SILICOSIS AND TUBERCULOSIS

IN

NORTHERN RHODESIAN COPPER MINERS

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INTRODUCTION.

In this thesis the author has undertaken a survey of the incidence of silicosis and tuberculosis in the Northern Rhodesian copper mining industry, with special reference to the occurrence and related problems of the diseases in the native workers who form the bulk of the employees in the industry.

Four mines are included in this survey and an account is given of the rock formation of these mines. A critical review of the methods and value of dust suppression is carried out with relation to the incidence of silicosis in the four mines. The survey includes an account of the clinical, radiological and pathological findings.

The thesis is based on aninvestigation which occupied the two years from August 1948 till July 1950. In addition a special research was made of the radiological, clinical and other records of the Northern Rhodesia Silicosis Medical Bureau from 1943 until the date of commencement of the present investigation and any relevant findings have been included.

Note: (a) Where there are figures illustrating the text, these have been inserted at the end of the appropriate sections.

(b) Many of the terms used in describing mining operations and occupations are peculiar to the country; definitions of these will be found at page 10 of the appendix.

HISTORICAL REVIEW.

Development of Mines.

Northern Rhodesia is one of the foremost copper producing countries in the world. In the past a number of small mines (Mtuga and Bwana Mkubwa and others) were worked but none of these are now working.

The present industry originated in 1923 when the British South African Company was granted prospecting rights in Northern Rhodesia. Geological exploration was instituted immediately afterwards and in 1925 sulphide ores of 5 per cent copper content were discovered at 100 feet. The richest deposits were found at Chambishi, Nkana, Nchanga, Mufulira and Luanshya.

Of these deposits only four, Nkana, Nchanga, Mufulira and Luanshya were developed and all are in production to-day, the mines at the first three places being known by the place names and that at Luanshya being known as Roan Antelope Mine.

In 1931 the price of copper fell to £27 per ton and developing at Mufulira and Nchanga was

stopped..../

stopped. In 1932 Mufulira was re-opened and started developing the same year. Since then Mufulira, Nkana and Roan Antelope have been producing copper steadily and later Nchanga started producing. Production has been continuous apart from a short period when there was a general strike of the Copperbelt miners.

Development of Legislation.

In the late nineteen thirties it was suspected that silicosis was occurring among the mine workers of the four mines. The medical staff of the mines, however, had not at that time recognised silicosis in employees other than in a few known to have contracted it elsewhere before engagement.

Furthermore these Medical Officers drew attention to the fact that the incidence rate of respiratory diseases in general was for employees no higher than for the dependants of employees and the figure as a whole was very low. In 1938, however, in spite of these assurances, a motion in the Legislative Council of Northern Rhodesia called for an official enquiry.

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The Industrial Diseases Committee was appointed and between February 1939 and October 1940, collected preliminary data - composition of rocks mined; nature, number and size of dust particles in the atmosphere of working places; fresh air supplies to and removal of dust from working places; methods in use to control dust production; and X-ray and other medical studies.

This data was submitted to Dr. A.J. Orenstein of the Central Mining Group of the Rand and Dr. L.G. Irvine formerly of the South African Miners' Phthisis Bureau, for their opinions. The eventual report (1940) of the Committee found that the potential risk of silicosis was present; that in view of the relatively short life of the mines, no weight could be attached to the failure up to that time to detect an overt case produced in Northern Rhodesia, and that ventilation and control of dust production were at least reasonably adequate. The Committee reported, however, that before introducing legislation on the lines of that of South Africa, an essential

preliminary..../

preliminary must be a detailed investigation by an expert, including a systematic radiographic and clinical study of African employees with longest service. The South African Legislation is embodied in the following Acts :-

Miners' Phthisis Act, No. 34 of 1911.
Miners' Phthisis Act, No. 19 of 1912.
Miners' Phthisis Act, No. 44 of 1916.
Miners' Phthisis Act, No. 40 of 1919.
Miners' Phthisis Acts Consolidation Act, No. 35 of 1925 (of which there were five Amending Acts).
Silicosis Act, No. 47 of 1946.

The investigation was carried out by Irvine and his first Report was published along with a statement by the Northern Rhodesia Government (1942). In this an assurance by the mining companies was given that "pending the completion of the investigations now being carried out by the Government, any cases of silicosis found to have been contracted on the Northern Rhodesia copper mines would receive compensation from the employing company in the same way as if silicosis had already been scheduled for compensation under the Workmens' Compensation Ordinance".

In his second Report (1943) after studying radiographic and post mortem material from Northern

Rhodesia.../

Rhodesia copper mines, Irvine reported "It is clear from these observations that a definite amount of silicosis is being produced in the Mufulira mine. The silicosis risk is definitely less in the other three mines but the risk cannot be regarded as negligible".

With the definite establishment of the occurrence of silicosis in the Northern Rhodesia copper mines, a demand was made for compensation and medical arrangements analogous to those of South Africa.

A report by Haslam (1943) gave an account of recommended action to be taken by the Northern Rhodesia Government in view of the discovery of Irvine.

In 1943 the Northern Rhodesia Government appointed a Committee to study these recommendations and, based on the Report (1944) of that Committee, there was presented to and passed by the Legislative Council in 1945, the Silicosis (Temporary Arrangements) Ordinance. This was essentially a temporary measure to meet immediate need.

This Ordinance of 1945 worked well but in the light of experience three amending Ordinances were

enacted...../

enacted, (1945, 1946 and 1947).

Finally with a view to adding the authoritative guidance of disinterested experts to local experience, a Commission was appointed in 1949 to advise the Government on the "Nature and form of legislation best suited to Northern Rhodesia". Its recommendations with one major modification were accepted by Government and the Bill was presented to Legislative Council in 1950.

AETIOLOGY.

Pneumoconiosis is a broad term denoting fibrosis of the lungs as a result of the inhalation of dust. Silicosis is a particular form of pneumoconiosis due to the inhalation of dust containing silicon dioxide. It occurs throughout the world and there is no known racial immunity. It is the most serious of all occupational diseases and its existence has been known to man, although not fully appreciated, for hundreds of years.

In Britain in the nineteenth century the disease was generally attributed to the unhygienic conditions to which miners were exposed but some appreciated that "miners' phthisis" was due to the inhalation of dust and some too, recognised that different underground occupations were more dangerous than others as far as rapidity in development of the disease was concerned. Another advance at this time was the appreciation of the distinction between the disease known as "miners' phthisis" and pulmonary tuberculosis. Our present knowledge of the aetiology of silicosis is

founded...../

founded on the studies in the industries where the disease is prevalent. One of the early investigations in Britain was that of Haldane (1904). He investigated the health of Cornish tin miners which was causing considerable anxiety at that time. In his report Haldane definitely ascribed the disease to the inhalation of dust derived from the rock mined.

Some years later Collis (1915) in a review of pneumoconiosis stated that free silica was the causative agent in the production of pulmonary fibrosis. Later workers set out to prove how the injurious silica acts. Mavrogordato (1929) following the work of his master Haldane made a valuable contribution to the study of the aetiology of silicosis.

The original view held was that the injurious effect of silica particles was by direct mechanical irritation but before proceeding to a consideration of the other theories of the mode of action of silica it might be an opportune moment to summarise our present knowledge of the aetiological factors of the disease. This knowledge is based on the observations of many workers in silicosis-producing industries.

From...../

From an investigation of the mineral residues from the lungs of deceased silicotic miners in the Rand McCrae (1913) showed that seventy per cent of the dust particles in such lungs were one micron or less in diameter. Similarly, Gardner (1937) and Kettle (1934) showed that the intensity of the reaction is in inverse proportion to the size of the silica particles.

From the work of these and many others who have described the disease in other silicosis-producing industries we have arrived at our present state of knowledge of the aetiology of the disease which may be summarised as follows :-

a) Silicosis is caused by the specific action on the lung tissue of silicon dioxide in the free state.

b) It has been shown conclusively that the incidence of silicosis varies directly with the extent of the dust concentration, the percentage of free silica in the dust and the length of exposure.

c) Following on the above it may be stated that with exposure below certain levels of

concentration...../

concentration of silica-bearing dust, even after prolonged exposure, the risk of developing silicosis is negligible. The safety or otherwise of the levels of dust concentrations varies with the percentage of silica present.

d) Particle size is of extreme importance in determining the amount of dust which gains access to and penetrates the alveoli. It has been generally accepted that the dangerous range is from 10 microns downwards, but it is now known that those between 5 and 10 microns are invariably removed in the respiratory tract. The most active particles are those of 2 microns and less. This is well exemplified in certain industries and processes in industries where the risk of silicosis is low although the free silica content of the dust is exceedingly high but the size of the particles is 10 microns or more. In the rock crushers in the copper mining industry here, such conditions prevail, yet there has not been a single case of silicosis even after

prolonged...../

prolonged exposure at this occupation.

e) It is now recognised that the activity of the particles is increased where the particles are freshly fractured.

f) Infection, especially tuberculous infection, is a most important factor in determining the advance of the disease.

Some of the above points are well illustrated in the industry here for it is found that at Mufulira where the silica content of the dust is high and where at one time the dust concentration was highest, the period of exposure required to produce silicosis was considerably less than at others of our mines.

These then are the established facts in the aetiology of silicosis. It is known that it is the minute particles of free silicon dioxide which gain access to the alveoli and produce pulmonary fibrosis, but what has not been proven is the mode of action of these silica particles.

As...../

As has been stated the original idea was that the damage was caused by the mechanical irritation of the silica particles. There followed the work of Gye and Purdy (1922 and 1924) and Gye and Kettle (1922) who suggested that the action of silica in the lung tissues is a chemical one. In these works the solubility theory was advanced in which it was shown that the silica dissolves in a colloidal form in the alkalis of the lung fluids and is then absorbed and acts as a tissue poison. As a result of this toxic action the phagocytes lose their phagocytic properties and their ability to deal with the tubercle bacillus. Although the solubility theory was generally accepted there were dissenters, notable among these being Heffernan and Green (1928).

Kettle (1932) further advanced the solubility theory by showing that where silica had a protective layer of iron, thus rendering the silica incapable of going into solution, it lost its toxic action. In 1939 Denny, Robson and Irwin showed that powdered

metallic.../

metallic aluminium can overcome the toxicity of silica in that it develops a coating of aluminium hydroxide thus rendering the silica insoluble.

King (1945), however, suggests that the solubility theory does not explain the problem fully, for he states it does not always work in practice. Again, in 1947 he states that the toxic substance is considered to be silicic acid and the toxicity of any stone dust would depend on its ability to release silicic acid. Again, however, he points out that this is not always the case.

Heffernan (1948) does not support the chemical theory and believes that the essential agent in the causation of simple silicosis is the freshly cloven silica particle and that the pathological process basically consists of the hydration of the silica particle at the expense of the cell protoplasm. He believes that the coating of silica particles

with...../

with powdered aluminium by Denny, Robson and Irwin rendered the particles inert not by reason of their being less soluble, but because the surface valencies of the silica particles were satisfied.

Policard (1947) states, "The surface of a dust particle which has been weathered is covered with molecules which have become unable to alkalinize their environment and unable to produce degeneration of protoplasm". He quotes the desert sand of North Africa which contains ninety per cent silica yet is pathologically inert.

King (1945) on the other hand found that dust kept dry for a period of years still retained its pathogenicity. Heffernan, in a personal communication this year states his belief that the central ideas stand, (1): that it is the freshly pulverised quartzite which is active and (2): that the explanation of this is to be found in the atomic

lattice..../

lattice structure of the mineral.

These then are the theories. In my experience here, as will be shown later, the greatest risk of the production of simple silicosis is in the occupations where the silica particles are freshly fractured.

METHODS OF OBSERVATION.

I. Organisation and daily working of the Silicosis Medical Bureau.

From 1943 until 1945 the work of the Bureau was carried out by members of the general health services. In 1945 a specialised staff was appointed and the nucleus of the Bureau formed. The work of this staff was done under difficult circumstances in a temporary building unsuited for the specialised work. Now, however, a new building has been built by the Northern Rhodesian Government. There are two main divisions of the building - administrative and medical. The building has separate entrances and waiting rooms for Europeans and Africans and photography room, X-ray room, change room, weighing hall and medical examination rooms are duplicated so that it is possible, if necessary, for a continuous stream of examinees of both races to be dealt with simultaneously.

The administrative area, in addition to the usual offices and library, has a records room which has floor space and filing facilities for clinical records and radiographs for the next twenty years.

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This part of the building has been so designed that the records room could be extended if found necessary.

On the medical side there are the usual offices and well equipped doctors' examination rooms. There is a photographic department where reduction X-ray prints and photomicrographs are made. The X-ray department has two units and one screening unit and a dark-room equipped with two processing units.

