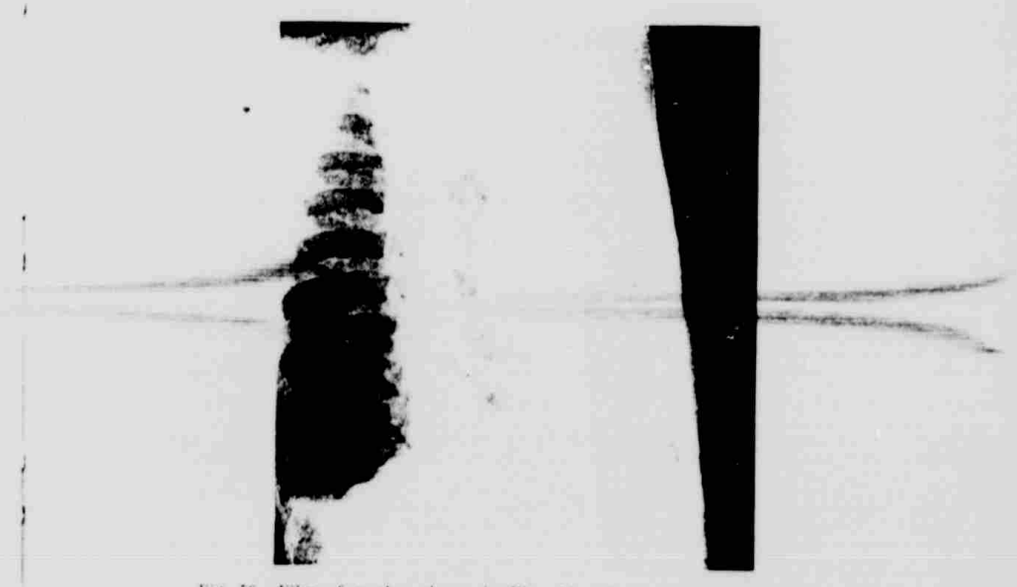


Fig. 56.—Film of worker shown in Figs. 54 and 55. Lateral view taken Dec. 11, 1943.

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Fig. 57.—Film of worker shown in Figs. 54 to 56 taken Jan. 17, 1941. Expansion of right lung has occurred with only small area of collapse in upper right portion.



Fig. 58.—Film of worker shown in Figs. 54 to 57 taken April 3, 1941. Normal lung expansion with scattered area of fibrosis in both lungs.

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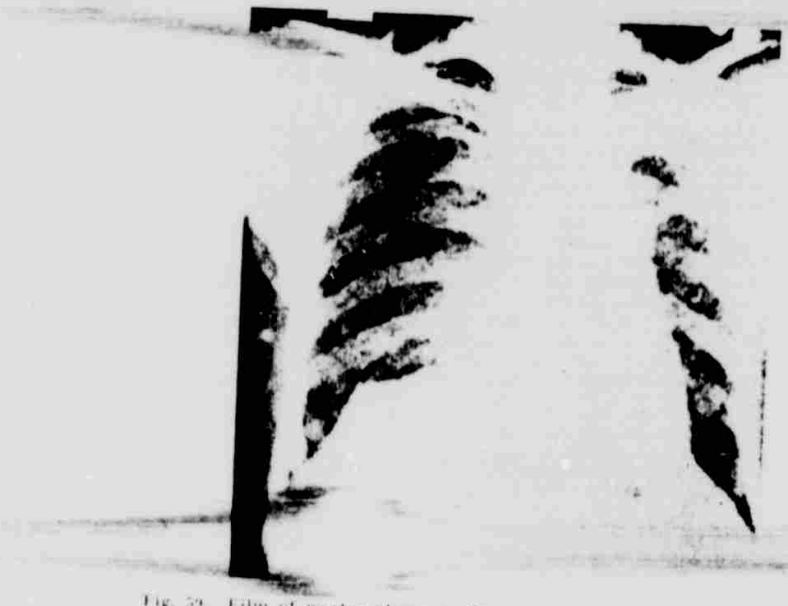


Fig. 59. Film of worker shown in Figs. 54 to 58 taken May 2, 1944. Lung has again collapsed on right side with large emphysematous bleb present.



Fig. 60. Film of worker shown in Figs. 54 to 59 taken June 11, 1944. Collapse of lung still present with large emphysematous bleb more distinct. Smaller blebs present on left lung with partial collapse of apex of left lung.

