

REPORT No. 3.



GOVERNMENT OF INDIA MINISTRY OF LABOUR

SILICOSIS IN MICA MINING IN BIHAR

OFFICE OF THE CHIEF ADVISER FACTORIES

1953

SILICOSIS IN
MICA MINING
IN BIHAR

PREFACE

Silicosis is associated with a variety of occupations in the manufacturing industries as well as in the mining industry. It may, therefore, appear anomalous that this disease should not have found a place in the Schedule of Occupational Diseases of the Workmen's Compensation Act.

In 1936, when the ratification of the I.L.O. Convention (Revised, 1934) concerning Workmen's Compensation for Occupational Diseases was discussed, the Government had given careful consideration to the possibility of adding 'Silicosis' to the Schedule, but they were forced to the conclusion that the conditions then prevailing in the country did not justify such a step. It was felt that the difficulty of diagnosing the disease which was common to all countries would be aggravated in this country because of the lack of adequate medical facilities except at the bigger centres. Further, it was felt that the long period which frequently elapses before the disease comes to light would make it necessary to set up an elaborate scheme for apportioning the liability for payment of compensation among different employers. Even if it were practicable to introduce such a scheme, it was considered doubtful whether the workers would be able to take advantage of it. The most important factor leading to the decision to omit silicosis from the list of compensable diseases was the lack of evidence regarding the incidence of the disease.

Silicosis has since been made a notifiable disease under the Factories Act, 1948 and the Mines Act, 1952. While it is appreciated that the disease cannot ordinarily be diagnosed except by persons having specialised knowledge of the subject, notification was considered as a first step towards stimulating interest in the study of the problem and, in a general way, for emphasising the need for preventing harmful exposures to dusts containing free silica.

The present report on silicosis in mica mines in Bihar is based upon a comprehensive study covering both the engineering and medical aspects of the problem. Both in planning the study and in carrying out the detailed field investigations we fortunately had the assistance of Dr. Harry Heimann and Dr. Samuel Moskowitz, Members of the Industrial Hygiene Unit now in India under the United States Technical Co-operation Administration Programme. Dr. M.N. Gupta and Dr. C.R. Harihara Iyer of the organization of the Chief Adviser Factories were the other two members of the team who conducted the detailed investigations.

This is perhaps the first comprehensive study on the subject of silicosis in this country. The organization of the Chief Adviser Factories had not, at the time, all the equipment and facilities necessary for carrying out investigations of this type. Work had to be so planned and co-ordinated as to make use of the none-too-readily available facilities wherever they could be obtained. A considerable amount of organization and detailed planning was therefore necessary and in this connection I would like to make a particular mention of Shri N.S. Mankiker, Chief Adviser Factories, who was responsible for the conduct of the study.

The study has yielded, among other things, valuable data on the incidence of silicosis and on its frequency rate in relation to dust exposures. The report is helpful also in that it indicates the lines on which similar studies might be carried out in other industries and occupations where the potential risk of silicosis exists.

NEW DELHI.

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Secretary,
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INTRODUCTION

India supplies the world with a major portion of all its high grade sheet mica, a material that is invaluable in the electrical industry. Before World War II India produced about 75 percent of the mica needs of that industry, and the bulk of it came from the Bihar mica field (1). Production has progressively increased, data for recent years showing an advance of from 120,000 cwts. in 1939 to 195,000 cwts. in 1951, the latest year for which such figures are available. Employment in the industry is about 27,000, of which 16,500 work underground.

That mica miners, in the course of their work, are exposed to the inhalation of rock dust that is high in its free silica content, and thus may develop the disease silicosis, has been known for some years. Suggestive evidence in this direction was presented to the Mica Enquiry Committee, in 1944-45 (1). Similar data appeared in a later report of another inquiry into the working conditions in the industry (2). Both reports recognized the need for a careful scientific appraisal of the problem. With the recent addition to the Office of the Chief Adviser Factories of the necessary equipment and technical assistance, it was felt that the time was ripe for such investigations to be undertaken. About the same time, a request was received from the Chief Inspector of Mines for assistance in carrying out an investigation into the problem of dust hazard in mining.

ENGINEERING SECTION

In the State of Bihar, mica is found in pegmatites, rock formations which are generally lenticular in shape. The pegmatites are surrounded by the country rock found in this section, which is usually schist. Pegmatite deposits vary greatly in size, up to 1000 feet in depth, to hundreds of feet in greatest horizontal dimension, and from a few feet to 50 or more feet in thickness.

Geologists are not in general agreement on the mode of formation of pegmatites. The composition is, however, well known. The pegmatites in the Bihar mica belt consist of granite-like minerals in that they contain principally quartz, feldspars, and mica. There are minor quantities of other minerals present in the pegmatites, such as tourmaline, beryl, garnet, and a variety of less common minerals.

Unlike granite, pegmatites are heterogeneous in structure and composition. It is common to find zones which are almost all quartz or almost all feldspars. While some mica is found distributed through large volumes of rock in the form of small flakes, there are deposits of large books of mica of some considerable thickness in portions of the pegmatites. These are the deposits that are sought.

Zones of mica-containing rock, in which the mica is of economic importance, are usually found near the walls of the surrounding country rock, and also near separations between rock that is largely quartz, and rock that is composed largely of feldspars. In mining for mica, the obvious

intention is to follow mica-bearing zones as much as possible. However, it is often necessary to excavate non-mica-bearing rock, such as is found between mica-bearing zones or even country rock, in order to reach mica-bearing zones.

Mica Mines

The usual underground mica mine consists of a vertical or nearly vertical shaft, which may not be continuous for the depth of the mine. Branching from this shaft are a number of horizontal, or almost horizontal, main galleries or levels at various depths. There are crosscuts or drifts which branch off the different level. The workings most frequently met were at a depth of about 200 feet.

Additional shafts, the functions of which vary, reach down to levels which may be worked. They may be either emergency exits, stacks for air movement within the mine, or haulage ways. None of the shafts is equipped with a lift, and entrance and exit is by means of ladders.

Shafts, adits, levels, and drives are of various cross sections. They are usually about five by seven feet, or six by eight feet, but they are sometimes restricted by rock debris to a cross section of three or four feet square.

Mining

Mining may be divided into several operations, namely, drilling, blasting, scaling, selection of mica, and mucking.

In many of the larger mines that are equipped with air compressors, drilling is performed with hand held pneumatic jackhammers. Drilling of from 20 to 40 holes, each about two feet in depth and about $1\frac{1}{4}$ inches in diameter, is done per eight-hour shift by a single gang of drillers. Each gang consists of three or four men, one who stands at the face and directs and turns the bit, the other two or three holding the jackhammer and applying the required pressure. The number of holes drilled per shift depends on the hardness of the rock and the type of equipment used. In any case, the usual time spent in drilling is about four hours per shift.

To the end of 1952 although dust control measures in mica mines were not specifically required by legislation, orders under Section 22 of the Mines Act, 1952 had been issued prohibiting, after a period of six months, the use of drilling machines not provided for wet drilling or with an efficient dust trap. Some mine owners had been using wet drilling methods for many years and air operated dust traps had been in use from late 1951. This subject is discussed in further detail in the section on Dust Control.

Some of the mines have no air compressors and some others have a compressor with capacity sufficient to operate only one drill. In the former mines, and in the latter when more than one drilling gang is to operate at once, hand drilling is done. This consists of having one driller holding a drill in position while two others pound the drill with sledge hammers. When the drill is held vertically, or nearly vertically, the bit has a tendency to stick in the rock which is being drilled. This is usually the case with

feldspar when it is soft or kaolinised but not with quartz, and to ease the movement of the drill bit small quantities of water are poured into the holes after the first few inches have been drilled. Hand drillers usually work about six hours per shift. They are also usually engaged in the operation of scaling which is described below.

After a sufficient number of holes have been drilled in a face to lengthen a drift or to remove the mica books, blasters begin their work. The proper amount of explosive is placed in each hole with the usual tamping and fuse, and the shots are fired. After a lapse of at least one-half hour after blasting, an examiner inspects the site to find out if any of the shots may have misfired. The one-half hour interval is supposed to be sufficient to clear the air of dusts and fumes resulting from the blasting so as to permit the entrance of the shot examiner and the mine superintendent or manager. Occasionally, at this stage, natural ventilation is assisted by the use of compressed air blowing into the working place.

After it has been ascertained that all the shots have been fired, a group of scalers begins to work. They may begin immediately after the examination for live explosive or not until 12 or even more hours after the examination. This will depend on their availability, whether there are two or more shifts working, and on other factors which do not take into consideration the concentration of dust and other contaminants still in the air.

The scalers, with hammers and chisels, remove loose rock from the face, roof, and walls of the recently blasted face to prevent later rock falls. They also chisel out exposed books of mica. In so doing, their operations resemble those of hand drillers, which in fact they are not scaling. It was estimated that hand drillers and scalers work about six hours per shift at these operations.

Shortly after the scaling is completed, and sometimes while the scalers are still working, a group of sorters select pieces of mica which have been dislodged during the previous blasting and scaling. After breaking off adhering rock, they place the mica into shallow metal pans, and throw the remainder of the rock to one side of the drive. After all of the usable mica has been selected, the remainder of the loose rock is raked into other shallow pans, each holding about 80 pounds of rock. The pans are carried to a small trolley on narrow rails which run to a haulage shaft, or they are manually carried to such a shaft. The loose rock or debris is hoisted to the surface in metal drums and dumped. The mica which had been selected as usable is also hoisted to the surface in drums or sacks. This is only a small fraction of the rock which is mined and handled. Mica selection and handling of debris are done by muckers who are exposed to dust for approximately three hours per shift.

Rock

The pegmatite rock which is worked may have a composition varying from almost pure feldspars to almost pure quartz. Based on the knowledge that mica is located in or near zones containing considerable amounts of quartz and that the tendency is to follow mica-bearing rock, it can be concluded that drilling is usually done in rock with a high quartz content.