There is also a well equipped pathological laboratory where microscopic and macroscopic lung sections according to the Gough (1949) technique are prepared. An additional laboratory deals with urine examinations, blood and sputum investigations. An animal house for experimental studies is to be built shortly.

The administrative arrangements include a statistical section. The medical staff consists of a chairman, medical specialist and five medical officers, to be increased to seven. In the ancillary medical staff there are two radiographers and a

pathological...../

pathological technician. In addition there are trained African processing assistants, microscopists, etc.

In the case of all miners in employment and of all candidates for engagement presented by the mining companies, the names of those coming for examination are notified twenty-four hours in advance, which permits us to have ready, when the men come, the necessary new papers for those coming for the first time and the previous records of those examined before. Approximately 120 examinations are done each day - 15 Europeans and 105 Africans. When the Bureau fulfils its full statutory duties at the beginning of 1951 the approximate total number of yearly examinations will be 45,000. The majority of these are routine annual examinations. The remainder are suspect cases who may have as many as four examinations a year. The apparent discrepancy in the large numbers of examinations compared with the smaller total labour force of the mines is explained by the large annual turnover of native labour. Miners are collected from the various mines by motor bus and arrive for examination at 8 a.m. each morning. The days of examination of miners from the different mines are staggered to ensure that production is interfered with as little as possible.

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In the case of examinations for first engagement (initial examinations) a new clinical history sheet is prepared, which before it comes to the medical staff, contains the detailed occupational history. In the case of periodical examinations a further clinical history sheet is added to the existing file, and this "continuation" sheet contains the occupational history since the last examination. Certificates are prepared and are signed by Europeans and thumb-printed by Africans. Each miner is then photographed by a special camera which incorporates the official Bureau number, the date and the signature of the European or the thumb-print of the African. The completed photographs are affixed to the respective certificates by the dry-mounting process which makes it impossible to remove and change the photograph for the purpose of impersonation.

The miner then passes to the X-ray room where he hands the radiographer a slip showing his official number which, with the date, is photographed on to the film simultaneously with the taking of the radiograph. On completion of the X-ray exposure the miner then passes to a weighing hall where his height, weight and chest measurements are recorded in his clinical history sheet.

Finally...../

Finally, he passes to the medical officer for examination.

I make a preliminary reading of the wet radiographs and suspect cases are referred for special examination such as screening, sputum examination and estimation of the erythrocyte sedimentation rate, etc.

By the afternoon the radiographs are dry, marked and ready for reading which takes place at 2 o'clock. The whole medical staff are present and the radiographs are read in conjunction with the clinical findings.

Employers are notified regarding the results of these investigations; tuberculosis is reported on the day of discovery to prevent the infected worker doing any further work.

II. Initial Examination.

It is now a condition of employment in the Copperbelt Mines that all persons both European and African, who are prospective miners must hold a valid Initial Certificate from the Northern Rhodesia Silicosis Medical Bureau. This certificate is issued after X-ray and clinical examination, provided the examination shows the person to be, "free from any disease

of..../

of the respiratory orgáns and in all respects physically fit for work as a miner". No miner can continue in employment or be re-engaged as such after expiry of his initial certificate (one year) unless, on re-examination, he is granted a Periodical Certificate for the issue of which he must be found free from tuberculosis and from silicosis in the third stage. Periodical Certificates are valid for one year, after which re-examination for a fresh Periodical Certificate is obligatory.

The holder of an expired Initial or Periodical Certificate, however, is allowed a period of grace of two years to renew his certificate provided he is not employed as a miner during that period and provided that at examination he is found to be free from tuberculosis and from silicosis in the third stage. After that period of grace, the certificate becomes finally invalid and its holder cannot resume mining without obtaining a fresh Initial Certificate, for which the much higher medical standard quoted above is necessary.

A miner on discharge and who has not been examined clinically and radiologically within six months is fully examined again.

The standard of fitness required by the

initial..../

initial examination of prospective miners is high. It is such, primarily to exclude from underground and scheduled surface employment, all those who are unlikely to be able to stand up to such employment. This is done in the interest of the man himself and also in the interests of employers to whom an unsuitable man would be a needless liability.

At the thousands of examinations carried out on Europeans, approximately 30 percent are rejected permanently at initial examination. The percentage of natives rejected is much less. This is not due to their standard of physique being higher than that of the Europeans but is due to the fact that they undergo a preliminary examination by the mine medical staff who eliminate all unsuitable candidates and only those considered fit are presented to the Bureau for examination and also to the fact that among European candidates for mining employment the proportion of older men with considerable mining service elsewhere is much higher than among native candidates. The initial certificate is issued on the following being fulfilled:-

1. A normal thorax on X-ray.
2. Sound constitution.
3. Healthy naso-pharynx - mouth breathers are invariably excluded.

4..../

4. Normal healthy chest with good expansion - $2\frac{1}{2}$ inches or more.

5. Age 18 - 40. These are not hard and fast limits but this is normally the age group from which candidates are accepted.

6. Absence of any obvious disabling disease e.g. cardiac, renal, nervous disorders, etc.

7. Approximately of standard weight for height. Rigid adherence to height-weight ratio is not practicable, for the small wiry man may be much below standard weight and yet fit in every way. Similarly with the very muscular man, he may be overweight yet absolutely fit and suitable for employment in a scheduled occupation.

8. Hearing and visual acuity of normal standards or slightly below normal.

Two extreme groups of constitutional make up are recognised :-

a) Pyknosomatic: This type is small and thick-set with broad shoulders and short thick neck and a tendency to obesity. Chest expansion is usually below normal and breathing mainly abdominal.

b) Leptosomatic: This group is at the other

extreme.../

extreme from the pyknosomatic group. They are usually tall and angular with a narrow, poorly developed chest and bad posture. They often have an unhealthy pallor of the skin. They are invariably underweight and muscularly under-developed. X-ray of the chest often shows old healed or latent tuberculous foci. The heart is narrow and their susceptibility to tuberculous infection is great. This group too is unsuitable for underground employment.

Between these two extreme groups are found the most suitable types for underground employment. They are well proportioned, of average height and weight and constitutionally robust. The chest is well developed and chest expansion good.

III. Periodical Examination.

Every miner employed as such has to undergo a periodical examination both clinically and radiologically every year or at shorter intervals if the Bureau thinks fit. When a miner is suspect then the Bureau has the power to call him for re-examination at much shorter intervals, e.g. three monthly. In

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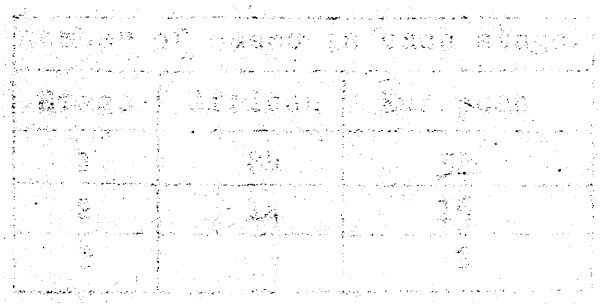
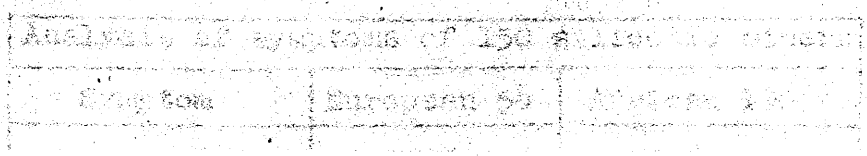
this way silicosis and tuberculosis are diagnosed in their earliest stages and anyone found to have tuberculosis or silicosis in the third stage is not allowed to continue work underground. First and second stage silicotics have the option to continue or stop work underground as they wish.





CLINICAL SURVEY.

These findings are based on the examination of many thousands of underground workers on the four mines and in particular on the repeated examination of one hundred and fifty unselected cases of silicosis (fifty Europeans and one hundred Africans). All stages are included and the distribution is given in Table I.

Table I.

Number of cases in each stage.		
Stage	African	European
1	84	32
2	14	16
3	2	2

The results of the survey are given in Tables II and III.

Table II.

Analysis of symptoms of 150 silicotic miners		
Symptom	European 50	African 100
Dyspnoea	90%	59%
Pain	4%	8%
Cough	70%	53%
Haemoptysis	Nil	Nil
No symptoms	6%	20%

The development of symptoms in silicosis is gradual and is modified if tuberculosis is present. Meiklejohn (1948) aptly expresses it in these words : "In uncomplicated silicosis the patient is distressed rather than sick whereas when tuberculosis supersedes, toxic manifestations appear, and the workman is soon sick and in declining health".

A. Symptoms.

(1) Dyspnoea. This is the most common symptom as shown by the above table. Amor (1943) considers that dyspnoea in simple silicosis is caused by :-

(a) Fibrous replacement of the lung tissue.

(b) Pleural thickening and adhesions limiting lung expansion.

(c) Development of emphysema.

Probably the main factor in the causation of dyspnoea is the presence of emphysema.

Robertson (1949) considers that some of the dyspnoea in early pneumoconiosis is due to bronchospasm and, using the iso-propyl derivative of adrenalin, he claimed improvement in forty-four out of fifty-eight colliers complaining of breathlessness.

It is significant that of the thousands of miners on the Copperbelt who have a diffuse pulmonary fibrosis, many do not complain of breathlessness and

many.../

many more who do, complain only of a very slight degree of dyspnoea. The extreme breathlessness associated with gross clinical emphysema of the collier of Britain, described by Hart and Aslett (1942) and which one has seen often in the miners of the Scottish coal fields, is rarely seen here.

One has frequently seen African miners with first stage silicosis who had no dyspnoea whatsoever and many more who had only a slight degree of breathlessness on exertion.

In correlation with this one rarely sees the typical barrel-shaped emphysematous chest. Gross or even pronounced emphysema is not a feature of the silicotic on the Copperbelt and hence resultant dyspnoea is not so marked as, say, in the coal miner.

In seeking an explanation for this there is one outstanding and significant item. An examination of the incidence of disease in general among the miners of the four mines, showed that the incidence of diseases of the respiratory tract, excluding pneumonias, was very low. This may be attributed to the excellent climate which we enjoy here. The coal miner of Britain, with its cold wet climate, suffers from respiratory tract infections, whereas such intercurrent

infections.../

infections are not nearly so common here. Bronchitis in coalminers with pneumoconiosis is common in Britain but not so on the Copperbelt. Bronchitis is an important factor in the production of emphysema and resultant dyspnoea ; even mild attacks greatly increase the degree of dyspnoea.

Gough (personal communication) does not believe that the explanation of focal emphysema is a climatic one and states that he has noticed a marked difference in the degree of emphysema in the pneumoconiosis due to coal, from that due to dust with a high silicotic content. He believes that this may be related to the position of the foci in respect of their mechanical interference with the respiratory mechanism.

This absence of focal emphysema is illustrated in the section illustrating the pathology of the classical silicosis encountered here. Generalised fine emphysema is present but there is no evidence of gross focal emphysema.

To sum up, dyspnoea on exertion is a fairly constant finding in silicotic European Copperbelt miners, but is not so common among similar African miners and the degree is less than described elsewhere. It is also very common to find miners in the

first..../

first stage of silicosis with no respiratory impairment whatsoever - this applies especially to the African miner.

(2) Pain. Chest pain was complained of by only a very few of the men examined. There was no definite localisation of the site. Mostly the pain was vaguely retrosternal but the bases of the lungs too were implicated. The few who did complain of chest pain stated that it was intensified by coughing and deep inspiration. The pain too was never constant, but intermittent. The pathological basis of this chest pain is probably explained by the occurrence of dry pleurisy and by the presence of pleural adhesions.

(3) Cough. Cough was complained of by 70 per cent of Europeans and by 53 per cent of the Africans. The cough of the silicotic is typical in that it is "dry" and unproductive. It occurs most frequently in the morning and in few of the cases under review was it accompanied by anything more than a little mucoid sputum.

(4) Haemoptysis. Haemoptysis in an uncomplicated case of silicosis was never observed. When seen, tuberculosis was always present. Occasionally, miners suffering from silicosis have observed a little blood streaked sputum after a particularly heavy bout of

coughing.../

coughing.

(5) Psychotic Symptoms. Recently there have been described neuro-psychiatric symptoms in silicosis. Included in these have been mentioned, lack of concentration, loss of initiative and emotional instability.

Such findings have not been experienced here. On the contrary it has been observed that miners suffering from silicosis tend to treat their condition lightly and in all ways are emotionally stable and mentally normal and only on rare occasions does their knowledge of having contracted the disease worry certain individuals. Even in such cases, none of the gross symptoms noted above has been observed.

Table III.