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The patient remained at home and at rest until April 3, 1944, at which time an examination showed the lungs to have re-expanded. In May of 1944 he suffered another attack of breathlessness and the film of that date shows that the lung had again collapsed. It also demonstrates a large emphysematous bleb on the lung surface. The film taken in June shows this bleb even more clearly as well as some smaller blebs in the opposite side.

The physical examination of this man in December, 1946, is interesting. On that date his weight was 122 pounds; height, 5 feet, 7 inches; respirations, 22; pulse rate, 76. He was slightly cyanotic and looked miserable. The clavicles were prominent and expansion very poor. The percussion note was hyper-resonant with underlying impairment on the right posteriorly and laterally toward the base. The breath sounds were almost inaudible except on the right anterior mid-chest region. Irregular fine crackling and explosive rales were present over the posterior portion of the chest posteriorly as well as in the left interscapular area and left base.

Diatomaceous Earth

In the introduction to the section of this book dealing with the dusts, it was mentioned that the diatoms, small aquatic plants, require silica for the formation of their skeletons or shells. Geologic studies indicate that for millions of years these silicious skeletons had been accumulating in the lakes and sea waters, existing during the Miocene Age, to form large deposits of material we now know as diatomaceous earth. Probably due to violent earth movements in prehistoric times, certain of these deposits became more abundant in some areas. On the west coast of California and Oregon there are regions rich in this material.

Of some 10,000 different species of diatoms, relatively few have any commercial value. The important ones are acicular or "needlelike" in form. In addition to the elongated form, another property of this substance is its exceedingly light weight. In finished form, ready for industrial application, it is fluffy. This lightness and fluffiness permits its wide use as filters, fillers, and absorbents; it is also used in paint, rubber, plastic moulding, packing and fire-proofing material, in insulators or as absorbents for acids, water, and impurities.

Crude diatomaceous silica is obtained by quarrying or open-pit mining. Today large power shovels have largely replaced hand quarrying. After removing this earth, it is sent to the mill where, in a drying process, all moisture is removed. The material is handled with great care to separate the diatoms from each other without destroying their structure. Then the separated diatoms are conveyed by air stream through a system of cyclones, traps, and kilns and finally packed for shipment.

For many years the opinion has been prevalent that in the diatomaceous earth industry the workers are not subjected to the development of any disabling fibrosis. Recently, however, there seems to be some ground for questioning the innocuousness of this substance. Little information has ever been published regarding the effects of diatomace-

ous earth and for that reason the author intends to present at least an intimation of recent developments.

Some years ago, Dr. Leroy Gardner experimented with samples of diatomaceous earth. Following these experiments he found silicotic changes which he was at a loss to explain. At that time his analyses of the raw material had to be carried out chemically. Later, when he had the advantage of the x-ray diffraction method, he found that if diatomite is calcined with certain fluxes, a portion of the amorphous silica is converted into cristobalite, a crystalline silica which is the potent cause of silicosis. Upon making this discovery Gardner believed that the original experiments were made upon calcined diatomite which caused the silicotic reaction.

At Saranac, Gardner continued his experiments with the raw earth material to find that the diatomaceous earth is harmless like other amorphous silica. An inhalation exposure for a period of two and one-half years produced no fibrosis of the lungs. The reaction was confined to phagocytosis. He then injected the diatomaceous earth which had been calcinated with flux containing about 25 per cent cristobalite. It was noted that this caused a nodular fibrosis.

In 1945 Gardner came to California to study the diatomaceous earth industry, to review collective x-ray films of the workers, and to consult with physicians engaged in caring for these men. In viewing the films of men who had worked for years in this material, Gardner wrote later to one of us that "silicosis is conspicuous by its absence." He noted an appreciable amount of benign, nonspecific pneumoconiosis "as one would expect in any group exposed to dust of any kind." The x-ray pattern is that of exaggerated linear markings, and clinically the men with these changes exhibited no symptoms or disability.

In the collection of films reviewed by Gardner, there was a very small group in which the upper portion of the lung fields showed localized shadows which he interpreted as evidence of a chronic infection, presumably tuberculous in origin.