It would have been virtually impossible to determine the average composition of the pegmatites being mined. Therefore, it was decided to take random samples of rock drilling at the places being worked in those mines which were visited. These drillings were screened through a 30-mesh sieve to remove flakes of mica. This step was taken since it is known that mica is not readily ground up and therefore does not materially, contribute to the dust which might arise from the processing (drilling, crushing and handling) of the rock as a whole. Moreover, drilling is not done into large mica deposits since that would destroy any economic value which the mica might otherwise have.

The samples of rock drilling were chemically analyzed using a phosphoric acid technique (3). These results were confirmed by laboratories of the United States Public Health Service. The results of the analyses are given in table 1. It will be noted that although the quartz content of the drillings varied from 11 percent to 67 percent, the median was 42 percent. Such a content of quartz is high for rock usually found in other mining operations.

Table 1.—Free silica content of rock drillings from mica mines.

Sample number	Free silica content in percent by weight
8	67
9	64
2	62
1	59
6	42
7	41
4	36
5	29
3	11

Visits to a number of mines disclosed that in some the workings were all quite dry. In other mines some of the workings were dry and some moist. In still others all the workings were moist. In moist work-

ings the rock varied from being slightly damp to being so wet that water seeped out.

Dust Control

At the time of this investigation, prior to January 1, 1953, some of the mines were still using mechanical (pneumatic) drills with no dust control. No mechanical ventilation, either exhaust or forced, was provided in any of the mica mines. The volume of air released from one pneumatic drill was approximately 100 CFM (cubic feet per minute) at atmospheric pressure. Since the average working has a cross-section area of about 35 square feet, the average air velocity produced by the air released from a drill is approximately 3 feet per minute, a rate which is hardly sufficient to carry a dust cloud away from the drillers.

In some of the mines where water is not readily available dust traps are being introduced. The dust trap consists of a short piece of heavy rubber tubing about four inches in diameter near one end of which is a slit rubber diaphragm through which the drill bit is passed. Air is exhausted from the tube by means of a compressed air-operated Venturi aspirator. The air enters the tube between it and the face, the exhausted air passing through a cloth bag which hangs from the equipment. This bag has approximately 10 square feet of filter area. The filtered air returns to the atmosphere near the drillers. In another type of dust trap the filter bag is replaced by a group of stocking filters within a metal housing at some distance from the drillers. The filter area in this equipment was also found to be approximately 10 square feet. Emptying of the filter bags was being done underground, on the floor of the tunnel, after each one to two shifts.

It was observed that wet drilling was the method most frequently adopted for the control of dust from drilling. This consists of using a hollow drill bit through which water is forced, emerging at the bit end. The flow of water is caused either by gravity, the tank of water resting at the surface, or by air pressure, in which case the tank of water can be near the drilling station. In either case, the water, and much of the drillings, flow from the hole in the form of sludge. Some 50 to 100 gallons of water are required for the drilling done by one gang of drillers per shift.

Hand drilling is done with no dust control measures. In the section on Mining, the description of hand drilling mentions the use of water at the bottom of a vertical or nearly vertical hole to prevent the drill sticking, but not for the purpose of dust suppression. Moreover, this use of water is more common in holes drilled in feldspar than in those drilled in the more hazardous quartz. Scaling is also done with no control measures for the suppression of dust.

Mucking is done with no intentional dust control. In such mines where the rock is moderately wet, the pile of debris after blasting remains wet during the selection of mica and the mucking and thus the dustiness is allayed to a degree,

Dust Exposure

In order to determine the exposure to dust to which the various occupational groups are subjected, nine typical mines, selected by the Inspector of Mines, were visited. By observation and inquiry for each category of employees, estimations were made of the numbers of hours spent at various tasks. Average dust concentrations of the air breathed during the performance of these tasks were also determined.

Dust samples were taken in the breathing zones of workers each for periods of up to 10 minutes, by means of the midjet variety of the Greenburg-Smith impinger (4). This instrument consists of a hand operated suction pump which draws the air to be sampled through a nozzle submerged in 10 milliliters (ml.) of dust-free distilled water. The nozzle is of such diameter as to permit a flow of air of 0.1 CFM when the suction behind it is 12 inches of water. The air containing the dust impinges against the bottom of the flask after it has passed through the nozzle. Dust particles striking the bottom of the flask have a very rapid change in velocity, are wetted by the water, and thus remain behind in suspension.

After sampling is completed, a representative portion of the suspension, or a portion of diluted suspension, if dilution is found to be necessary, is introduced into a ruled counting cell. The Spencer bright-line hemocytometer cell was used. The cell is examined under a microscope which is fitted with an Abbe condenser, a 16mm. objective, and a 30x ocular. Either daylight or a substage lamp is used for illumination (5).

After permitting the dust particles to settle for two minutes or longer, the number of particles visible within a definite area are counted. The depth of the cell being known and so also the area from the rulings in the cell, the volume of liquid in which the counted particles were contained can be calculated. This count is multiplied by the ratio of total volume of sample (or its final dilution) to the volume of liquid in the cell in which the particles counted was contained. This product is divided by the quantity of air sampled, in cubic feet. The final result is expressed in million (1,000,000) particles per cubic foot of air, abbreviated mppcf, and is usually expressed to two significant figures. This method of collection of dust particles and their counting gives the count of particles of sizes from slightly below 1 micron to the maximum found suspended in air, usually about 5 microns. It should be emphasized that this method of counting does not necessarily give the same results as other methods of dust collection and counting since each method of collection and each optical system used in counting has a different particle size range for which it is most efficient.

The dust counts found in each occupation are given in table 2. It can be seen that uncontrolled pneumatic drilling gave rise to average dust concentrations of from 600 to 1,000 mppcf depending on whether dry or moist rock was drilled, and that the use of a dust trap reduced the dustiness by from 47 to 51 percent. Wet drilling reduced the dustiness by over 99 percent. Hand drilling and scaling produced dust concentrations averaging 60 mppcf, and mucking 40 mppcf. However, mucking of moist rock produced dust concentrations averaging only slightly above 5 mppcf.

Table 2.—Dust counts at various occupations in mica mining.

Occupation	Number of samples	Dust counts in million particles per cubic foot of air	
		range	mean
Mechanical (pneumatic) drilling			
No control			
dry rock ..	5	630 — 1,700	1,000
moist rock ..	3	380 — 1,000	600
Dust trap			
dry rock ..	5	350 — 610	530
moist rock ...	6	28* — 490	250
moist rock ..	5	110† — 490	290†
Wet drilling			
dry rock ..	5	4.7 — 9.2	7.0
moist rock ..	16	3.0 — 23	7.9
Hand drilling and scaling			
dry rock ..	4	24 — 300‡	97
moist rock ..	3	9 — 43	21
Mucking			
dry rock ..	3	15§ — 210	84
moist rock ..	2	3.5 — 7.0	5.3
General air ...	4	1.3 — 11	3.8

- Notes:*
- * One dust count of 28 mppcf was obtained while drilling using a dust trap. The rate of drilling was 3.5 inches per minute as compared with the usual drilling rate of 5 to 12 inches per minute.
 - † Results obtained after discarding the dust count of 28 mppcf. This does not affect the value of the mean materially.
 - ‡ Less than 1 hour after blasting.
 - § Work done 12 hours after blasting.
 - || Work done 1 hour after blasting.

At two faces, one of dry rock and the other of wet rock, an opportunity was afforded to collect air samples for dust counts under three different experimental working conditions, namely, pneumatic drilling without control, pneumatic drilling using a dust trap, and pneumatic wet drilling. The results of these dust determinations are given in table 3. These results indicate that the reduction in dustiness in these controlled experiments and at these two specific locations, where all other conditions were identical, was 61 to 69 percent by the use of a dust trap, and again over 99 percent by the use of wet drilling.

Table 3.—Comparative dust counts at two different types of rock faces, under different working conditions.

Mechanical (pneumatic) drilling	Number of samples	Range mppcf	Mean mppcf
Dry rock			
wet drilling	5	4.7—9.2	7.0
dust trap	5	350—610	530
no control	1	1,700	1,700
Moist rock			
wet drilling	5	3.8—5.9	4.7
dust trap	3	310—490	390
no control	1	1,000	1,000

When a sufficient number of dust counts for each occupation was obtained, the mean count for each was multiplied by the fraction of the shift to which the particular occupational group was exposed. These products, termed the "average daily exposure to dust", are shown in the last column of table 4. Thus, it will be noted that while pneumatic drillers who used no dust control were exposed to an average of 400 mppcf, those who used a dust trap to 200 mppcf, and those who did wet drilling to but 3.5 mppcf. Hand drillers had an average dust exposure of 45 mppcf, and muckers 15 mppcf.

Table 4.—Dust exposure by occupation of mica miners.

Occupation	Average dust count in mppcf	Hours per day of exposure	Average daily exposure to dust in mppcf
Mechanical (pneumatic) drilling			
No control	800	4	400
Dust trap	400	4	200
Wet	7	4	3.5
Hand drilling and scalling			
	60	6	45
Mucking			
	40	3	15

Discussion

It is generally agreed that the average daily exposure to dust which arises from operations performed on rock that is high in free silica (quartz) should not exceed 5 mppcf, when the methods of collection and counting described in the previous section are employed (6,7).

It is apparent from table 2 that there was no operation in mica mining, in which the average dust count was less than 5 mppcf. as shown in table 4, pneumatic wet drilling, since it is done for only four hours per day, is safe from the point of view of the health hazard due to dust, and is the only form of drilling that is safe. Similarly, mucking of wet rock alone is a safe operation, but, generally, muckers handle dry as well as wet rock, and on the average are exposed to concentrations of dust which are above the safe level.

It should be noted that the presence of water in the rock that is being worked has an effect on the dustiness of the air while working those rocks. The presence of water is not, however, sufficient to give adequate control in drilling unless enough additional water flows through the drill bit into the hole being drilled so as to wet most of the dust that is being produced.

Wet drilling of moist rock gave two dust counts of 22 and 23 mppcf. No other count during wet drilling, either of dry or moist rock gave a dust count in excess of 10 mppcf. During the wet drilling which produced one of the high counts, it was found that the rate of flow of water through the drill bit was only 0.1 gallons per minute. The recommended minimum rate of water flow is 0.6 gallons (0.75 U.S. gallons) per minute (8). Most of the counts were made while using adequate amounts of water during the drilling operations.