Analysis of the signs of 150 silicotic miners		
Signs	African 100	European 50
Diminished chest expansion	95%	90%
Alteration in breath sounds	50%	57%
Adventitae	16%	25%
Other signs, e.g. clubbing of fingers	Nil	Nil
No signs	3%	5%

B. Physical Signs.

The physical signs in silicosis are often extremely difficult to determine and there are none which are specific of the disease. In early cases of silicosis it is sometimes quite impossible to elicit any abnormality of the lungs on physical examination. This is the view also of others - Amor and Evans (1934).

(1) Diminished Chest Expansion. Diminution of chest expansion was present in varying degrees in 90 per cent of Europeans and 95 per cent of Africans. As the disease progresses the expansion of the chest gradually decreases and expansions of less than one inch are not uncommon. This diminution of the chest expansion was found to be the most constant physical finding. The final appearance of the "fixed chest" of the advanced case of silicosis is typical - the chest wall is rigid - the whole chest wall appears to move as one piece. Where emphysema is present the same appearances are manifest but in addition the chest is barrel shaped.

(2) Diminished Air Entry - Alteration of Breath Sounds. Diminished air entry is common and the normal inspiratory-expiratory ratio is altered, the inspiratory murmur being shortened and the expiratory murmur prolonged as a result of the diminished elasticity of the lungs.

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At the same time there is diminution in the volume of the inspiratory phase.

Although the inspiratory murmur may remain vesicular there are usually quite characteristic alterations in the character of the breath sounds. As the disease progresses the inspiratory murmur develops a harsh high pitched quality and in late stages it may become almost inaudible. The prolongation of expiration does not alter.

(3) Adventitiae. The typical silicotic chest is "dry". Occasionally one hears basal ronchi usually associated with a bronchial catarrh. But, as has been said, intercurrent respiratory infections are not common here and only infrequently are adventitious sounds present. When moist râles are heard then tuberculous infection should be suspected.

(4) Alteration in the Percussion Note. In early cases there may be no appreciable alteration in the percussion note but as the disease progresses generalised impairment may be noted. Where basal emphysema exists a typical hyper-resonant note can be elicited. Gross dullness is seldom noted even in the presence of coalescing silicotic masses.

(5) Clubbing of the Fingers. Clubbing of the fingers

is..../

is very rare in an uncomplicated case of silicosis.

(6) Loss of Weight. In simple silicosis uncomplicated by tuberculosis any appreciable loss of weight was not observed.

(7) Response to Exercise Tolerance Test. A poor response to standard exercise tolerance tests is not common in early silicotics. When the condition is advanced, however, it is impaired.

In the above tables detailed descriptions are presented in spite of the fact that many consider that an analysis of the type and incidence of symptoms elicited from men found to be suffering from silicosis would serve no useful purpose. This is the view held by Caplan (1947). He bases this on the fact that the Indian underground worker is influenced by his hope of compensation. The African miner has not reached this stage and I am convinced that his complaints, if any, are genuine.

(8) Erythrocyte Sedimentation Rate. In order to make an assessment of the value of the erythrocyte sedimentation rate in silicosis an investigation of one hundred healthy African recruits with no mining service and one hundred African miners suffering from silicosis and

infective.../

infective silicosis was carried out.

A similar investigation was carried out on fifty Europeans with silicosis but without controls as the normal average European male value of 5 mm. in one hour (Whitby 1946) was accepted.

The technique described by Westergen (1926) was employed and was as follows :-

0.4 c.c. of 3.8 per cent solution of sodium citrate was drawn into a record syringe; the syringe was then introduced into a vein and blood drawn up to the 2 c.c. mark. This mixture was then drawn up into a Westergen tube and set in the stand. Care was taken to ensure that the tube was maintained in a vertical position. A reading was taken at the end of one hour. No corrections were made. The results of these investigations are shown in Tables IV and V.

Table IV.
Erythrocyte Sedimentation Rate
in 100 African Silicotics.

	Controls	Silicosis	Infective Silicosis
Number of cases	100	62	38
Average E.S.R. reading in one hour	11.4 mm.	15.5 mm.	37.6 mm.

Table V.

Erthrocyte Sedimentation Rate in 50 European Silicotics.

	Controls	Silicosis	Infective Silicosis
Number of cases	-	31	19
Average E.S.R. reading in one hour	5 mm.	7.8 mm.	19.6 mm.

It will be seen from the above tables that the erythrocyte sedimentation rate of the healthy African male is higher than that of the male European. The average value in this series was 11.4 mm. in one hour; the lowest recorded was 3 mm. and the highest 20 mm. This high value of the erythrocyte sedimentation rate in the apparently healthy African is probably due to the fact that he suffers from various chronic and subclinical infections, often parasitic.

In cases of simple silicosis (including all stages from generalised arborisation to large mottling) in Africans the erythrocyte sedimentation rate is usually raised above the "normal" of 11.4 mm. in an hour - in this series the average was 15.5 mm. in one hour. In Europeans,

however..../

however, with simple silicósis it was found that the erythrocyte sedimentation rate was often normal or only slightly raised - in this series the average reading was 7.8 mm. in one hour.

Where silicosis was complicated by infection the erythrocyte sedimentation rate was always raised in both Europeans and Africans - the African value being proportionately higher than the European in accordance with their respective normal values.

The cases of infective silicosis quoted, in the above tables, radiographically all showed areas of massive fibrosis which had developed from discrete mottling in a period of five years or less. They are in fact examples of rapidly progressing silicosis due to the presence of an infective element.

The finding that the erythrocyte sedimentation rate is increased in infective silicosis of rapid progression is similar to the finding of Fletcher (1948) who states that the sedimentation rate is good evidence as to the activity of the lesion. In the most progressive

group...../

group in coal miners (those showing marked progression in less than five years), 86 per cent had an abnormal sedimentation rate of 10 mm. in one hour, or over. Heimann (1946) on the other hand suggests from a study of 65 mine workers that a raised sedimentation rate does not necessarily indicate the presence of pulmonary infection.

It is an interesting feature that the African miner with infective silicosis and associated high sedimentation rate frequently develops tuberculosis.

Although the sedimentation rate has an undoubted value in assessing the presence of infection in silicosis, it should always be associated with other clinical investigations when making such an assessment.

C. Respiratory Disability.

Much has been written on the assessment of and means of assessing the disability in cases of pneumoconiosis, many of them elaborate and involved and not suitable for routine use. For example the method of determination of the ventilation equivalents of oxygen and carbon

dioxide.../

dioxide, as described by Pelnar (1949) is not practicable in routine examination.

The chief disability resulting from pneumoconiosis is breathlessness on exertion or breathlessness even at rest. Cough too can be a disabling factor but the assessment of the disability of those suffering from pneumoconiosis is mainly an assessment of their dyspnoea.

It has been my experience that, in assessing this disability, the tests should be as simple as possible and in making an assessment this should have reference to the patient as a whole and not merely to his respiratory system.

Garrard (1949) in her work on the assessment of vital capacities in miners by the Benedict apparatus concluded that one could not depend on any formula for an accurate assessment of vital capacity loss as individuals differed so considerably. That author suggests that an "impairment" during the course of a dusty occupation is of little value owing to the wide variations in the "expected" vital capacity.

Although..../

Although it is an accepted fact that the X-ray is the chief factor in the diagnosis of silicosis, it has little place in determining the degree of disability. This is illustrated in Table VI below.

Table VI.

Comparison of dyspnoea with the radiological stages of silicosis in 100 African Silicotics.

Radiological stage	Number of cases	Average state of dyspnoea
6	52	1.3
7	25	1.3
8	5	1.8
9	3	1.6
10	15	1.8
All stages	100	-

0 - Normal
1 - Mild dyspnoea on exertion.
2 - Moderate dyspnoea on exertion.
3 - Marked dyspnoea on exertion.

Results were obtained by taking a mean reading of the above stages of dyspnoea. From the above table two conclusions may be drawn: (a) there appears to be no close correlation between the degree of dyspnoea and

the.../

the radiological stage of silicosis and (b) on the whole dyspnoea in African silicotics is considerably less than that encountered in silicotics in other silicosis-producing industries, e.g. coal mining. Gough (1947) believes there is little correlation between radiological progression and progression of dyspnoea.

In this series it was found that in the early stage of silicosis the African miner has often no disability whatsoever, even when X-ray shows a diffuse generalised small mottling. Similarly, in the later stages, there may be fairly pronounced radiological changes with little dyspnoea on exertion and only slight impairment of working capacity. Again, in some cases with generalised arborisation but with no specific radiological signs of silicosis, e.g. in some cases with long exposure in one of the lesser dusty occupations underground, it was found that their dyspnoea on exertion may be considerable. Gough (1947) states "Massive fibrosis is compatible with respiratory efficiency provided the non-fibrosed part of the lung is not emphysematous".

Disability should be assessed after a careful physical examination of the individual, a detailed clinical history, full details of occupation and working capacity.

Included...../

Included in such an examination should be :-

(a) Full clinical examination of the lungs including the measurement of the chest expansion. Where this has been observed over a period of years and comparative figures are available it is of value in assessing disability.

(b) A simple form of exercise tolerance test. The one employed here consists of the man performing twenty genuflexions within a minute. At the end of such exercise the degree of breathlessness is observed and is placed in one of four categories :-

0 = Normal.

1 = Mild dyspnoea on exertion.

2 = Moderate dyspnoea on exertion.

3 = Marked dyspnoea on exertion.

The pulse rate is observed immediately before and after exercise and the time taken for the pulse rate to return to resting rate is noted.

(c) Erythrocyte sedimentation rate.

(d) Sputum examination.

The tendency to-day is to establish complicated procedures for the estimation of respiratory disability. I consider that such procedures lose a great deal of their value if they do not include an examination of the patient as a whole. If this is done and the simple

tests..../

tests quoted above are used, a fair and reliably accurate estimate of the disability can be made. This is especially true if one is not confined to a single examination but has the advantage of making such observations over a period of months or years on the same individual. This gives the added advantage of obtaining a basis for comparison and an intimate knowledge of the patient himself.

RADIOLOGICAL CLASSIFICATION AND STANDARD RADIOGRAPHS.

The radiograph of the chest is the most important factor in establishing a diagnosis of silicosis. As a result, it should be as near technical perfection as it is possible to obtain. It should be emphasised that the radiograph in itself is not sufficient to establish a diagnosis of silicosis; a thorough clinical examination and detailed occupational history are also necessary, but the chest radiograph is undoubtedly the most important single factor in making such a diagnosis and in observing progress of the disease. The radiographic technique in use here is described below.

Two X-ray units are in use, each four valve of 90 K.V.P. by 500 m.a., supplied by General Electric, fitted with C.R.T. 1 - 2 Coolidge rotating anode tube of focal spot 1mm. or 2mm.

Chest exposures are made as follows :-

Projection: Postero-anterior at full inspiration with the tube centred on the 4th or 5th dorsal vertebrae.

Distance: 60 inches. (152cm.)

Focal Spot: 2mm.

Screens: Kodak ultra-speed.

Milliamperes.../

Milliamperes: 350.

Time: 0.1 seconds.

K.V.P: 49/55 according to the thickness of the chest wall.

No filters are used apart from those incorporated in the tube. All the above conditions are kept constant, the only variable being the K.V.P., which varies according to the thickness of the chest wall. In serial radiographs of the same individual, however, the K.V.P., is also kept constant provided there has been no variation in weight since the previous examination. Kodak ultra-speed, code 3 films are used. In addition, if there are any clinical or radiological indications, patients are also screened.

Radiological Classification.

The classical type of silicosis is encountered on the Copperbelt of Northern Rhodesia, and is similar to that seen in the gold mines of South Africa. As a result of this and because the early work of the Northern Rhodesia Silicosis Medical Bureau was done with the co-operation of the staff of the South African Silicosis Medical Bureau, it was decided to adopt their classification - Simson, Strachan and Irvine, (1930).

This classification has been found most

suitable..../

suitable in describing the radiological appearances of pneumoconiosis as it occurs in the copper mines here.

There are ten classifications ranging from a normal thorax to an advanced degree of silicosis. In addition there are further classifications indicating the presence of tuberculosis etc. A copy of the form used is shown in Table I.