At the time of Gardner's death the status of the diatomaceous earth problem was simply this: an exposure to this substance did not produce true silicosis. To those of us on the Pacific coast it was becoming more and more apparent that we were dealing with a new entity. To help clarify the thinking on this point, a meeting was held at Santa Barbara in April, 1947. Among others, this meeting was participated in by Lanza, an authority in the field of pneumoconiosis and one who had conferred frequently with Gardner on the diatomaceous earth problem, by Karns of Stanford, an able pathologist who had also spent some years at Saranac, by Walter Anderson of Lompoc, who has cared for these workmen for many years, and by Reginald Smart, of Los Angeles, whose

knowledge of the diatomaceous earth problem is exceeded by no one. From this meeting came the following observations:

1. The workmen exposed to the straight diatomaceous earth (not calcined) may reveal by x-ray evidence of an increase in the perivascular markings with degrees of fibrosis. This picture is similar to that seen in any workman who has spent some years exposed to a dust. In other words, the x-ray picture may be that of a benign pneumoconiosis and the workmen reveal no signs, symptoms, or disability.

2. Those who have been exposed to the calcined earth present an entirely different picture and one that is far different from that seen in silicosis. The x-rays are conspicuous by the absence of discreet nodulation. There is a marked increase of the perivascular markings and fibrosis. The x-rays give one the impression of an infection being present as suggested by the fuzziness and haziness. Pneumothorax is common.

The pathologic picture is that of marked fibrosis, shrinkage of the lung tissue, and contraction of the veins (as in contrast to the contraction of the arteries seen in silicosis). It was noted that the inhalation of the diatomaceous earth and its presence in the lung seemed to inhibit infectious processes, especially tuberculosis. Dr. Caldwell, of the Santa Barbara Tuberculosis Sanitarium, testified that in his opinion, if tuberculosis became superimposed upon this pulmonary affection, it was cured in shorter time than in the average individual. This, the reader will recognize, is in sharp contrast to the susceptibility of the individual with silicosis to tuberculosis.

The peculiar reactions within the lung of the diatomaceous earth worker appears to be due to the action of cristobalite, a crystalline silica, and, to a less extent, to tridymite. It is believed that these two substances become released or activated when subjected to high temperatures.

Much work remains to be done on the study of the affect of diatomaceous earth upon the exposed workman. This will take the combined investigation of the clinician, pathologist, roentgenologist, and possibly the chemist in the field of molecular structures.

Tripoli

The effect of exposure to tripoli dust was considered by McCord [5] and reported by him in 1936. In 1943 McCord, Meek, and Harrold [6] added considerable information to McCord's original study. It appears that the term "tripoli" has been used to designate a form of free silica which is soft, porous, and friable. Tripoli is not to be confused with diatomaceous earth. The x-ray diffraction pattern of tripoli is that of quartz. Being a quartz containing approximately 98 per cent free silica, it would be expected to produce a high incidence of silicosis among those who work with it. But on the contrary, the incidence of silicosis from exposure to tripoli is relatively infrequent.

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McCord and co workers concluded that there are in existence certain deterrents which inhibit the injurious action of tripoli, namely:

"1. The high canaliculation (porosity) of true tripolis eventuates in a large surface area per unit of mass (specific surface).

"2. High specific surface favors adsorption phenomena of which hygroscopic films are one aspect.

"3. Related to surface phenomena is an unusual degree of dipolar electrical attraction. A dipole is a positive and negative "free charge" fixed in one mass unit, with a total charge of zero, but having attraction for other dipoles on other units or on neighboring surfaces. Tripoli does possess extensive electrostatic charges "true charges," but this is equally true of quartz silica and other dusty materials with behavior different from tripoli.

"All the foregoing natural properties operate to provide a measure of coherence between fine tripoli particles so that a relatively greater degree of resistance is offered to those forces that tend to thrust the materials into the atmosphere as suspended dust. Once in the atmosphere, dipolar attraction is markedly diminished as interparticle distance increases.

"4. The fourth protective feature is artificial. Adsorption forces leading to hygroscopic films on particle faces necessitate the waterproofing of tripoli prior to use as a foundry parting. The chemical nature of the waterproofing coating favors no, or diminished, physiologic reaction. These materials have melting points well above body temperature and are not known to be removed by any physiologic process. The extent of physiologic inertness appears to depend upon the efficacy of the coating process. Not all, and particularly not all particles below 5 microns, are coated.

"Recognizing tripoli as a highly silicious substance and thus potentially dangerous when in a suitably fine state, these four-mentioned factors are marked as contributors to the low incidence of silicosis among those workers engaged in its manipulation."

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