Dust traps have been used successfully elsewhere as a means for the control of dust during pneumatic drilling. For such effective control air must flow into the hood surrounding the drill bit at a rate above a specified minimum; this air flow must not decrease materially as the filter becomes filled, and the filter must be efficient enough to return reasonably clean air to the working atmosphere. From the fact that dust traps in the present survey gave a reduction of only 50 percent in the dustiness produced by drilling with no controls, it may be concluded that one or more of the requirements were not met. No study of the characteristics or operation of the dust traps was made at this time, but will be the subject of a future study. It is of interest to note that none of the drillers who were medically examined gave an occupational history of ever having done pneumatic drilling with a dust trap.

MEDICAL SECTION

Methods

From the engineering study it was apparent that the major occupational disease hazard in the mica mining industry was from the inhalation of dust having a relatively high free silica content; in other words the problem was that of silicosis with its attendant complications. For this reason the medical examinations were limited essentially to the lungs and heart. In addition, limited information was elicited with reference to the eyes and ears.

A cursory examination was made of the corneae to observe the presence or absence of pitting or scarring, in view of the potential exposure to fast-moving foreign particles in mining operations. Each miner who was examined was also queried as to his ability to hear normally, since the noise attendant at pneumatic drilling could adversely affect his hearing.

Figure 1 is a copy of the form which was used for recording the medical data as they were obtained. It will be observed from this form that following the recording of the basic data for each worker, such as the name, home address, place of birth, age, sex, and name of current employer, the occupational history was obtained. Because of the great importance necessarily attached to this part of the history, reliance for its accuracy was not placed solely upon the miner's statements; in practically all instances corroboratory information was obtained from an informed representative of the current employer.

Figure 1.—Medical form used in survey

MICA STUDY
Medical Examination Form

Case No..... Date.....
Name.....Address.....
Birthplace..... Sex M F Age.....
Name of employer.....
Ticket No.....

OCCUPATIONAL HISTORY

Specific job	Dept., industry, or firm name	Time in years	Remarks
present.....
prev.....
prev.....
prev.....
Total underground			

If driller, No. of years with jackhammer.....No. of years
wet drilling.....No. of years with dust trap.....

SYMPTOMS

Ears: hearing G P tinnitus Y N
Cardio-respiratory: dyspnoea Y N oedema Y N chest
discomfort Y N
cough Y N expectoration Y N hemoptysis Y N

PHYSICAL EXAMINATION

Nutrition G P resp. rate...../min. temperature.....°F.
Eyes: cornea: opacities Y N pitted Y N
Lungs: auscultation N A.....
Cardio-vascular:
heart sounds: A₂>=<P₂
murmurs Y N syst. diastol. apic. basal.....
rhythm irregular Y N.....
pulse rate.....oedema of ankles Y N

X-RAY INTERPRETATION

Film condition G F P				
Lung field markings-normal		Heart or aorta enlarged	1	2
linear	1	Diaphragm adh.	Y	N
		oblit angles		
G G	1	TBC infiltr.	Y	N
nod	1		
conglom	2		
			
Blood smear				
Diff. W.B.C.—	y. polys	%	
	m. polys	%	
	lymphos	%	
	monos	%	
	eosinos	%	
	basoph	%	

Signature

Following the recording of the occupational history, the worker was privately questioned about symptoms referable to his ears, his heart, and lungs. He was then examined. In the objective examination his oral temperature was obtained and his pulse and respiratory rates were noted. He then stripped to the waist and his heart and lungs were auscultated. In listening to the lung sounds the observations were limited to the presence or absence of adventitious sounds (râles). In the case of the cardiac examination, observations were limited to the occurrence of murmurs, the nature of the rhythm, and the relationship of the intensity of the second pulmonic heart sound to that of the second aortic heart sound. Finally, observation was made for the presence of ankle oedema.

Two drops of finger-prick blood were then obtained and blood smears were prepared on glass slides. These were stained with Wright's stain and, later, a differential leucocyte count was made in which 100 white cells were classified for each person. The primary purpose of the differential leucocyte count was to determine the percentage of eosinophilic polymorphonuclear leucocytes which factor would then be of assistance in the differential diagnosis between the clinical entity tropical eosinophilia and nodular silicosis.

For each miner examined a chest X-ray on an 11 x 14 inch film was made, using appropriate voltage and exposure time at 6-foot target distance. All of the X-rays were subsequently interpreted for the presence and degree of pulmonary dust effect, the presence of tuberculous infiltration, and the configuration of the heart shadow. Further details of the manner of these interpretations are discussed below.

All of the medical examinations were made at two hospitals, one in Kodarma and the other in Giridih (Bihar). The workers to be examined after being selected by the Mine Inspector, were transported to the examination sites in lorries by the mine supervisory staff. The original basis for the selection was that all available pneumatic drillers with relatively longer periods of continuous employment should be examined. Subsequently, it was decided to include other miners as well, if they had had relatively long periods of employment underground. It appears to have been unlikely that self-selection was made by the miners for

symptoms of illness that they might have had. As will be noted below, self-selection was done by the members of the mine supervisory staff who were examined. But, they are treated separately, and this will be discussed in a subsequent section of this report.

Results

General Data

There were 329 mica miners, all males, who were examined. There were no women employed underground since, at least 1945, when India ratified the International Labour Office Convention in regard to the employment of women in underground work.

The age distribution of the workers examined is shown in table 5. There were 129, or 39.3 percent, between the ages of 20 and 29; 139, or 42.4 percent, between 30 and 39; 38, or 11.5 percent between 40 and 49; and 14, or 4.2 percent, between 50 and 59.

Table 5.—Distribution of examined mica miners by age.

Age	Number	Percent
20—29 ..	129	39.3
30—39 ..	139	42.4
40—49 ..	38	11.5
50—59 ..	14	4.2
no data ..	9	2.7
Total ..	329	

All were from local native stock, including a small number of aborigines. The miners generally came from families whose traditional work was farming. In fact many of them owned plots of farm land which they tilled in season, some even taking temporary annual leave to do so. Most of the men began their mining experience at a relatively young age, and started with the more menial tasks above ground; then later entered underground work. Table 6 shows the distribution of the examined miners by number of years that they had worked underground. The bulk of the men (84.2 percent) had spent six or more years underground in mica mines. Only two men had previously worked in other types of mines, and this possibly complicating factor may be disregarded for present purposes.

Table 6.—Distribution of examined mica miners according to total number of years worked underground.

Time in years	Number	Percent
1—5	52	15.8
6—10	180	54.8
11—15	60	18.2
16 and over	37	11.2
Total	329	

The distribution of the examined miners according to occupation at the time of the survey appears in tables 7 and 8. It will be observed from these tables that of the 321 for whom data in this regard were obtained, 66, or 20.6 percent, were pneumatic drillers who worked without dust control; 104, or 32.3 percent, were pneumatic drillers who did wet drilling; 62, or 19.3 percent, were hand drillers; and 89, or 27.7 percent, were classed as muckers. Of each group of pneumatic drillers about 85 percent worked at this same occupation for five years or less, and only one had so worked for 11 years or longer. Of the hand drillers and muckers, about 75 percent in each category had been engaged in the same occupation for six years or longer, and 25 percent of the hand drillers and 11 percent of the muckers had been similarly employed for 11 years or longer. The age distribution of the miners by present occupation as shown in table 7, is in conformity with the data just described as to the duration of time in their present occupations.

Table 7.—Distribution of examined mica miners by age and present occupation.

Age in years	Pneumatic drillers with no dust control		Pneumatic wet drillers		Hand drillers		Muckers		
	No.	%	No.	%	No.	%	No.	%	
20—29	22	33.3	47	45.2	20	32.2	39	43.8	
30—39	31	47.4	49	47.0	28	45.0	28	31.5	
40—49	8	12.1	6	5.8	9	14.5	12	13.5	
50—59	5	7.6	1	1.0	0	—	7	7.9	
no data	0	—	1	1.0	5	8.1	3	3.4	
Total	66	(20.6%)	104	(32.3%)	62	(19.3%)	89	(27.7%)	321*

* For eight of the miners data for present occupation were not obtained.

Table 8.—Distribution of examined mica miners according to years spent in present occupation.

Years in present occupation	Pneumatic drillers with no dust control		Pneumatic wet drillers		Hand drillers		Muckers	
	No.	%	No.	%	No.	%	No.	%
— 5	56	84.4	90	86.5	14	22.5	23	25.8
6—10	9	13.8	14	13.5	32	51.6	56	62.9
11 and over	1	1.6	0	—	16	25.8	10	11.2
Total	66		104		62		89	
	(20.6%)		(32.3%)		(19.3%)		(27.7%)	321*

*For eight of the miners data for present occupation were not obtained.

Chest X-Rays

In clinically evaluating the effect of dust upon the lungs, the chest X-ray is of paramount importance. This is especially true in exposures to dust containing free silica, as in the present study. Many investigations of the effects on the lungs of silica dust inhalation have amply documented the importance of the roentgenographic findings. It is not to be inferred, however, that correlative medical data, such as medical history, physical examination, and occupational history, are not to be obtained. On the contrary, such data are of great significance especially for differential diagnostic purposes.