TABLE I

Medical Specialist's First Reading	No.	The Radiograph shows :
	1	Normal thorax.
	2	Slight increase in linear striation.
	3	Moderate increase in linear striation.
	4	Well marked increase in linear striation.
	5	Generalised arborisation. Very well marked increase in linear striation.
	6	Generalised arborisation with partial small mottling.
	7	Generalised small mottling.
	8	Generalised medium mottling.
	9.	Generalised large mottling.
	10	Diffuse opacity; slight/moderate/extensive upper/middle/lower RIGHT upper/middle/lower LEFT
	11	Appearances partly/mainly infective in type (i.e. indicative of arrested or latent infection).
	12	Appearances suggestive of tuberculosis of lung RIGHT/LEFT (i.e. suggestive of active tuberculosis infection).
	13	Apparently definite tuberculosis of lung RIGHT/LEFT (i.e. definitely indicative of active tuberculosis infection).
	14	Pleural thickening RIGHT/LEFT.
	15	Pleural effusion RIGHT/LEFT
	16	Consolidation: upper/middle/lower RIGHT upper/middle/lower LEFT. (i.e. not suggestive of tuberculosis, but of pneumonia, neoplasm, etc.)

17...../

Medical Specialist's First Reading	No.	The Radiograph shows :
	17	Peribronchial thickening/Hilus thickening.
	18	Heart asthenic/vertical in type.
	19	Heart enlarged.
	20	Aorta enlarged/Aortic aneurism.
	21	Other changes.....

Note: Numbers 6 and 7 above are the conditions which generally characterise the First Stage of Silicosis; Numbers 8 and 9 the Second Stage; and Number 10 the Third Stage.

Radiographs within normal limits.

The recent work of Lodge (1946), gives an excellent description of the pulmonary vascular markings and it is now generally accepted that the normal pulmonary pattern is produced by the pulmonary vessels.

The normal linear or dendritic shadows radiate from both hila and taper off towards the periphery of the lungs. Variations in the densities of these linear shadows are described in the present classification as increase in linear striation.

Fig: 1 shows a normal thorax, Fig: 2 a slight increase in linear striation and Fig: III a moderate increase in linear striation. It must be appreciated that this increase in linear striation varies greatly, with the radiographic technique even in the same individual,

for...../

for even slight alterations in penetration will alter the appearance of the linear striations, soft films tending to be read higher than hard films. Fletcher (1949), points out the serious disagreement among doctors experienced in reading silicosis films concerning the limits within which a film may be regarded as normal. In his paper ten doctors were asked to classify one hundred and two radiographs into five categories on two separate occasions with an interval of several weeks. The number of films considered certifiable ranged from five to forty-five. A review of the cases applying to the Silicosis Medical Boards during the first half of 1948 showed that twenty-two per cent fell into the class where the opinions of the doctors concerned would differ. Fletcher attributes this to a mental standard of comparison which may be variable and suggests accepted standard films. To obviate these difficulties we have employed a standard penetration and a set standard of films.

It may be that the chest radiographs are over or under read, but the essential of a set standard has been established and the majority of the radiographs are comparable. Comparable serial radiographs are necessary for noting progression of the disease. We have aimed at the production of such radiographs and I think with a

measure of success and within the industry here we produce a film of standard penetration. However, the difficulty of films of varying penetrations is met with here also, for many prospective miners are recruited from South Africa, America, Canada and Britain and the films received from these countries have variations in penetration.

In Fig: III it will be noted that the linear shadows are more numerous and more marked and extend to the periphery of the lungs. In the areas between these, however, the lung fields are clear. Such appearances are not specific of any particular pathological condition and may be seen in chronic bronchitis or advancing age.

Intermediate Stage:

Fig: IV shows well-marked increase in linear striation and Fig:V the next stage, generalised arborisation. The stage of well-marked increase in linear striation is suggestive of early dust disease, but in itself is not diagnostic.

The stage of generalised arborisation represents a further advance in number and extent of the linear shadows radiating from the hila. The hilar shadows are enlarged. This stage of generalised arborisation is

comparable..../

comparable with the stage of reticulation described in Welsh coalminers by Hart and Aslett (1942), but the reticular changes found in the classical silicosis of the Copperbelt, are coarser than the fine changes described in the Welsh coalminers, where the appearances are produced over a long period by the inhalation of mineral dust of relatively low silica content.

It is the South African policy in certain circumstances to diagnosis first stage silicosis in cases presenting a generalised arborisation - Smith (1947). This is based on their knowledge that approximately 50 per cent of such cases at post-mortem have a slight degree of silicosis.

We have not adopted that policy in the Copperbelt for it is considered that, to diagnose the disease during life, the earliest specific signs of discrete nodulation must be present.

Silicosis.

Fig: VI represents the stage of generalised arborisation with partial small mottling and is the first appearance which is specific of the disease, in that it shows the presence of silicotic nodulation.

Figs: VII, VIII and IX show still further

advances...../

advances. Fig: VII represents generalised small mottling. It will be noted that the nodules are discrete and generally disseminated throughout both lung fields. Figs: VIII and IX show generalised medium mottling and generalised large mottling. It will be noted in the above radiographs showing specific nodulation that striation has disappeard.

It should be emphasised that in the various stages discussed above there is no infective element present. Further, in the stages of well-marked increase in linear striation these appearances may be due to diseases other than pneumoconiosis, but when a miner on first going underground presents the radiograph of a normal thorax and subsequently in the course of years underground develops an abnormal increase in linear striation, I accept these progressive degrees as being due to the continued inhalation of silica bearing dust. It must also be stated that it is not necessary for a miner to progress successively through the stages described but it has been my experience that provided infection does not supervene and provided there is a continuation of employment in the more dusty occupations, especially machine drilling, the stage of well-marked increase in linear striation is invariably a precursor

to...../

to generalised arborisation and subsequent mottling. Where, however, there is no such further exposure there is invariably no progression from this stage to recognisable silicosis. This observation is based on the examination of miners who had left mining employment with well-marked increase in linear striation and who have presented themselves up to five years later for "benefits" examination. In only one of these cases had the condition advanced to recognisable silicosis.

In addition it has been observed that in the lesser dusty occupations, the stages of well marked increase in linear striation and generalised arborisation developed over a long period of exposure, frequently occur in miners who do not develop silicosis subsequently. It is considered that the classification described above is eminently suited to the description of pneumoconiosis as it occurs here. It is readily appreciated that such a classification would not be adequate in describing the disease as it occurs in other industries and because of these fundamental differences in the radiographic appearances of the disease in the various industries, it will be difficult to introduce an international classification.

In addition to the above classification the

same..../

same series of radiographs may present (a) massive shadows of progressive fibrosis, (b) frank cavitation or calcification due to tuberculosis. The significance of these findings is discussed later under the section on complications.

The presence of a latent infective element does not materially alter the radiograph until the stage of nodulation is reached. At this stage, however, the nodules are less discrete, larger and of varying sizes and density; this is illustrated in Fig:X (compare with Fig: VIII).

The detailed results of the number of cases in each of the ten stages is given in the chapter on occupational incidence.

Classification of the Stages of Silicosis.

From the scientific aspect the classification approved by the 1930 international conference on silicosis has been adopted. In this classification the stages are sub-divided as follows :-

First Stage.

Symptoms referable to the respiratory system may be slight or even absent. Capacity for work may be slightly or not at all impaired. There may be departure

from...../

from the normal in percussion and in ausculatory signs, and the radiograph must show an increased density of the linear shadows and the presence of discrete shadows indicative of nodulation.

Second Stage.

There is an increase of the physical signs observable in the first stage and the radiograph shows an increase in the number and size of the discrete shadows indicative of nodulation with a tendency to their coalescence. There must be some degree of definite impairment of working capacity.

Third Stage.

All the above conditions are grossly accentuated and indications of massive fibrosis are usual. There is serious or total incapacitation.

As a whole the above classification is suitable also for compensation purposes but it was found that a more general classification was preferable to cover the cases where the radiograph showed specific signs of silicosis but these were minimal and yet were accompanied by considerable impairment or working capacity. In such cases the broader classification detailed below permitted such a case to be certified as, say, second stage silicosis.

A person is certified as having first stage silicosis when the Bureau after both clinical and radiological examination of the person concerned and having regard to the said person's occupational history and to any other factor considered by the Bureau to be relevant, is satisfied that silicosis is present in the lungs of the person in question and that the silicosis is accompanied by no physical incapacity for work or by only very slight incapacity for work which is attributable to the said disease.

A person is certified as having silicosis in the second stage when the Bureau is satisfied as aforesaid that silicosis is present in the lungs of the person in question and also that the silicosis is accompanied by definite and appreciable physical incapacity for work which is attributable to the said disease.

A person is certified as having silicosis in the third stage when the Bureau is satisfied as aforesaid

(a) that silicosis is present in an advanced condition in the lungs of the person in question with radiological evidence of generalised nodulation throughout the lung fields and of massive fibrosis;

and (b) that the silicosis is accompanied by complete

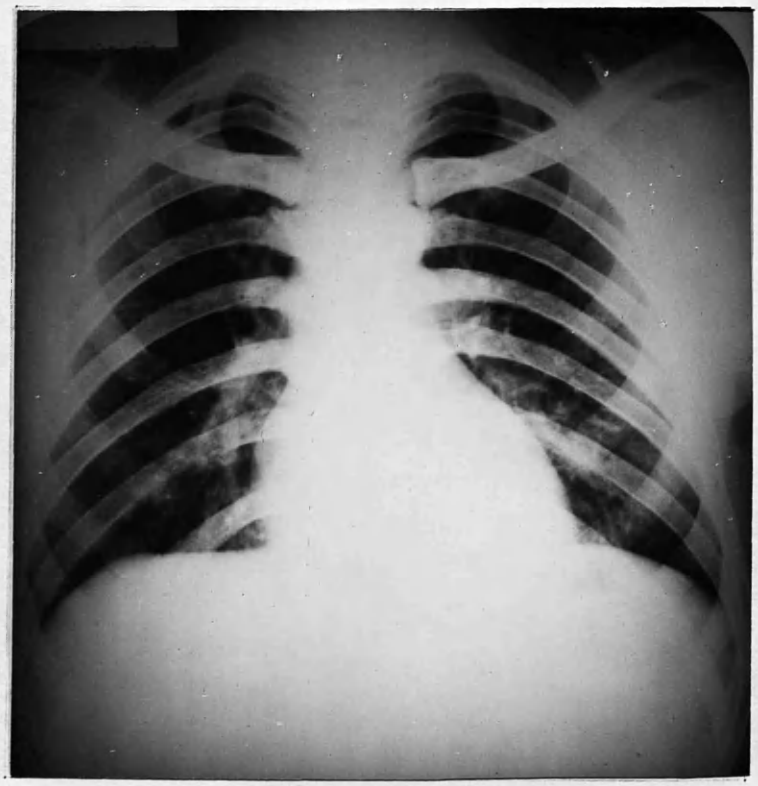
or...../

or serious incapacity for even moderately heavy work which incapacity is attributable to the said disease.

The above classification is broad and elastic and allows a liberal interpretation of the stages, and this is necessary for here we have reciprocal compensation arrangements with South Africa and Southern Rhodesia and in the case of a man with silicosis and with service in all three countries, each authority has to agree to the certification.

Figure I.

Normal Thorax.

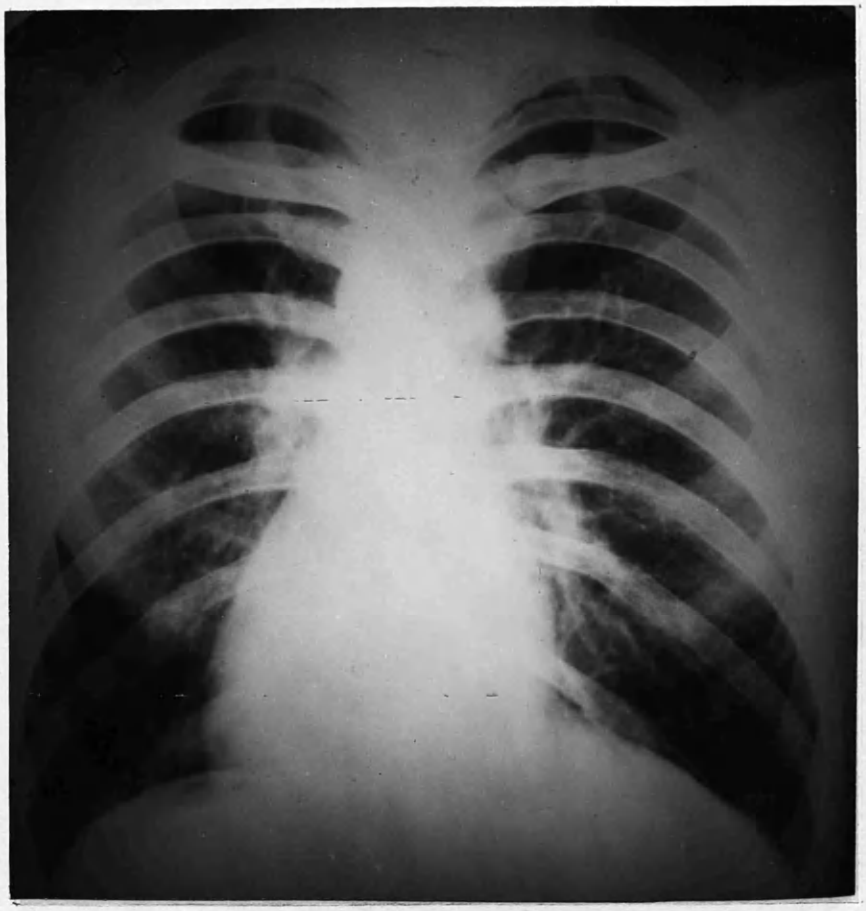


Native recruit with no mining service. The heart is normal in shape and size. There is only slight extension of the dendritic shadows from the hilar areas.