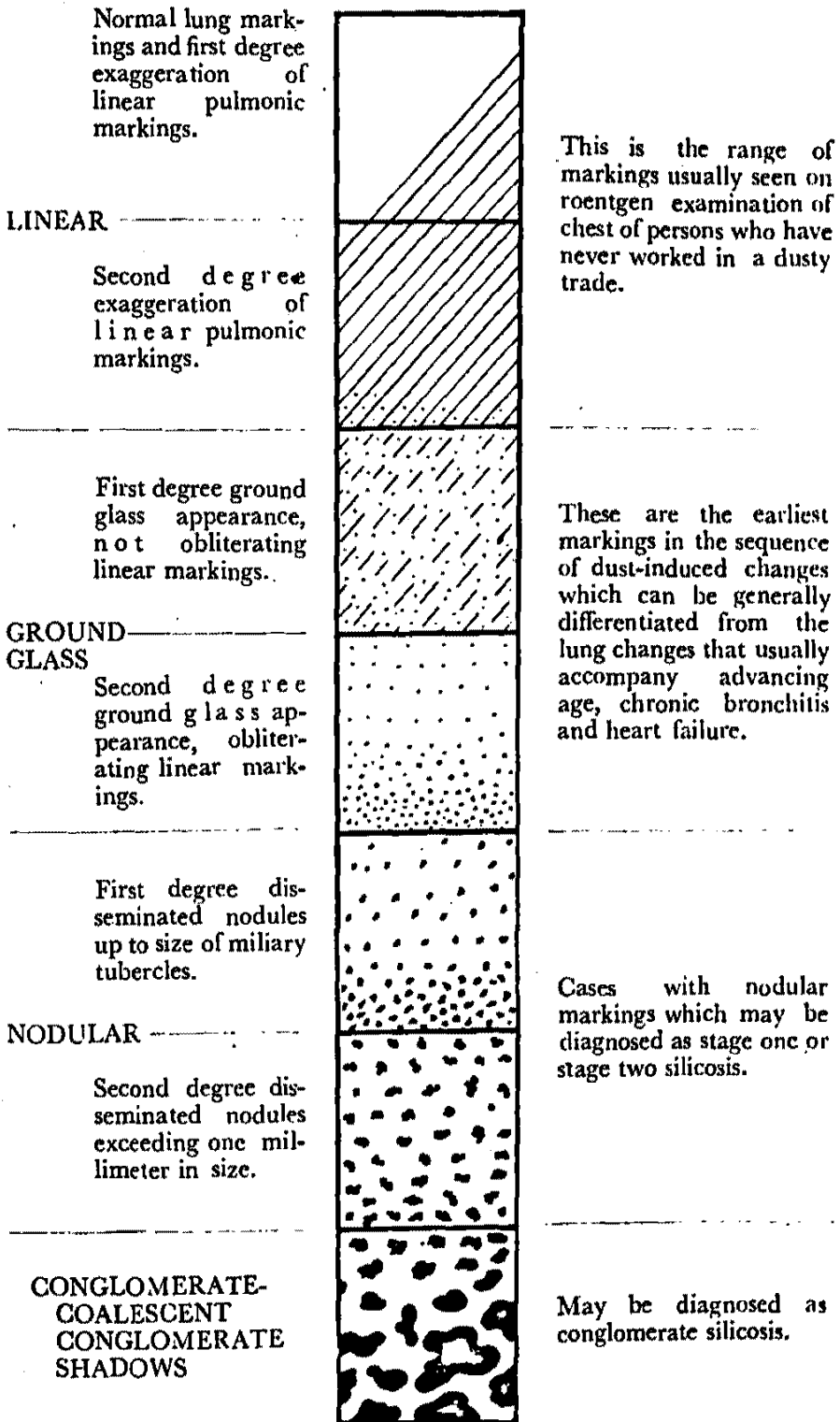
All of the X-ray films of this survey were read by two physicians who have had considerable experience in such interpretations. Films in respect of which there was any doubt as to interpretation were carefully reviewed two or even three times, where necessary, until a single conclusion was recorded.

Pulmonary Fibrosis

Silicosis, a disease due to the inhalation of dust containing free silica, is a progressive fibrotic disease of the lungs which is revealed by X-ray first by a generalized haziness of the lung fields; later, millet-sized nodules appear throughout the lung fields; still later, the nodules become larger and finally agglomerate into tumorous masses. The pathogenesis of the disease has been amply discussed in the medical literature (9, 10, 11, 12) and need not be described in the present report.

Roentgenographically, the stages of silicosis have been variously described. In the present survey the classification used was the one which has been described by the Division of Occupational Health of the United States Public Health Service (13), and with which one of the authors of this report has had considerable experience. In this classification the findings are graded according to the intensity of linear fibrosis, appearance of graininess (ground glass), and, finally, nodulation. Figure 2 graphically shows the scheme used to represent the stages in the progression of the pulmonary fibrotic state due to silica dust inhalation. Figures 3 to 7, inclusive, typical of X-rays from the present survey, are shown, together with the pertinent clinical data for each.

Figure 2.—Scheme representing the sequence of lung-field markings in a typical case of uncomplicated silicosis.



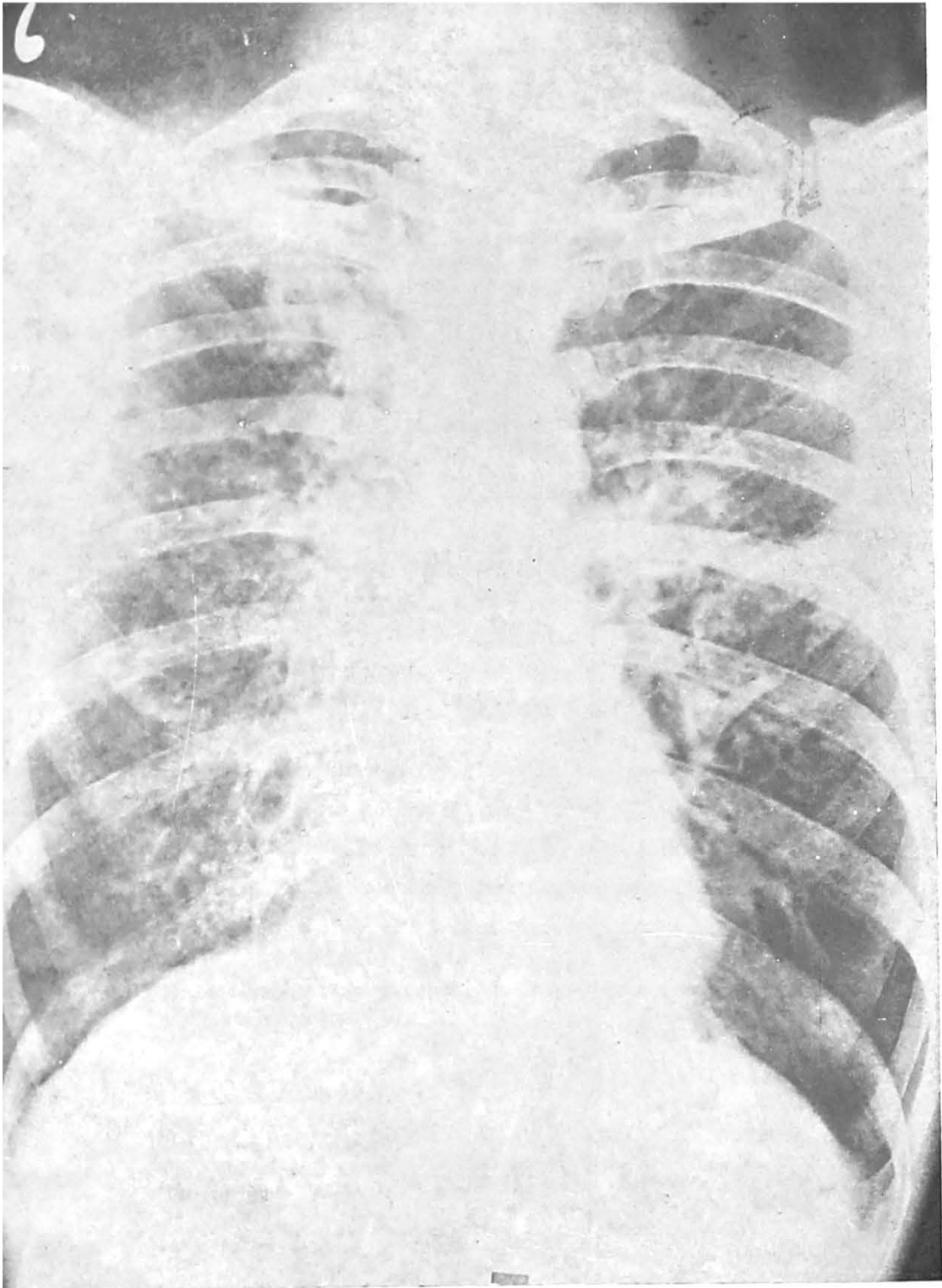


Figure 3.

Figure 3. —Nodular stage one silicosis with tuberculosis.

Case No. 96. Male, age 40. He was a member of the mine supervisory staff, having been a shift boss underground for 13 years and, later, a mine manager for seven years.

He had no complaints referable to the cardio-respiratory system. His temperature was 99.1°F., his pulse 144 and his respiratory rate 24 per minute. Lung examination elicited medium moist rales at the left apex. Examination of the heart was negative, and the second aortic sound was louder than the second pulmonic sound.

Roentgenogram was interpreted as nodular stage one silicosis, complicated by incipient active tuberculosis.

Figure 4. —Nodular stage two silicosis.

Case No. 88. Male, age 32. He was engaged in mica mining for 10 years. He had done mucking for two years, hand drilling for two years, and pneumatic drilling with no dust control for six years.

He complained of dyspnoea, a sense of chest constriction and productive cough. His respiratory rate was 24, temperature 98.2°F., and pulse 92 per minute. No abnormal lung sounds were found. Cardiac auscultation was negative, and the second pulmonic sound was louder than the second aortic sound.

Roentgenogram was interpreted as nodular stage two silicosis.

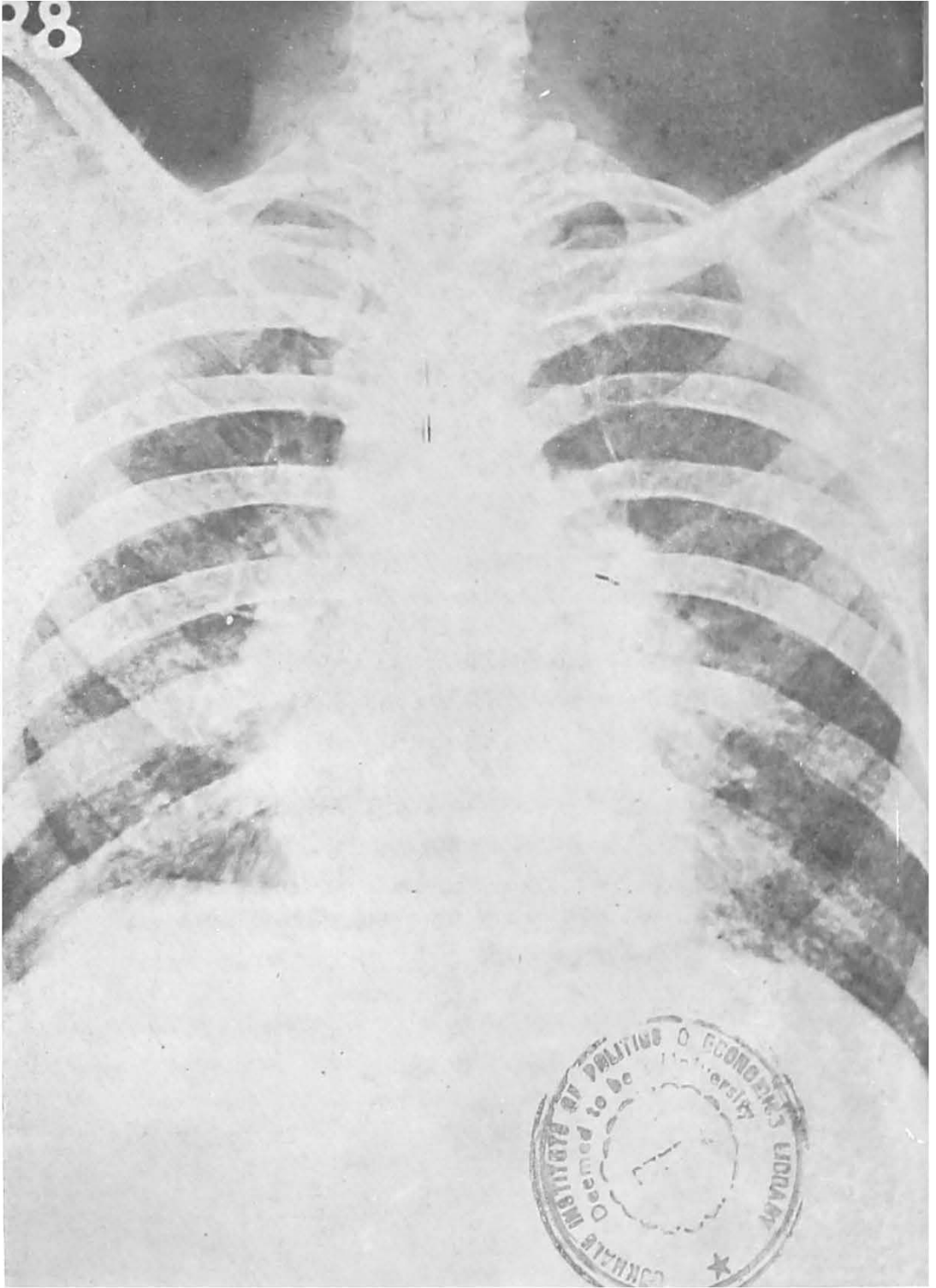


Figure 4.

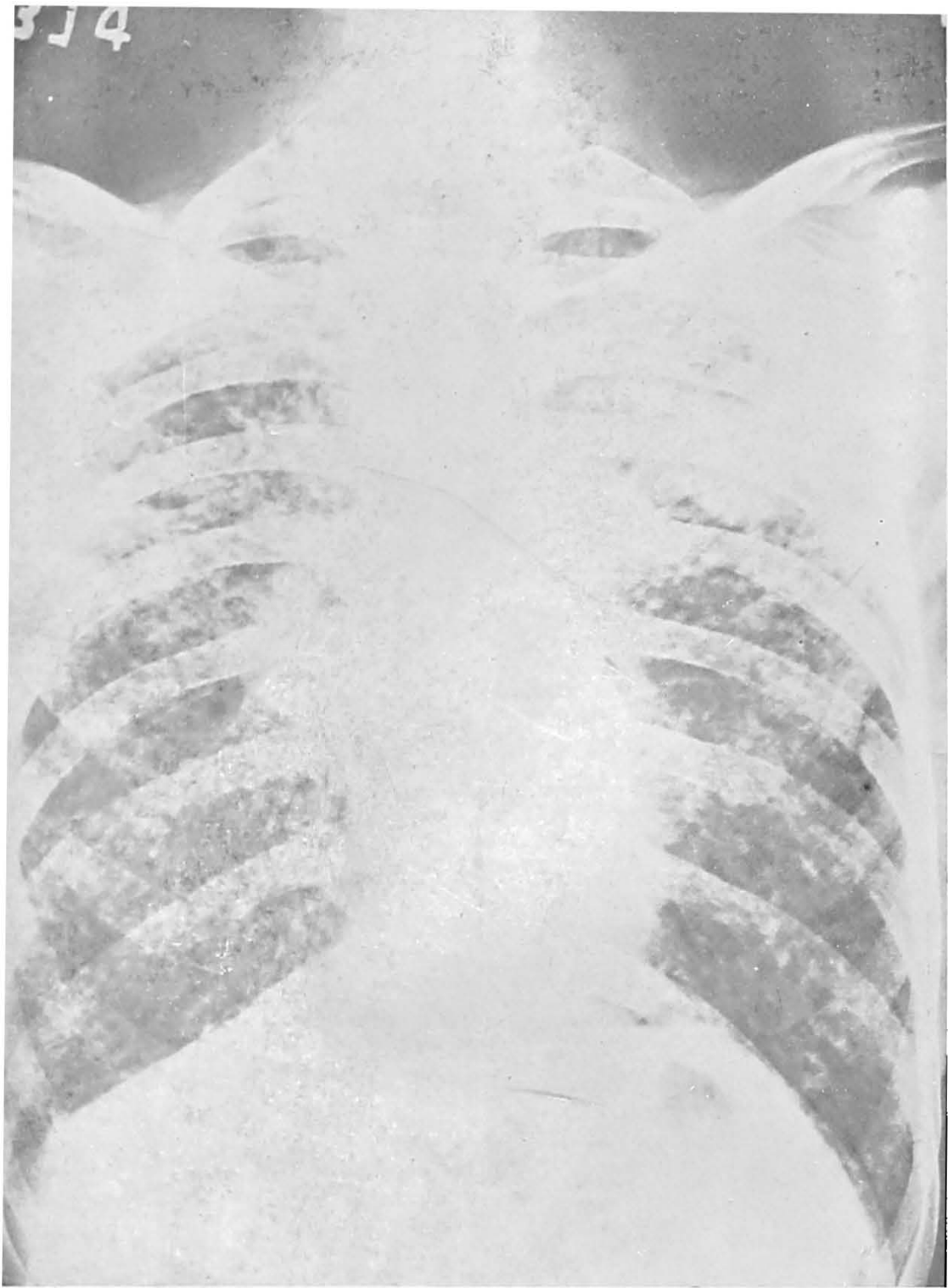


Figure 5.

Figure 5. —Nodular two silicosis with tuberculosis.

Case No. 314. Male, age 49. He was a member of the mine supervisory staff, having been in charge of a mining shift for two years, and a mine manager for the past 27 years. When in charge of a shift he spent full-time underground, supervising all activities of the miners. As a mine manager he spent about one-half his time underground.

His complaints were a productive cough for about five years and an attack of haemoptysis five years ago. He had a respiratory rate of 36 per minute, a temperature of 100.8°F. (in the morning), and a pulse rate of 110. Lung examination revealed medium moist rales at the left apex and right mid-chest region, anteriorly. Heart examination was negative, with the pulmonic second sound louder than the second aortic sound. Sputum was positive for the tubercle bacillus.

Roentgenogram was interpreted as nodular stage two silicosis, complicated with moderately advanced tuberculosis.

Figure 6. —Conglomerate silicosis with tuberculosis.

Case No. 331. Male, age 32. Up to the age of 22 he was a farmer. He then began his mica mining experience, starting as a hand driller. After five years at hand drilling, he worked with a pneumatic drill without dust control for five years. For the recent few months he has been a contractor.

He complained of dyspnoea and a dry cough. The respiratory rate was 26 per minute, temperature 98.4°F., and pulse rate 108. Medium moist rales were heard at the left mid-chest, posteriorly. There were no cardiac murmurs, and the second pulmonic heart sound was louder than the second aortic.

Roentgenogram was interpreted as conglomerate silicosis with moderately advanced tuberculosis, active.