Figure II.
Slight increase in Linear Striation.

European with two years "underground other" service at Nchanga. There is a slight increase in the number and extent of the linear shadows radiating from the hilar areas.

Figure III.
Moderate increase in Linear Striation.

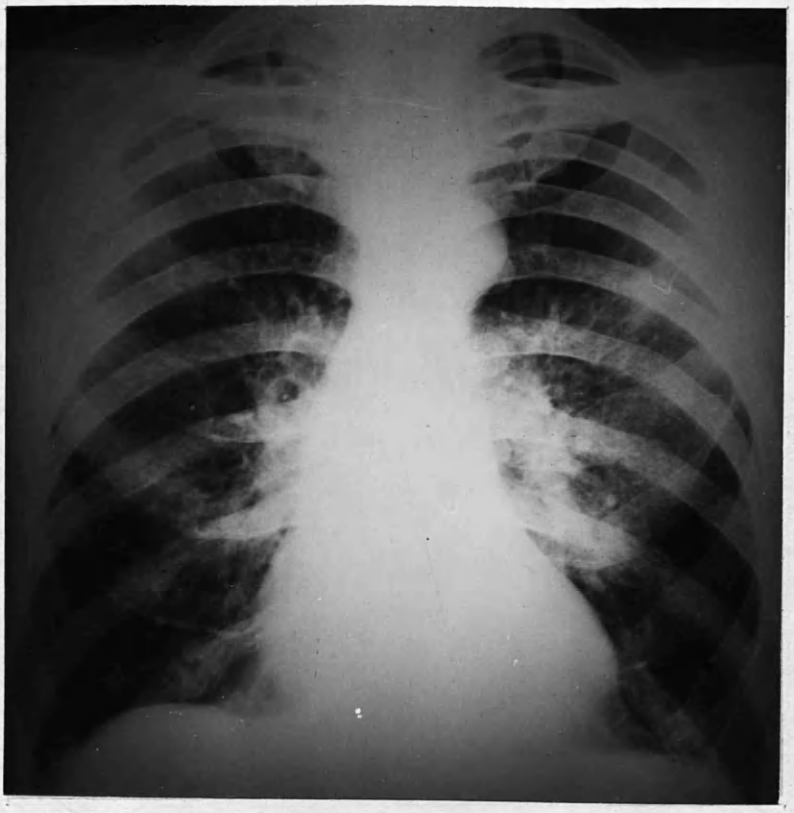


African with three years machine service at Mufulira. There is a moderate increase in the number and extent of the linear shadows extending from the hilar areas. The hilar shadows are slightly increased.

Figure IV.
Well marked increase in Linear Striation.

European with 10 years as underground fitter at Nchanga. This illustrates a well marked increase in the linear shadows which extend from the hilar areas to the periphery of both lungs. The hilar shadows are increased especially on the left.

Figure V.
Generalised Arborisation.

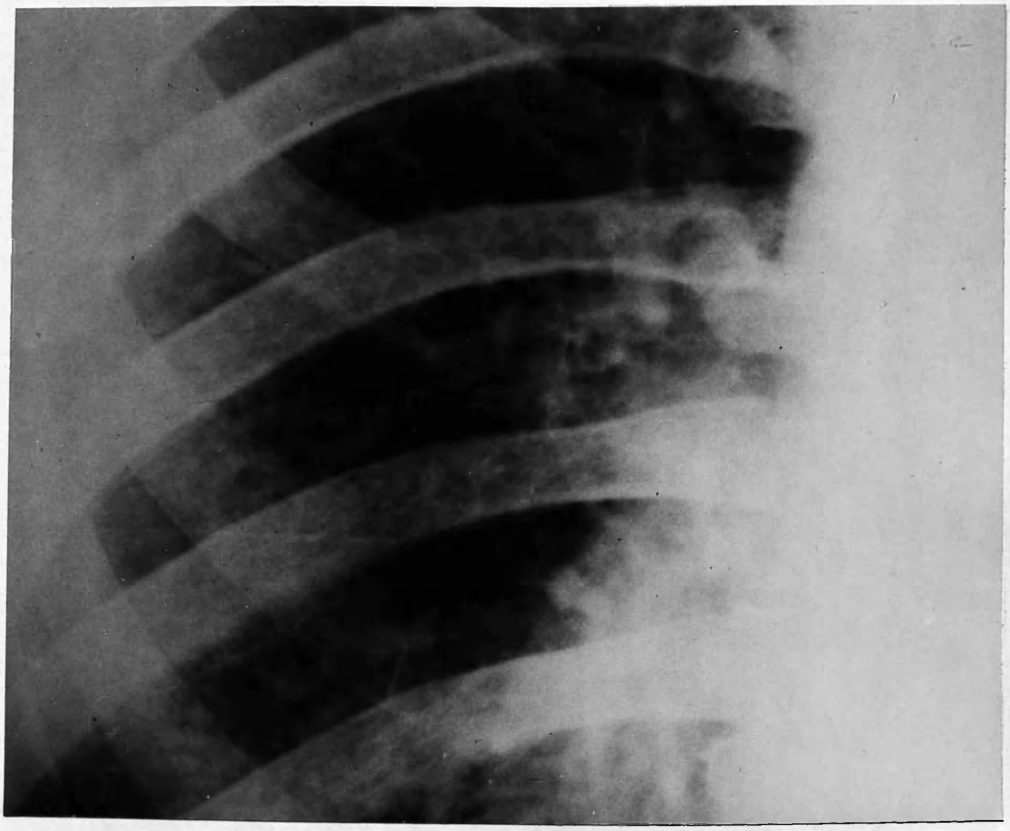


This radiograph is from a European with 15 years machine service at Nkana. Here there is a well marked increase in the linear shadows and both lung fields are occupied by these linear shadows which extend to the periphery of the lungs. The hilar shadows are increased in extent and density.

Figure VI.
Generalised Arborisation
with partial small mottling.

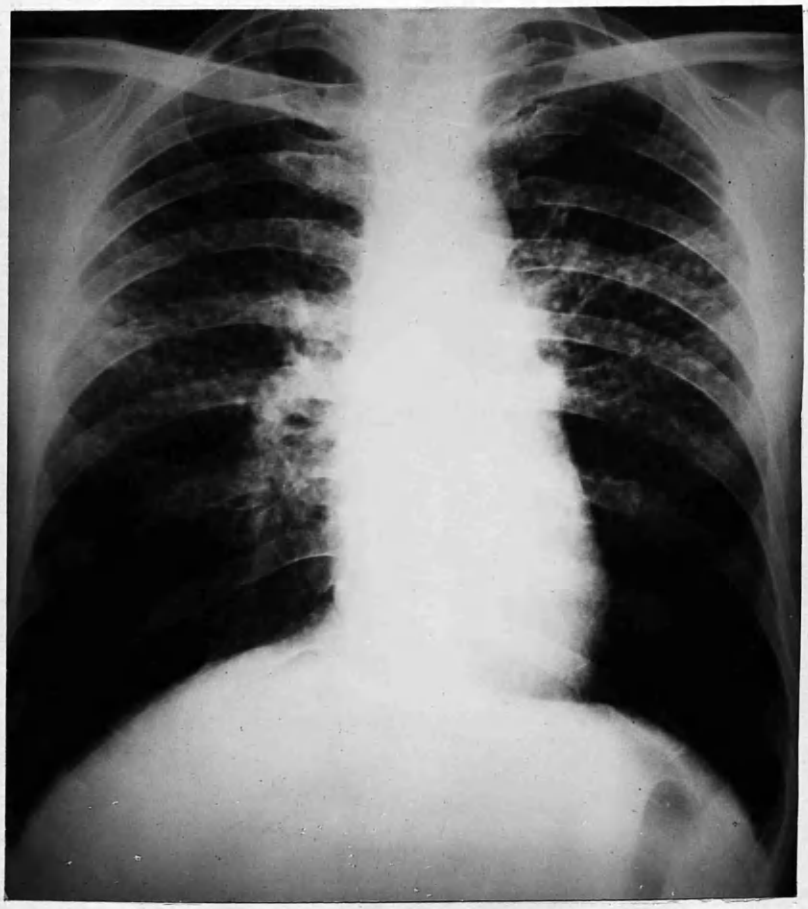
Native with 7 years service underground at Mufulira, the majority of which (5 years) was spent on machines. This is the earliest radiographic appearance diagnostic of silicosis. In the upper and mid zones discrete nodules can be seen superimposed on a generalised arborisation. The hilar shadows are increased in size and density.

Figure VI (a).
Generalised Arborisation
with partial small mottling.



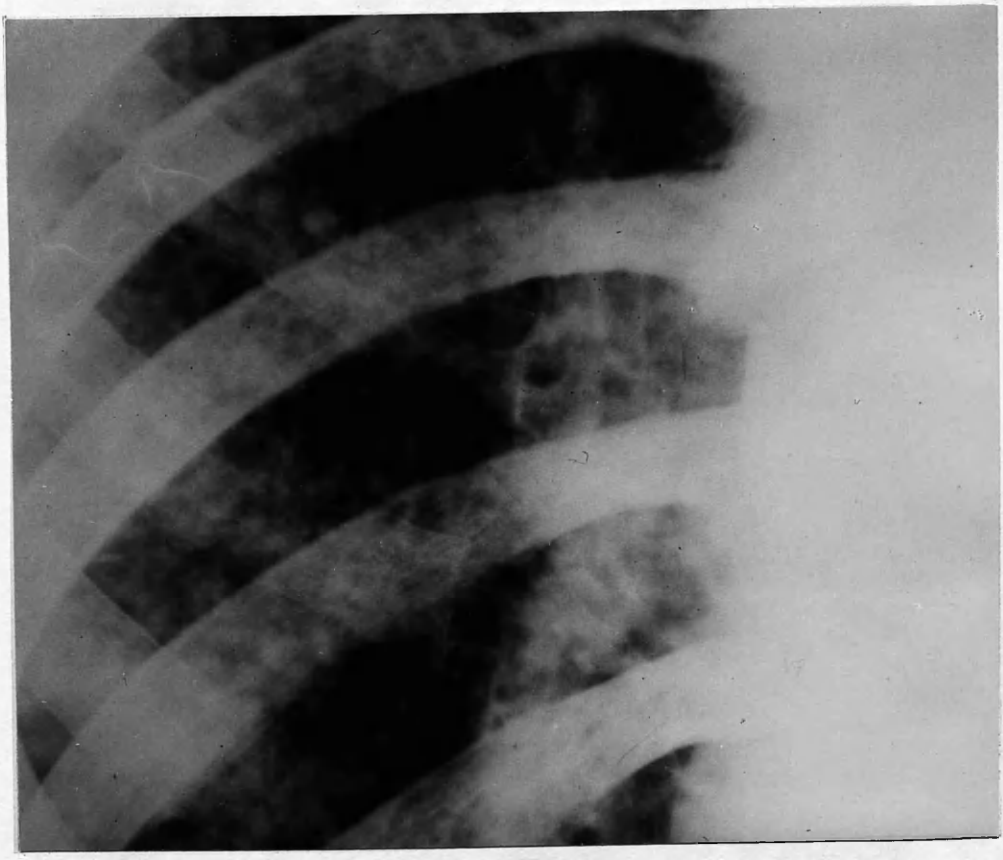
This is a contact print of the right mid zone of Figure VI and shows the fine mottling.

Figure VII.
Generalised small mottling.