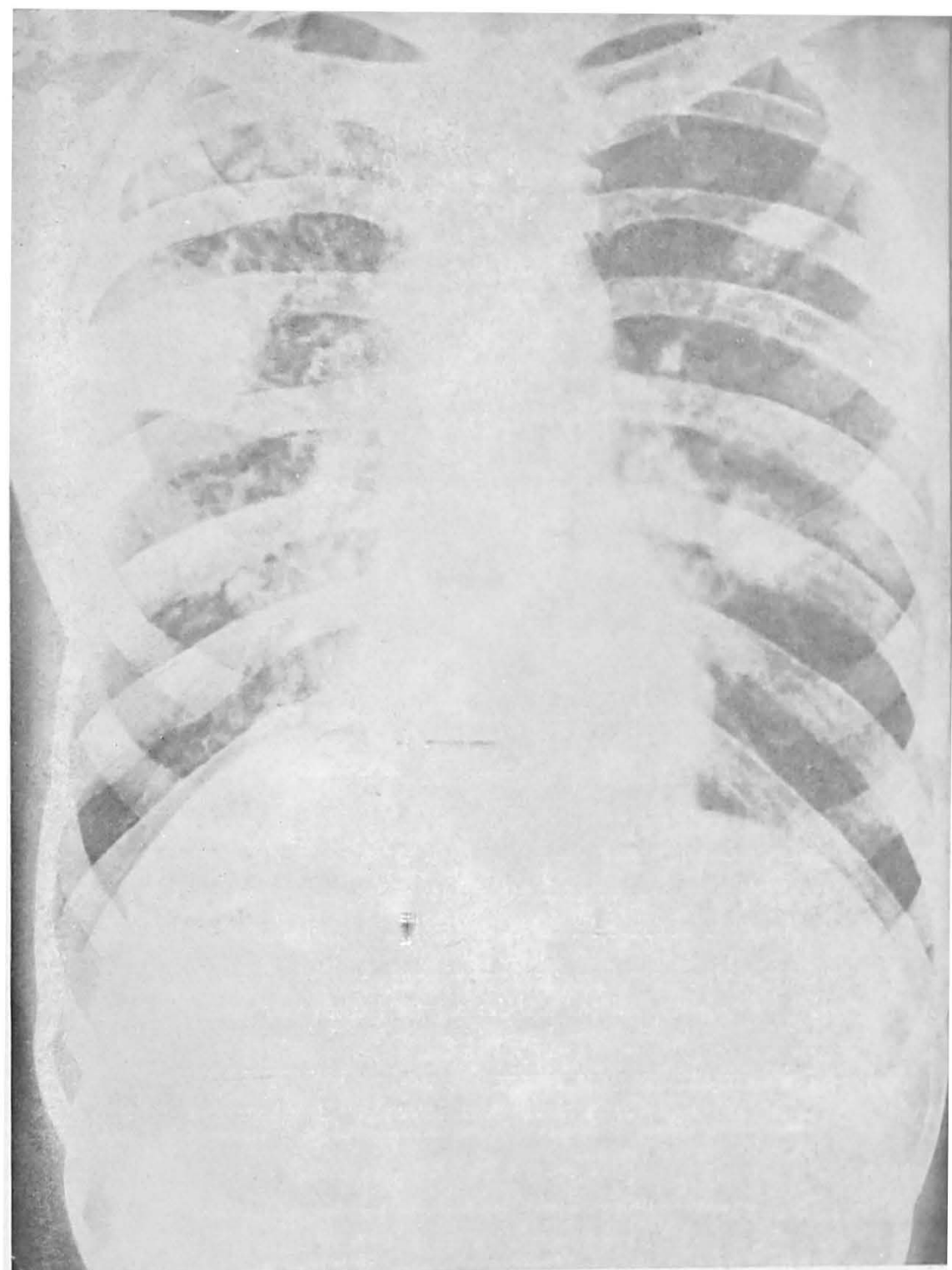


Figure 6.

624 L

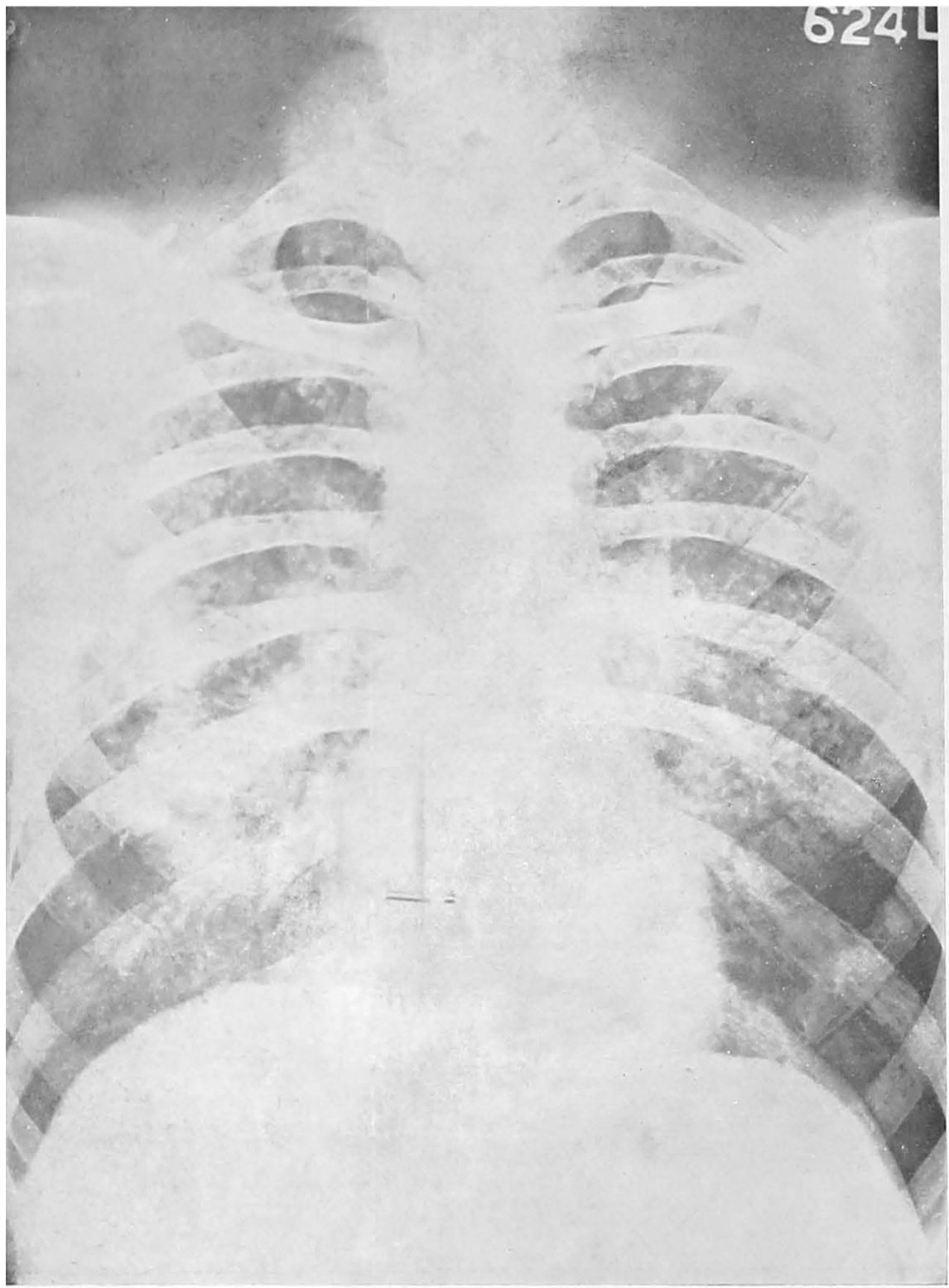


Figure 7.

Figure 7. —Conglomerate silicosis.

Case No. 624. Male, age 30. He began his work in mica mines as a hand driller for two years, starting at the age of 18. After that he did pneumatic drilling with no dust control for eight years. For the last two years he has been employed as a pneumatic wet driller.

He complained of dyspnoea, a sense of chest constriction, and a dry cough. The respiratory rate was 22 per minute, temperature 98.0° F., and pulse rate 84. Examination of the lungs was negative. Cardiac examination was normal, and the second pulmonic sound was equal in intensity to the second aortic sound. Sputum was negative for tubercle bacilli.

Roentgenogram was interpreted as conglomerate silicosis.

Generally, films indicated as normal, linear exaggeration one, and linear exaggeration two may be considered to be within normal limits or due to lung changes unrelated to the dustiness of the occupational environment. The ground glass one appearance may or may not be due to the dust in the occupational environment. Films showing the ground glass two appearance, with the history of exposure to silica dust and with other medical findings essentially negative, are strongly suggestive of an effect due to the dust of the occupational environment. Generalized nodulation and conglomerate masses of nodules appearing in the roentgenogram, together with data of an occupational exposure to silica dust and the other medical data, signify lung changes due to the dust. These latter stages (nodulation to conglomeration) are classed as true silicosis.

As mentioned earlier, one of the local endemic diseases which must be considered in the differential diagnosis of nodular silicosis in India is tropical eosinophilia ("eosinophilic lung"). This disease, which is characterized in part by a very high percentage (40-80 percent) of circulating eosinophiles, is not infrequently associated with a chest roentgenogram that simulates the nodular one stage of silicosis (14, 15, 16, 17). In the present survey there were four miners whose roentgenograms were typical of nodular one silicosis, and who had over 35 percent of circulating eosinophilic polymorphonuclear leucocytes. Because of the high eosinophile percentages, it was considered that they might have been cases of eosinophilic lung rather than of nodular silicosis; therefore, they were discarded from our series. All figures hereafter quoted in this report exclude these four miners.

There were 329 mica miners whose examinations and chest X-rays were complete. Of this number 51, or 15.5 percent, showed lung X-ray markings of linear exaggeration two or lower values; 57, or 17.3 percent, showed ground glass one markings; 109, or 33.3 percent, showed ground glass two markings; 78, or 23.7 percent, showed nodular one stage of silicosis; 20, or 6.2 percent, showed nodular two stage of silicosis; and 14, or 4.2 percent, had conglomerate silicosis. Thus, there were 112, or 34.1 percent, who had nodular or conglomerate silicosis.

Table 9.—Distribution of examined mica miners by degrees of pulmonary fibrosis observed by chest X-ray.

	<i>Degrees of pulmonary fibrosis</i>							Conglomerate	Total
	Normal	Linear exaggeration		Ground glass		Nodular			
		one	two	one	two	one	two		
No.	2	1	48	57	109	78	20	14	329
%	0.6	0.3	14.6	17.3	33.3	23.7	6.2	4.2	

The pertinent literature revealed that a similar survey for lung disease among mica miners was made by the United States Public Health Service in the State of North Carolina (18). In that survey, in which all the techniques used were the same as in the present study, it was reported that 3.6 percent had nodular or conglomerate silicosis.

Pulmonary fibrosis and dust exposure—the etiologic relationship of dust containing free silica to the disease silicosis is well established. In this report evidence will be presented from the present survey which will show a direct correlation between the two factors, dustiness of occupation and silicosis.

Various factors of the occupational history were used for this purpose ; these were the present occupation of the miners, the total number of years spent in underground work, the occupation of the miner which contributed the greatest degree of dustiness regardless of duration of exposure, and the "time-intensity" factor. The "time-intensity" factor, calculated for each worker, was determined by multiplying the Average Daily Exposure to Dust of a given occupation (from table 4) by the number of years that he had spent in the occupation. If he had had several occupations in mica mines, the products were added together to result in a total time-intensity factor for that employee. It appeared reasonable to expect that the time-intensity factor would be the most important in relating dustiness to pulmonary disease, for the disease develops as a cumulative effect, generally taking many years to appear.

Time-intensity factor and degrees of pulmonary fibrosis—All the examined miners were divided by degrees of pulmonary fibrosis into three groups. All cases that had X-ray readings of ground glass one or less were placed in one group. The second group comprised the miners who had ground glass two readings of the chest X-rays. The last group consisted of the nodular and conglomerate silicosis cases. Then, for each group an average time-intensity factor, based upon the time-intensity factors for each of the men comprising the group, was calculated. From these data the following were then calculated by standard statistical methods: Standard deviation from the mean, differences between means of the three groups of pulmonary dust effects, standard error of the difference of the means between Pairs of the groups of pulmonary dust effects, and the ratio of the difference of means to the standard error of the difference. Table 10 shows these figures. The calculated figures for the group having X-ray readings of ground glass one or less appear twice in the table, in the first as well as in the last line, for ease of comparison with the adjacent figures.

Table 10.—Correlation between pulmonary dust effect and “time-intensity” factor of dust exposure.

Degrees of pulmonary fibrosis	Mean Time-Intensity	Standard Deviation	Difference of means	Standard error of difference	Diff. of Means
					Standard Error of difference
Ground glass one or less (108 cases)	497	460	219	84	2.61
Ground glass two (109 cases)	716	744			
Nodular and conglomerate (112 cases)	1105	1082	608	111	5.48
Ground glass one or less*	497	460			

*Horizontal line 1 is repeated on line 4 for ease of comparison with the adjacent line of figures.

It will be noted from this table that the mean or average time-intensity factor increases regularly with increasing pulmonary dust effects. This is as anticipated. The data show that there is less than 1 chance in 200 that the difference between the first two groups (ground glass one or less, compared to ground glass two) is accidental. The differences between the other groups are such that the possibility of their having occurred by chance alone is less than 1 in 1,000. Such differences are of high statistical significance.

In table 11 the effect of the time-intensity factor on frequency rates of silicosis is shown, with emphasis placed on ranges of time-intensity. The rates are calculated on the basis of the total number in the diagnostic group. Thus, 21 percent of the nodular and conglomerate cases of silicosis had a time-intensity factor of dust exposure of up to 200, whereas 54 percent of the same group had a factor of over 800. Not shown in the table, because of necessary coarse grouping, is the fact that five cases of nodular silicosis were found among the miners whose time-intensity factor of exposure was less than 100, and in most of these it was 90. These five cases represent only 4 percent of all the silicotics and only 1.5 percent of all the miners. The data suggest that the recommended time-intensity factor, for prevention of silicosis, should not exceed 100, a figure which would correspond to five million particles per cubic foot of air, combined with an estimated span of 20 years of exposure.

Table 11.—Distribution of mica miners by exposure to dust expressed as "time-intensity" factor, according to pulmonary fibrotic effect. (Percentage rates calculated on total in each diagnostic category).

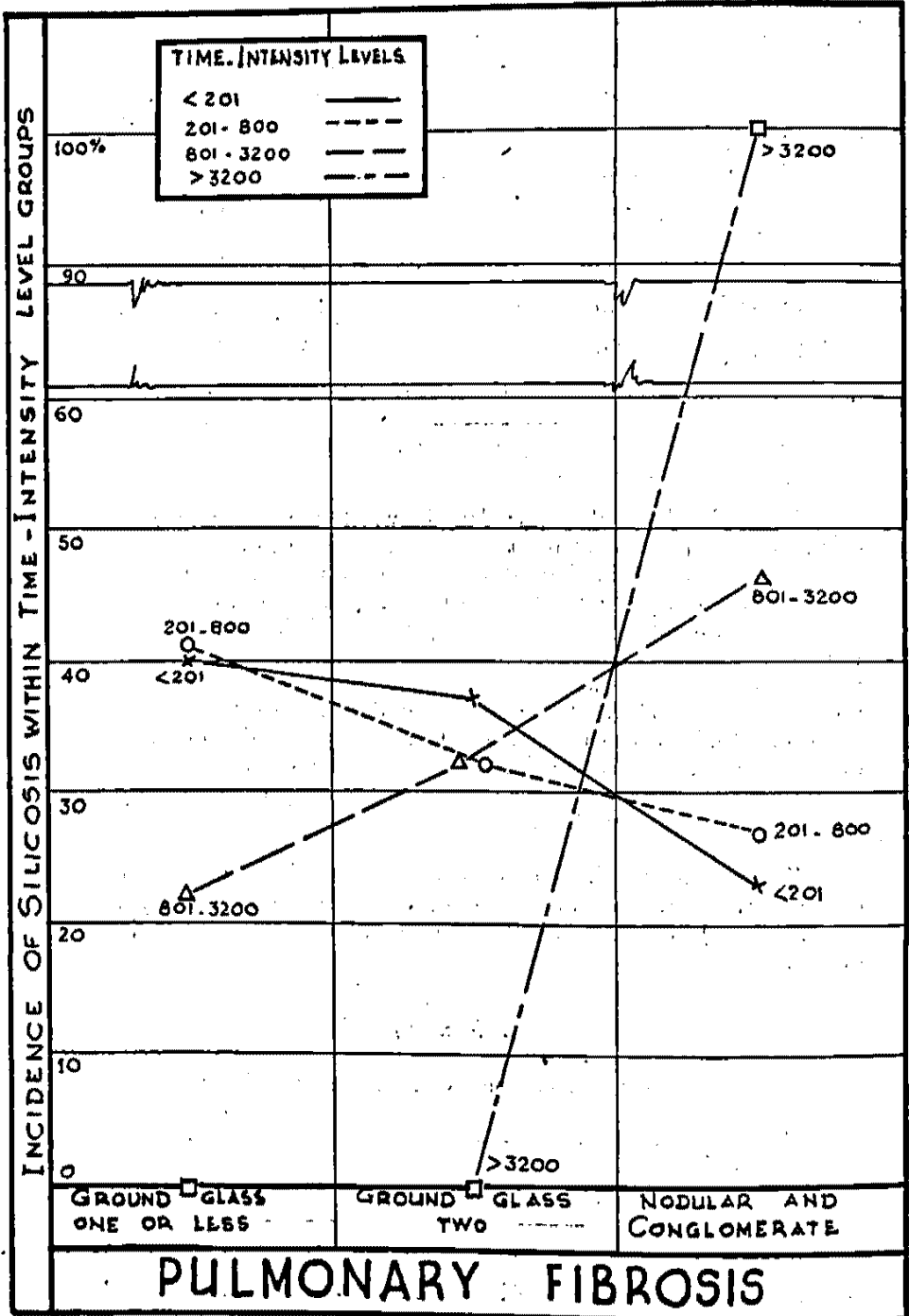
Time-intensity factor	<i>Pulmonary fibrosis</i>					
	Ground glass one or less		Ground glass two		Nodular and conglomerate	
	No.	%	No.	%	No.	%
to 200	39	36	37	34	23	21
201 to 800	43	40	34	31	28	25
801 to 3200	26	24	38	35	55	49
above 3200	0	0	0	0	6	5
Total	108	100	109	100	112	100

Table 12 shows the same data in which the frequency rates were calculated on the basis of the total number of men in each time-intensity factor range. This table indicates that of all of the miners who fall in the time-intensity range of up to 200, 23 percent had silicosis, whereas of those whose time-intensity was 201-800, 27 percent had silicosis. Of those who were in the range of 801-3200, 46 percent had the disease, and, finally, 100 percent incidence was found among the miners whose time-intensity exposure was over 3200. These significant data are shown graphically in figure 8. Again, it can be seen that there is a progressive increase in frequency rates of silicosis with increase in time-intensity factor, until a rate of 100 percent is reached in the small group of six persons who had time-intensity levels of over 3200.

Table 12.—Distribution of mica miners by exposure to dust expressed as "time-intensity" factor, according to pulmonary fibrotic effect. (Percentage rates calculated on total number in each time-intensity range).

Time-intensity factor	<i>Pulmonary fibrosis</i>					
	Ground glass one or less		Ground glass two		Nodular and conglomerate	
	No.	%	No.	%	No.	%
to 200	39	40	37	37	23	23
201 to 800	43	41	34	32	28	27
801 to 3200	26	22	38	32	55	46
above 3200	0	0	0	0	6	100

Figure 8.—Distribution of mica miners by exposure to dust expressed as “time-intensity” factor, according to pulmonary fibrotic effect.



These data confirm the concept of a relationship between degrees of dustiness, as well as duration of exposure, of mica mining on the occurrence of the disease, silicosis. Of less interest, possibly, is the relationship of present occupation and total time spent in underground work, respectively, to pulmonary fibrosis. Suffice it to say that no correlation existed between present occupation and pulmonary fibrosis, and, that a fair degree of correlation was found between total time spent in underground work and pulmonary fibrosis.

These data emphasize the concept of the etiologic relationship between *all* previous dust exposures to the occurrence of pulmonary fibrosis, and reemphasize the value of a good and complete occupational history in a suspected case of silicosis. Certainly, knowledge of the present occupation alone would be inadequate in evaluating the potential hazardous exposure in the case of a disease such as silicosis which requires many years to become manifest. Finally, these data make incontrovertible the fact that pulmonary fibrosis (silicosis), as observed in this survey, was directly related to the dustiness that existed in the miners' occupational environment.

Maximal dust exposure and pulmonary fibrosis—As was observed in tables 2 and 3 pneumatic drilling without dust control was the occupation which was associated with the highest level of dust exposure, by far. Since this single occupation might have been the greatest contributing cause for silicosis in a number of cases, the data were analyzed to test this matter.

Table 13 shows the data arranged according to whether the miner had or had not ever done pneumatic drilling without control. Of the 152 who had done such drilling during their working careers, 44 percent had nodular or conglomerate silicosis. For those who had never done such work the frequency rate for silicosis was 25 percent. Statistical analysis applied to these data proved that the difference in the rates for silicosis in the two groups was of high significance.

Table 13.—Distribution of mica miners by occupation in which there had been the maximal dust exposure, according to incidence of nodular silicosis.

Occupation of maximal dust exposure	Nodular and conglomerate silicosis	
	Number	Percent
Pneumatic drillers without control (152 cases)	67	44.0
All others (177 cases)	45	25.4

This interesting finding suggested the need for studying the factor of time in the occupation in which there had been the greatest dust exposure.