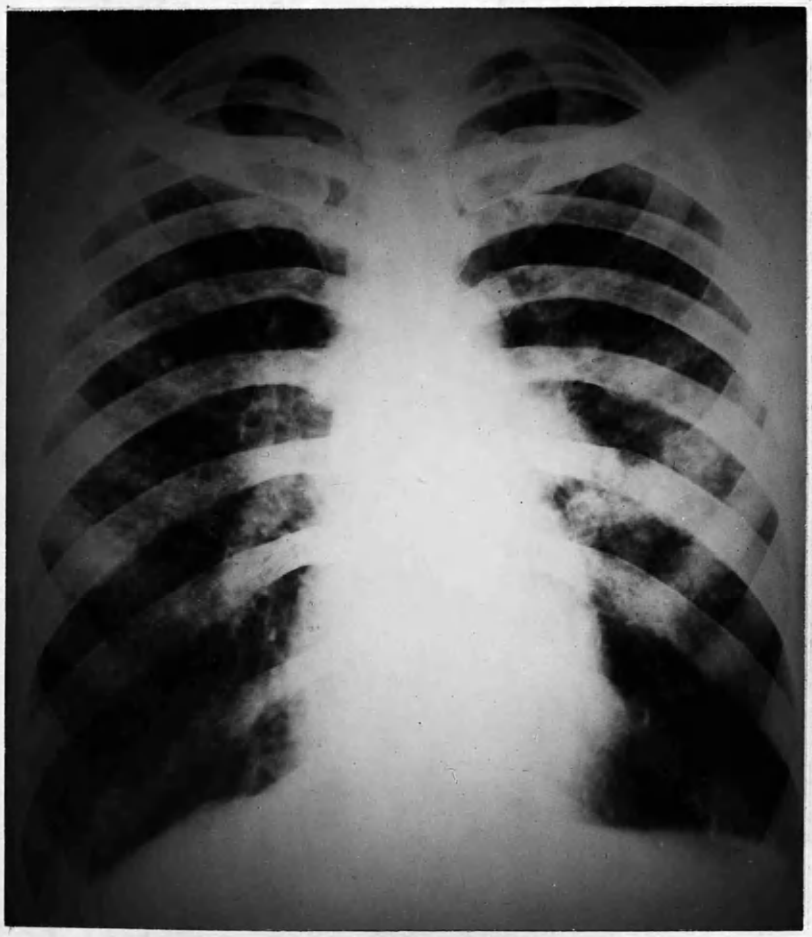
European with 13 years underground service at Nkana and 12 years underground service at Mufulira. Both lung fields are occupied by discrete nodules.

Figure VII(a).
Generalised small mottling.



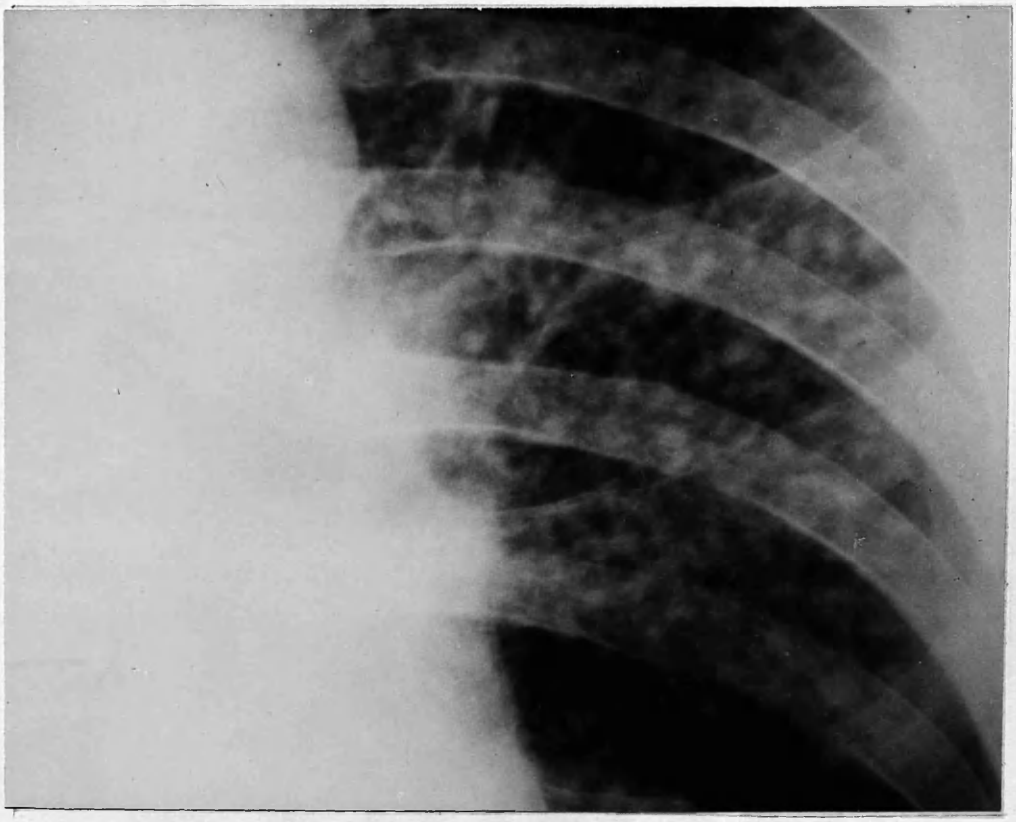
This is a contact print of the right mid zone of Figure VII and shows the discrete nodulation.

Figure VIII.
Generalised medium mottling.



African with 6 years machine service at Mufulira and 6 years machine service at Roan. Both lung fields are occupied by discrete nodules of medium size. The hilar shadows are increased in size and density.

Figure VIII(a).
Generalised medium mottling.



This is a contact print of the left mid zone of Figure VIII and shows discrete nodules of medium size.

Figure IX.
Generalised large mottling.

African with 10 years machine service at Mufulira. Again the nodules are discrete and disseminated throughout both lung fields.

Figure X.
Generalised medium mottling.
infective type.

African with 13 years machine service at Mufulira. Here the nodules are not discrete and are of varying sizes. ESR was 60 mm. in one hour. Note the inferior accessory lobe.

OCCUPATIONAL INCIDENCE.

I. General.

When I originally started this part of the investigation I included both European and African miners, the greater part of whose underground service had been spent at the copper mines.

After reading many thousands of chest radiographs with associated clinical examinations and correlating these with the occupational histories it was decided to abandon the investigation as originally visualised, since it was found that although the numbers were great, a truer appreciation of occupational risk could be obtained from smaller numbers who had worked exclusively on the copper mines here and whose service or the greater part of it, had been at one occupation.

As a result of this it was decided to disregard the Europeans altogether as a high proportion had underground service outside the four copper mines - mainly in the gold mines of South Africa and Southern Rhodesia and in the coal fields of Britain. Some of the Europeans, also, had worked in the Cornish tin mines and in the haematite mines of Cumberland and in the coal mines of Australia. The number with exclusive service here was regarded as being too small to be significant,

especially...../

especially as many had been employed in several underground occupations.

This investigation is based, therefore, on 4,844 African miners with underground service only on one or more of the four mines and with five or more years service and on 150 cases of silicosis all of whom, with a few exceptions, had exclusive service on one or more of the four Northern Rhodesia mines. Primarily, an analysis of each underground group was made, e.g. lashers, trammers, grizzley boys, scrapers, whistle boys, timber boys, jumpers, track layers, fitters, etc., but as there was no significant difference between the groups it was decided to combine them into one large group of "underground other". The one group which, by itself presented significant findings was that of the machine boys.

It became obvious from the beginning of the investigation that the most dangerous occupation from the point of view of the development of silicosis was that of machine boy. All underground workers are liable to develop silicosis but in the combined group "underground other", the incidence is low. The significant

feature...../

feature in the machine group is that they are the only underground workers who, when at work, are constantly in contact with a concentration of particles of silica-bearing dust from rock recently fractured.

Grizzley boys are exposed similarly during "mud" blasting of rock but only for very short periods and at very infrequent intervals. Others, such as trammers and lashers are exposed to a high dust concentration but the dust here is "old".

In compiling the tables below the incidence is given as a percentage of the 4,844 men examined who had five years or more service on the Copperbelt only, and not as a percentage of the total Africans employed underground. If the larger number of all underground African employees had been taken, this would have included many with service in mines outside the Copperbelt where the risk of silicosis may be minimal and also those with service in other mines where the risk of silicosis is greater than here.

By...../

By confining the figures, then to those with service in one or more of the four mines and with service exclusively or almost exclusively at one occupation a true appreciation of the occupational risk in these mines was attained.

II. All X-ray Categories.

Tables I and II show the comparative incidence of normal and abnormal radiographs between machine boys and the "underground other" group. As stated above an analysis of the combined "underground other" group by occupations showed no significant findings but a sub-group within that group composed of lashers, grizzley boys, scrapers and trammers was found to be more prone to develop pulmonary fibrosis and subsequent silicosis than any others in this group. Since, however, the figures were not greatly significant, all have been included in the combined group.

Table I shows a detailed X-ray reading of the 4,844 men examined with their average length of service.

Table II shows the numbers in both groups with radiographs which show appearances within normal limits, and radiographs showing abnormal increase in linear striation indicative of an incipient silicosis and radiographs showing definite silicosis.

It...../

It will be seen from this table that only 22.81 per cent of machine boys presented a radiograph within normal limits after an average service underground of 77.5 months compared with 73.1 per cent "underground other" who had radiographs within normal limits after 82.6 months underground service.

In machine boys with radiographs showing abnormal increase in linear striation, the figure is 0.99 per cent with an average of 102.3 months compared with 1.16 per cent of "underground other" with the longer average service of 110 months.

Although the machine boys developed abnormal X-ray appearances in a shorter time the percentage is lower and contrary to what one would have expected. The difference too in the average length of service is too small to be of any significance. The figures in this group, however, are relatively small.

In those showing definite silicosis, however, there is a significant difference; 1.65 per cent of machine boys had definite silicosis after an average of 113 months compared to only 0.29 per cent "underground other" with an average of 111.0 months service.

III. Occupational Incidence - Silicosis.

The occupational incidence of silicosis in the

150 cases of that disease with service only in one or more of the four mines is shown in Table III. The figures here are striking for 96 of the total 150 worked as machine boys only and their service varied from 50 to 180 months. A further 40 cases had worked as machine boys and also at some other occupation. The remaining 14 had no machine service. In the whole group 90.6 per cent had wholly or partly machine service while only 14 per cent had "underground other" service.

IV. Mine Incidence.

Table IV shows the mine incidence of the 150 cases of certified silicosis. It will be seen that by far the largest number have service confined to Mufulira Mine. In the remaining three mines the difference in the incidence is of minor significance.

These findings are as might be expected, for the percentage of free silica in the rock at Mufulira is high compared with Roan Antelope and Nkana. At Nchanga, however, the free silica content of the rock is comparable to Mufulira and yet the incidence of silicosis there is low. The explanation for this is, I think, the fact that Nchanga has been in production for approximately eight years less than the others and secondly the number of men exposed to the risk of the development of silicosis

is...../

is very much smaller.

Although the number is low it will be seen that already the incidence is greater than at the Roan or Nkana, each of which has at risk about the same number as has Mufulira.

V. General Incidence.

From 1943 till 1949 the overall incidence of silicosis in the four mines in African underground and surface schedules workers has been one per thousand per annum.

The figure is considerably higher in Europeans but this does not reflect a true picture of the risk here for many developed silicosis in the gold fields of South Africa or had considerable pulmonary fibrosis as a result of such work before starting mining in the Copperbelt.

The figure for African workers is strikingly low in view of the relatively high silica content of the rock mined. The main reason for this is that there is a large annual turnover of African labour - as much as 70 per cent. This is not the policy of the mines but the habit of the Africans themselves.

As a result of this shifting mining population few stay in an occupation with a silicosis risk

sufficiently..../

sufficiently long to develop the disease. There is no doubt that if such were not the case the incidence of silicosis would be very much higher.

VI. Individual Susceptibility.

In a study of the occupational incidence of dust fibrosis it is evident that a miner exposed to silica bearing dust in his working lifetime underground is liable to develop silicosis but it is not inevitable that he should. Why is it then that one miner may develop silicosis in say ten years and another working alongside him for the same period does not? This is one of the most interesting problems of the disease. That there is a personal factor involved is undoubted, but that personal factor is still unknown. We are well equipped here to study the problem, for there are hundreds of native miners working under the same conditions in the same operations anf for approximately the same length of time in each of the four mines.

In a preliminary study of the problem in the four mines several groups were observed who had substantially the same occupations and the same service and in the same mine. The disparity of the radiographic appearances of those groups after ten years' service was extreme and ranged from a normal thorax to moderately

advanced...../

advanced silicosis.

Having established the fact that among miners with similar exposures to harmful dust, some developed silicosis and some did not, an attempt was made to discover the reason.

The first factor to be investigated was the constitutional make-up of these groups including height-weight ratio, chest expansion, general chest configuration, presence or absence of any disease of the upper respiratory tract and whether there were any defects of breathing, e.g. mouth breathing. There were no significant differences, and indeed it was found that some miners who had advanced to silicosis were powerfully built, with good chest development and adequate expansion while others, whose radiograph was within normal limits, were small, rather undeveloped and with poor chest development and expansion. It is felt that the answer does not lie here.

The next point to be considered was whether, although the working conditions and the exposure appeared to be the same, there might be unappreciated differences in the amount of dust inhaled. After personal observation of these various operations I cannot believe that over a period of, say, ten years there can be such a difference

in...../

in the dose of harmful dust inhaled as to produce silicosis in one man and allow another to escape with a normal chest.

Another factor which might play a part, namely infection, was also investigated. We recognise here an "infective type" of chest radiologically, where there is evidence of an asthenic or vertical type of heart, increased hilar shadows and old healed calcified foci with peribronchial thickening. However, the answer does not lie here for in some who had developed silicosis these appearances were conspicuous by their absence while in others, with no evidence of silicosis, they were present. That infection does influence the development and advance of silicosis is undoubted but this is not the complete answer. This is best exemplified in the gross variations in time taken to develop simple silicosis in individuals similarly exposed, where there is presumably no infective element present.

In Table I it will be seen that there is a sharp drop in the average duration in the underground work in the "underground other" group. This suggests that some of the cases in the reading marked stage 4 in the Table are non specific in the case of the "underground other" worker.

Again the length of time falls for the four

cases...../

cases in stage 8. The time for this group to develop silicosis is even less than the time to develop well marked increase in linear striation and suggests that the development of mottling from well marked increase in linear striation depends on individual idiosyncrasy and not on exposure to dust.

In machine boys there is a gradual increase in the length of service in the various stages up to stage 6.

After this the length of service drops from 120 to 102 months and only rises to 118 months in stages 9 and 10.

Again this suggests a factor of individual idiosyncrasy in the progression of the lesions from stages 6 to 7 and also that in the progression of the lesions from 6 to 10 another factor rather than silica dust, either (a) tuberculosis or (b) an unknown factor probably infective, may be responsible.

In any consideration of the progression of silicosis the question of the continuation of employment must be mentioned.

Here on the Copperbelt first and second stage silicotics have the option to continue or stop work underground as they wish. Such action has been criticised by some (Smith, 1947), who believe that all miners who have developed silicosis should be removed immediately from

their dusty occupation. Medically such an opinion is sound as it is obvious that removal from the cause of the disease is desirable. Gardner (1946) does not support this view and points out that the damage to the lung has already been done. Also it has been shown that simple silicosis may progress to massive fibrosis in the absence of further exposure to harmful dust. Of fifty miners with simple silicosis (radiographs showing generalised arborisation with partial small mottling to generalised medium mottling) who continued working underground, nine developed massive fibrosis after a five year period. Of a similar series of thirty two cases of simple silicosis but who had no further exposure to siliceous dust, six developed massive fibrosis after a five year period. It will be seen that the proportion in each group developing massive fibrosis is almost identical. Meiklejohn (1949) too does not support the view that all silicotics should be compelled to leave underground work and stresses the importance of the social factors.

In addition, I believe there is more to be considered than the medical aspect - the economic position of the individual must be taken into consideration and one other which is equally important, namely, that the

average...../

average miner does not readily adapt himself to a new trade. In Stewart's (1948) account of post mining employment of colliers discharged from underground employment with pneumoconiosis it was found that a considerable percentage did not obtain employment and many of those who did, did so only in an unskilled capacity involving heavy manual labour for which their condition was entirely unsuited.

These remarks apply to the European miner here and to a degree also to the African miner, but an appreciable proportion of the latter on discharge do not seek re-employment in mining but return to their villages and to village life. However, the same view, that the option to continue underground work with silicosis until the third stage is reached is held for the African also, for when the African miner with silicosis returns to his village he has every chance of living in close contact with a case of open pulmonary tuberculosis, whereas if he continues employment in the mines he is well housed in an African township, is well fed and continues under strict medical supervision.

From my own experiences here I am convinced that this is the correct procedure. There are many African miners certified years ago as having silicosis, who are

working underground to-day and are fit and well. Their fate, if they had returned to their villages with the possibility of infection and notoriously bad nutrition, would undoubtedly have been otherwise.

There are certain qualifications to the opinion expressed above, namely that, where silicosis develops rapidly in a young individual, then he should be removed forthwith from further exposure to harmful dust.

On the other hand, where the disease develops slowly over a long period of years and only manifests itself in the later stages of a man's life then, as stated above, he should be given the option to continue underground work up to and including second stage silicosis.

VII. Conclusion.

An analysis of the incidence of silicosis occurring in the four mines shows that all underground workers are liable to develop silicosis.

The highest incidence is recorded in machine boys working in development ends and stopes.

It is considered that the relatively low incidence at Nchanga is due to the smaller number of men exposed to the risk and to the fact that this mine has

been...../

been in production for considerably less time than the three others.

It is believed that in time Nchanga will produce proportionately more cases of overt silicosis.

The incidence of silicosis in African underground and surface scheduled workers would be very much higher if there was not such a large annual turnover of labour.

With the excellent ventilation and modern mining methods now existing in all four mines it is unlikely that the incidence of silicosis will ever be high.

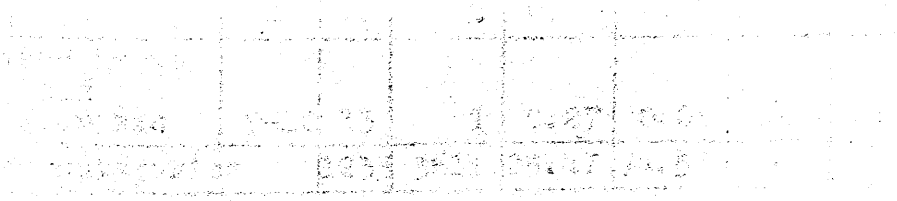


Table I.

Comparison of the Percentage Incidence of X-Ray Abnormalities in 3,611 Underground Other Workers and 1,233 Machine Boys, Expressed as a Percentage of 4,844 Underground Workers Examined.

1943 - 1950.

X-Ray Reading	Stage	Number		Percentage of Total		Average duration of Underground Work in Months	
		M	U/G O	M	U/G O	M	U/G O
Normal Thorax	1	406	1627	8.38	33.59	69.5	79.0
Slight Increase	2	405	1336	8.36	27.58	79.5	81.5
Moderate Increase	3	294	578	6.08	11.93	83.4	87.3
Well Marked Increase in Linear Striation.	4	38	47	0.78	0.96	100.2	114.0
General Arborisation.	5	10	9	0.21	0.19	104.3	106.0
General Arborisation with Partial Small Mottling.	6	21	4	0.43	0.08	120.1	109.0
Generalised Small Mottling	7	24	5	0.50	0.10	102.1	116.0
Generalised Medium Mottling	8	22	4	0.45	0.08	113.1	101.0
Generalised Large Mottling and Massive Fibrosis	9-10	13	1	0.27	0.02	118.0	117.0
All X-Ray Categories		1233	3611	25.47	74.53	-	-

M denotes Underground Machines.
U/G O denotes Underground Other.

Table II.

Comparative Tables showing Percentage Incidence, according to Length of Service, of X-ray Abnormalities among 4,844 Underground Workers (3,611 "Underground Other" and 1,233 "Machine Boys".

1943 - 1950.

	Radiographs showing Appearances Within Normal Limits			Radiographs showing Abnormal Increase in Linear Striation			Radiographs showing Definite Silicosis			
Occupation	Total No	% of Total	Aver Serv in Mths	Total No	% of Total	Aver Serv in Mths	Total No	% of Total	Aver Serv in Mths	All X-ray Categories
Machine Boy	1105	22.81	77.5	48	0.99	102.3	80	1.65	113.3	1233
Underground Other	3541	73.1	82.6	56	1.16	110.0	14	0.29	111.0	3611
Total	4646	-	-	104	-	-	94	-	-	4844

Table III.

Occupational Incidence of Silicosis occurring in Miners with Service Exclusively in the Copperbelt, according to Length of Service at date of First Certification.

1943 - 1950.

Service in Mths at Date of First Certification	Number of Cases										
	M	M & Sc	M & Gr	M & Ti	M & La	M & Tr	La	Gr	Sc	Ti	Tr
50-59	1			1				1			
60-69	4		2								
70-79	14				1			1			
80-89	11			2	2				2		
90-99	16	1		1	2	1					
100-109	12	3	2	1			2	1	1		
110-119	13		1		1		2				1
120-129	9	1	2	1	2		2				
130-139	9			3		1					
140-149	2			1							
150-159	3	1		1				1			
160-169	1	2			1						
170-179	1				2						
180-189				1							
Total all cases	96	8	7	12	11	2	6	4	3	-	1

M denotes Machines
Sc denotes Scraping
Gr denotes Grizzleys
Ti denotes Timbering
Tr denotes Tramming
La denotes Lashing.

Percentage with Machine and Machine and Other Service 90.6
Percentage with Underground Other Service 9.4

Table IV.

Incidence of Silicosis on the Four Copperbelt Mines

1943 - 1950.

Mine	Years of Service				Total all Cases	Percentage of Total U/Ground Workers at each Mine.
	5 - 7	8 - 10	11 - 13	14-16		
Mufulira	23	67	28	-	118	3.4
Nchanga	-	2	-	-	2	0.09
Roan	-	-	1	-	1	0.01
Nkana	-	1	1*	-	2	0.04
Mixed Copperbelt Service	4	7	8	8	27	0.16
Total	27	77	38	8	150	

* Had 14 months underground service in the Belgian Congo.

COMPLICATIONS.

1. Tuberculosis and massive fibrosis.

A description of tuberculosis as a complication of silicosis follows, but it is relevant and indeed necessary to discuss pulmonary tuberculosis generally, especially as it occurs in the African underground and surface scheduled worker and it is opportune to do so at this point.

The view is widespread in Northern Rhodesia that an epidemic of pulmonary tuberculosis is possible amongst the native population. This is based on the belief that the native here presents a virgin soil for infection by the tubercle bacillus and that he has not yet developed an inherited immunity from generations of exposure to infection. Originally I was inclined to accept this view on my experience that where a native had developed pulmonary tuberculosis, he had little or no resistance to the disease, for he dies rapidly of an acute caseating lesion. However, resistance to infection and resistance to the disease already established are two different aspects of immunity, and I no longer support the view referred to for I have been forcibly impressed by the low incidence of pulmonary tuberculosis in the large native mining community here. The native community on which this is based, is the twenty thousand

native..../

native mine workers whom we examine annually. It is to be remembered also that this is not a static population for the annual turnover of labour is in the region of seventy per cent so that the number of persons examined is in reality very much higher than twenty thousand.

The incidence of pulmonary tuberculosis in this population for the years 1943-1949 was 1.05 per thousand per annum. The equivalent figure for similar European mine workers was 1.26, slightly higher than the incidence in the native population. There are no comparable figures available for the non-mining population of the country but I believe that the incidence in the towns is very little higher, but may be considerably higher in the native villages.

This low incidence of pulmonary tuberculosis in native miners here, and the similar low incidence in non-mining natives on the Copperbelt area of Northern Rhodesia has led me to believe (a) that there are no grounds for the belief that pulmonary tuberculosis is an industrial disease and (b) that if the native population of Northern Rhodesia had not acquired a certain immunity to the disease, then the incidence would be very much higher.

To substantiate this, I chose a random group of five thousand native miners including fresh recruits

straight..../

straight from the villages who had no mining service. The ages of this group ranged from 18 years upwards, with the majority between 25 and 40. Chest radiographs of these five thousand underground workers, surface scheduled workers, and recruits, showed the presence of healed calcified lesions in just over eighty per cent.

Recruitment for the mines is from all over Northern Rhodesia and a percentage analysis of the above figures on the basis of area of recruitment showed no significant features whatsoever - the percentage with healed lesions being equally distributed throughout the whole territory.

I believe that the majority of natives have their primary infection in their early teens. No large scale Mantoux testing has yet been done, but such as has been done supports this view.

When, however, an adult native develops pulmonary tuberculosis the disease is rapidly fatal with rapidly spreading caseation and cavitation. The typical chronic fibroid pulmonary tuberculosis of the European is rarely seen.

There has been no satisfactory explanation for the acuteness of the disease as it occurs in the native. It has been suggested that malnutrition is the cause and I believe that it probably at least

plays...../

plays a part.

It may be that the virulent progress of a lesion once established is associated with the comparatively recent introduction of the disease amongst the natives here, but I think there must be some inherent factor present to explain the rapidity of the development, and acute course of the disease.

To summarise, I believe that infection with the tubercle bacillus is now widespread in the natives of Northern Rhodesia and that they have developed a certain inherited immunity, and as a result, the belief is now untenable that an epidemic of pulmonary tuberculosis is imminent.