Accordingly, as shown in table 14, all those who had ever done pneumatic drilling without dust control were sorted out by time spent in that occupation and by the incidence of nodular and conglomerate silicosis.

Table 14—Distribution of pneumatic drillers without dust control as the occupation in which there had been the maximal dust exposure and years in that occupation, according to incidence of nodular silicosis.

Time in years	Nodular and conglomerate silicosis	
	Number	Percent
— 5 (129 cases)	51	39.5
6—10 (21 cases)	14	66.7
Above 10 (2 cases)	2	100.0
Total (152 cases)	43	44.0

It will be noted that there is a progressive increase in the incidence of silicosis with increase in the time spent in uncontrolled pneumatic drilling. However, the number who had done such drilling for longer than five years was too small for statistical analysis. Of special interest is the fact that the group that had done uncontrolled pneumatic drilling for up to, but not more than, five years had an average of 2.3 years in that occupation. Nevertheless, 39.5% of them had nodular or conglomerate silicosis, confirming the concept that pneumatic drilling without dust control is a most hazardous occupation from the point of view of the responsibility for causing silicosis. The elevated silicosis rate for such short periods of time of occupational exposure is unusual; but, it is not remarkable in view of the high level of dustiness of the occupation and the high silica content of the rock from which the dust originated. Supervisory staff—As mentioned earlier in this report, there was a group of 39 persons of the mining supervisory staff who were examined. Since no precise data were available as to their occupational dust exposures, they were excluded from consideration when the data for the 329 miners were considered. However, the supervisory staff group afforded some data of interest.

Since the socio-economic level of the supervisors as a group was considerably above that of the miners, it was felt that further comparisons could be made which might direct attention to the fact that low socio-economic levels with their attendant evils, such as inadequate nutrition, were not primarily responsible for the incidence of pulmonary disease that was observed. Furthermore, it was found that the distribution of time spent underground by the supervisors was similar to that of the miners.

Of the 39 examined, 15, or 39 percent, had nodular or conglomerate silicosis; and 7, or 17.9 percent, had pulmonary tuberculosis. These rates are quite similar to those of the miners. Symptoms and signs—The symptoms that may occur in silicosis include the following: Dyspnoea, cough, and a sense of constriction of the chest. The signs that occur on medical examination in silicosis are rather inconstant and indefinite. Among such signs are adventitious breath sounds (râles) and abnormal breath sounds. In the present survey only râles were searched for, and abnormal breath sounds were not recorded.

It has been suggested by some authorities (19, 20, 21, 22, 23) that the heart is usually involved in silicosis and is damaged by pulmonary hypertension, which in turn is due to the compression of the pulmonary capillary bed caused by the fibrotic process. It might be expected that such a situation, if it occurred, would induce an exaggeration of the second pulmonic heart sounds in its relation to the second aortic sound. For these reasons this sign was investigated in the present survey.

Dyspnoea was a complaint in 29 percent of the men who had silicosis. A sense of chest constriction was present in 27 percent, and cough in 33 percent. The cough was productive in 25 percent and non-productive in 8 percent of the silicotics. In 5.7 percent of the cases pulmonary râles were heard, and these were either musical or "small moist" in character.

Table 15 shows the relationship of silicosis, as observed in this survey, to the intensity of the second pulmonic heart sound. The second pulmonic sound was louder than the second aortic sound and vice-versa, each for 39.7 percent of the silicotics. It is apparent, therefore, that in the present survey no correlation was found between silicosis and the relationship of intensity of the second aortic and second pulmonic heart sounds.

Table 15.—Distribution of miners with nodular silicosis, uncomplicated with pulmonary tuberculosis, according to relationship of intensity of second aortic to second pulmonic heart sound.

Relationship of intensity of A_2 to P_2	Nodular and conglomerate silicosis	
	Number	Percent
$A_2 > P_2$	29	39.7
$A_2 = P_2$	15	20.6
$A_2 < P_2$	29	39.7

Pulmonary Tuberculosis

The relationship of silica, dust inhalation, and of silicosis, to pulmonary tuberculosis is amply discussed in the literature (24, 25, 26, 27). Suffice it to say at this time that pulmonary tuberculosis generally occurs with a relatively high frequency among persons exposed to the inhalation

of silica-bearing dust, and among silicotics pulmonary tuberculosis generally runs a course that is different from that of non-silicotics.

In the present survey there were 61 miners, or 18.6 percent, who had roentgenographic evidence of pulmonary tuberculosis, in part confirmed by clinical data. Classifying these cases by extent of involvement, according to the criteria of the (United States) National Tuberculosis Association (28), it was found that 27 of the 329 mica miners, or 8.2 percent, were incipient cases; 21, or 6.4 percent, were moderately advanced; and 13, or 4.0 percent, were advanced cases. Dividing them according to their clinical activity or inactivity, based upon the characteristics of the X-ray shadows, as well as upon clinical data which included a single examination of the sputum specimen, it was found that of the 61 cases of pulmonary tuberculosis 40, or 66 percent, were clinically active, and 21, or 34 percent, were inactive.

These frequency rates are very high. Ukil (29) cites figures for unselected population groups of 2 to 5 percent for urban areas, 1 to 2 percent for semi-rural areas, and 0.5 to 1.0 percent for rural areas. Ukil also quotes data from two tuberculosis surveys among industrial workers in the Calcutta area in which incidences of 4.3 and 7.0 percent were the rates found. In a recent survey which was made by the Chief Adviser Factories of 158 chromite and magnesite miners in the State of Mysore (30), and in which the techniques used were the same as in the present survey, a rate of 0.7 percent was found for pulmonary tuberculosis. In that survey the exposure to silica dust was of a very low order or magnitude.

In the present survey a correlation was found between degrees of pulmonary fibrosis and incidence of pulmonary tuberculosis. Of the 61 cases of tuberculosis, 39, or 64 percent, also had nodular or conglomerate silicosis. Since it had already been shown that there is a statistically valid correlation between dust exposure in this survey and the incidence of pulmonary fibrosis, it may be concluded that there is also a correlation between dust exposure and the frequency rates for pulmonary tuberculosis.

Other Medical Findings

Eyes and Ears

Corneal opacities were found in only three miners, or 0.9 percent. No case of corneal pitting was observed. Defective hearing was a complaint for eight persons, that is in 2.4 percent.

Cardiac Findings

Based upon the medical histories and the single examinations, as well as upon the size and configuration of the roentgenographic cardiac shadows, determination was made as to the presence or absence of heart disease. Such disease was found in two persons, a frequency rate of 0.6 percent. In both, who showed no signs of congestive heart failure, the etiologic type was considered to be rheumatic heart disease.

RECOMMENDATIONS

It is recommended that:

1. Only wet drilling be permitted pending an investigation of the reasons for the ineffectiveness of the dust traps. Wet drilling should be done with a minimum flow of water through the drill of 0.6 gallons per minute, the water being turned on before the air to the pneumatic drill.

2. Wet drilling in excess of four hours per day per driller should not be permitted unless sufficient mechanical ventilation, either exhaust or forced, is provided to reduce the dust concentration during drilling to below 5 mppcf.

3. After blasting and completing the examination for unfired shots, the face, walls, roof, and floor of the working, and the loose rock at and near the site of blasting should be thoroughly wetted.

4. There should be an interval of several hours, between the time of wetting down the section blasted and the loose rock and the time that scalers, mica selectors, and muckers are permitted to enter and begin work in the section.

5. Hand drilling should not be done without providing sufficient mechanical ventilation to maintain a dust concentration below 5 mppcf in the breathing zone of the workers.

6. A medical control programme should be considered which should include periodic chest X-rays for selected groups of mica miners.

SUMMARY AND CONCLUSIONS

A survey of the problem of free silica exposure and silicosis in mica mining in Bihar is reported. In the survey medical examinations were made of a representative sample of 329 miners, including chest roentgenograms on 11 × 14 inch films. The chemical nature of the rock dust, as well the enumeration of the degree of dustiness of the mining operations, was determined. The following significant observations were made:

1. The rock dust to which the miners were exposed varied in silica content from 11 percent to 67 percent, with a median of 42 percent.

2. The degree of dustiness varied from one occupation to another, and was highest (an average of 800 mppcf) for pneumatic drilling done with no dust control measures, and lowest for wet drilling (an average of 7 mppcf).

3. Nodular and conglomerate silicosis was found in 34.1 percent of the miners examined, and was directly associated with the degree of dustiness of the occupations as well as the duration of time that they had worked at those occupations.

4. Pulmonary tuberculosis was found in 18.6 percent of the miners.

A series of recommendations is made which will materially assist in minimizing the hazard of pulmonary disease in mica mining.

ACKNOWLEDGEMENTS

This survey would not have been possible without the assistance and co-operation of many individuals, agencies, and groups. We are indeed grateful to all of them. Our thanks go to Mr. N. Barraclough, Chief Inspector of Mines, and his staff, especially Inspector of Mines, Mr. S.S. Prasad, for their continued active co-operation in arranging for the workers' examinations and mine visits. We wish to thank Mr. R.S. Misra, Coal Mines Welfare Commissioner for his help. For the facilities necessary to make the medical examinations, we are grateful to Dr. S. Prasad of the Kodarma Hospital and to Dr. H.C. Chatterjee of the Railway Collieries Hospital, Giridih. Dr. K.S. Krishnan of the Coal Mines Welfare Hospital, Dhanbad, kindly lent us the portable X-ray unit that was used for the survey in Kodarma. Our thanks are also due to Prof. M.S. Thacker, Director, Indian Institute of Science, Bangalore for providing us with the necessary laboratory facilities for carrying out the analyses of the rock samples.

The mine owners and managers were all most helpful. We thank especially the officials of the following firms: Chaturam Horilram, S.K. Sahana and Sons Ltd., Nund and Samont Co., Ltd., India Mica Supply Co., Chrestien Mica Industries Ltd., and Jetmull Bhojraj.

Finally, the co-operation of the mica workers themselves, in presenting themselves for study, was most commendable.

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