Primary infection occurs in childhood and the early teens. The disease when manifest is rapidly fatal with caseation and cavitation - the chronic fibroid type of tuberculosis being rarely seen.

In considering pulmonary tuberculosis as a complication of silicosis the outstanding fact is that it is the most common complication of all: it has not, however, been determined how and when the infection takes place. Is it that the tuberculous infection is present and latent before the development of silicosis and the

resultant...../

resultant lesion is merely a reactivation of this already existing focus or is it that tuberculous infection occurs after silicosis is manifest? However it may occur, it is abundantly clear that where silicosis exists, active recognisable tuberculosis is prone to supervene.

When tuberculosis does supervene on silicosis, and it may do so at any stage of the disease, the signs and symptoms are predominantly those of the former. The course of the disease varies; it may run a chronic course but is almost always rapid just (as has been pointed out above) as it is in simple tuberculosis in African miners. In a series of sixty-six cases of simple tuberculosis or tuberculosis complicating silicosis in Africans, it was found that the average duration of life from the date of diagnosis was 11.7 months. This series includes only cases where the diagnosis was confirmed by the isolation of tubercle bacilli from the sputum or by post mortem confirmation. In fifty-four of these cases the cause of death was confirmed by personal knowledge, but in twelve who had returned to their villages the date of death was obtained from the District Commissioner and the mode of death from the headman of the village. Where the report was

"he...../

"he had lost much flesh and died with much coughing and the spitting of blood" it was accepted that he died of his tuberculous infection. A larger series of one hundred cases could have been quoted if one had accepted that all deceased native miners with tuberculosis or tuberculosis complicating silicosis had died of their tuberculous infection. In many, however, it was impossible to obtain any details of the mode of death and therefore the numbers were reduced to sixty-six who beyond any doubt died of their tuberculous infection.

From these figures it can be seen that when tuberculosis supervenes in an African miner the course of the disease is rapidly fatal. This (as noted above) has been my experience also with the general African population and is not peculiar to miners. I have seen cases, however, of the combined disease where the African miner was still alive five years after the original confirmed diagnosis had been made, but these are the exceptions.

It should be stated that these findings apply to untreated cases of tuberculosis. There are few facilities for the treatment of the disease here. In addition, the native is seldom willing to continue hospital treatment for any length of time. One such

case...../

case will illustrate this. An African miner was admitted to hospital with a unilateral basal tuberculosis with a central cavity. Artificial pneumothorax was induced and serial radiographs showed progressive improvement. Clinically too his condition improved, but at this stage he walked out of the hospital and was never seen again. When the projected sanatorium is built for the treatment of tuberculosis in Africans I am convinced that it will have to provide a small township where relatives of the patients may live. Otherwise the patients themselves will not stay.

When tuberculosis has supervened on silicosis there is a rapid breakdown in health and where formerly the man was relatively well or at the most dyspnoeic he now presents toxaemic symptoms, with alteration in the physical findings accompanied by constitutional weakness, wasting and pyrexia. The blood sedimentation rate is always considerably raised in such cases. The sputum becomes more copious and haemoptysis may occur.

The radiological appearances change too. There is a rapid development of diffuse opacities of different sizes. Their edges are ill-defined and of varying densities and the distribution is irregular. Also, where tuberculosis is superadded to a simple silicosis

there...../

there may be rapid extension of previously stationary opacities or there may occur a rapid appearance of a previously non-existent lesion. Such lesions tend to develop asymmetrically and cavitation may occur in these areas of tuberculous consolidation.

These various features are illustrated by the following four cases.

Case History 1.

African

Age 30 (approx.)

History.

In March, 1945, he was examined and found to have first stage silicosis. The radiograph showed generalised small mottling. His occupational history at that time was 122 months on machines at Mufulira. Clinically there was little of note and his only complaint was of mild dyspnoea on exertion. However, he chose to leave mining and return to his village where he stayed until re-examined in March, 1950. He had no further exposure to dust having been farming since his original examination in March, 1945.

At this examination (March 1950) the findings were as follows :

History...../

History.

He complained of cough with copious sputum. He had lost some weight. There was no haemoptysis nor did he complain of night sweats.

Physical Findings.

He was fairly well built and there was no gross loss of weight. The percussion note was impaired at both upper zones. The R.M. was broncho-vesicular at these areas and the vocal resonance increased. Occasional râles were audible at these areas. Otherwise the R.M. was diminished and there was generalised prolongation of expiration.

Radiograph (Fig. I.)

The nodules have increased in size and are more numerous and widely disseminated throughout both lung fields. They are less discrete and of varying densities. There are now two extensive opacities at the left upper zone and the right mid zone. There is calcification of the nodules at both lower zones.

His sputum was now positive for the tubercle bacillus and his E.S.R. was 100 mm. in an hour.

Diagnosis.

Tuberculosis complicating silicosis.

Case History 2.

African.

Age 40 (approx.).

History.

In February, 1945, he was examined and found to have silicosis in the first stage. At that time he had worked 40 months as a machine boy and 94 months as a timber boy at Mufulira. The radiograph (Fig. II) on that occasion showed a generalised arborisation with partial small mottling at both upper zones. He had no complaints whatsoever, and clinically apart from a generalised prolongation of expiration no abnormality was found.

He returned to his village and was re-examined in February, 1950, with no further exposure to dust and the findings were as follows.

History.

He complained of cough with copious sputum, sometimes blood stained.

Physical findings.

He looked toxic and ill and there was marked infra- and supra-clavicular hollowing. There was dullness to percussion at the right upper zone and left mid zone. There was whispering pectoriloquy at

the...../

the right upper zone and the R.M. was bronchial at the left mid zone. There were numerous fine râles audible at these areas.

Radiograph (Fig. III).

On this occasion there is an infiltration at the left upper zone and extensive infiltration involving the whole right lung. At the right mid zone there is a cavity with a fluid level. Diaphragmatic adhesions are present.

His sputum was positive for the tubercle bacillus and his E.S.R. was 94 mm. in an hour.

Diagnosis.

Tuberculosis complicating silicosis.

Case History 3.

European.

Age 56.

History.

He was examined in February, 1947, when he complained of cough and dyspnoea on exertion. At that time he had 60 months machine service at Roan Antelope. In addition he had worked in various mines in South Africa for 320 months.

Clinical examination showed him to be dyspnoeic on slight exertion. Air entry was poor, especially at

both..../

both bases; otherwise there was no abnormality detected.

The radiograph (Fig. IV) at that time showed a generalised arborisation with sparse small mottling. He was diagnosed as first stage silicosis.

He continued to work at Roan Antelope and he was examined at six-monthly intervals. Serial radiographs at six-monthly intervals showed no material change until February 1950. At this examination the following findings were noted.

History.

Six weeks prior to this examination he found that he was easily tired and not fit for his job which had been on the surface and unscheduled since the time of his original certification. His cough which previously had been unproductive was now accompanied by copious sputum occasionally blood stained. He had lost ten pounds in weight in a few weeks.

Physical Findings.

He was dyspnoeic even at rest and had obviously lost weight. There was some facial cyanosis.

The percussion note was impaired at the right mid zone. The R.M. was broncho-vesicular and the vocal resonance increased at this area. There were numerous râles audible over the greater part of the right lung.

E.S.R. was 78 mm. in an hour and his sputum was positive for the tubercle bacillus.

The radiograph (Fig. V) on this occasion showed a dense opacity involving the greater part of the right lung. There was no infiltration of the left lung.

Diagnosis.

Tuberculosis complicating silicosis. This case demonstrates the sudden onset of a tuberculous lesion in lungs already damaged by silicosis. His general condition deteriorated rapidly after this examination.

Case History 4.

African.

Age 30 (approx.).

History.

Previous to the onset of the present condition his only complaint had been of slight dyspnoea on exertion. Two months previously he noticed that his dyspnoea had increased considerably. He lost ten pounds weight in a month. His cough which had hitherto been infrequent and unproductive was now constant with occasional blood-stained sputum. He felt unable for his work as a machine boy.

Occupational...../

Occupational history.

74 months on machines and 37 months on grizzleys at Mufulira.

Physical findings.

He appeared toxic and ill and there was obvious evidence of recent loss of weight. The pulse rate was increased and he was febrile.

There was impairment of the percussion note at the right upper zone with diminished air entry at this area. Over this area numerous moist râles were audible. Elsewhere the R.M. was vesicular with generalised prolongation of expiration.

Radiograph (Fig. VI).

Where previously the radiograph had shown the discrete nodulation of a simple silicosis there is now an opacity in the right sub-apical region with a tendency to coalescence in the left upper zone. Below the opacity in the right side at the periphery there is a cavity. The hitherto small discrete nodules are increased in size and are disseminated throughout both lung fields. The edges are fluffy in appearance and their density varies.

Diagnosis...../

Diagnosis.

Tuberculosis complicating silicosis.

Post Mortem.

He died four months after the above examination and the diagnosis was confirmed.

Massive Fibrosis.

In uncomplicated silicosis the rate of progression of the disease is slow but when infection is superadded progressive massive fibrosis results.

These lesions develop suddenly in a background of simple silicosis and have a characteristic distribution being found chiefly as rounded masses in the subapical regions and in the mid zones close to the hilar areas.

That the progression to massive fibrosis is due to infection is substantiated by the number of cases of simple silicosis that develop massive fibrosis after leaving a dusty occupation. Progression of simple silicosis on the other hand appears to be dependent on continued exposure to siliceous dust, but simple silicosis too, may progress after withdrawal from a dusty occupation but this is, I think, due to the action of dust already occupying the lungs which has at the time of withdrawal from further exposure, still not produced further fibrotic changes. The nature of the infection causing

progressive...../

progressive massive fibrosis is invariably tuberculous. Gough (1947) believes that, in spite of the fact that there is frequently no naked eye or microscopic evidence of tuberculosis, it always plays a part. I base my belief mainly on clinical observations. In a series of 52 miners with massive fibrosis 31 or 60 per cent developed proved tuberculosis with a positive sputum within a four year period.

In addition it has been observed that the erythrocyte sedimentation rate in massive fibrosis is invariably raised. The radiological appearances too are indistinguishable from tuberculosis.

The following case illustrates these features :-

Case History 5.

African.

Age 48 (approx.).

History and Physical Findings.

He was first examined in October 1946 and diagnosed as a first stage silicosis. He had no complaints and physical examination revealed impairment of percussion at both apical regions with bronchial breathing at these areas. There were no adventitae and the remainder of the lung fields revealed no abnormality.

Occupational History.

110 months machines at Mufulira.

Radiograph.

The radiograph at this examination presented two massive rounded shadows involving both apices.

He continued working as a machine boy at Mufulira and was examined at six-monthly intervals until my final examination in March 1949. Serial radiographs showed no difference throughout and the physical findings remained unaltered.

At the examination in March 1949, however, he complained of loss of weight and cough with fairly copious sputum of two months' duration. The physical findings on this occasion revealed the presence of râles at both apices and his sputum was positive for the tubercle bacillus. He had lost nine pounds in weight. The radiograph (Fig. VII) was indistinguishable from all his previous ones. He returned to his village and no further examination has been possible.

Diagnosis.

Massive fibrosis terminating in active tuberculosis.

2. Emphysema.

The formation of emphysematous bullae is a

fairly...../

fairly common complication of silicosis. The characteristic radiographic appearance is of areas of increased translucency and within the emphysematous areas the normal lung markings are scarcely visible or not at all.

Emphysema occurs most frequently at the apices and such a case is illustrated in figure VIII. Such appearances are uncommon in silicosis here and radiographs showing definite emphysema occur in less than 5 per cent of cases. This is more fully discussed in the section on symptomology.

3. Pneumothorax.

When rupture of an emphysematous bulla occurs, pneumothorax results. This is usually localised by the presence of pleural adhesions. The following case demonstrates a localised basal pneumothorax. It is the only case of pneumothorax I have observed here.

Case History 6.

This African miner, aged approximately 38, was first examined on the 7th September, 1948. He had been working until the time of his examination. At that time he had a total of 121 months mining service - 80 months on machines and 41 months timbering at Mufulira.

History.

His only complaints were of a dry, unproductive cough and dyspnoea on exertion, of one year's duration. A few weeks before examination his dyspnoea had suddenly worsened - probably as a result of the pneumothorax.

General.

He was a well developed, muscular boy. His weight was 150 lbs. He was dyspnoeic even at rest.

Physical Findings.

His maximum chest expansion was just under one inch and there was diminished movement of the left lung. The percussion note was impaired over the whole right lung and there was dullness at the left middle and upper zones. The respiratory murmur was bronchial in both lungs and the vocal resonance was increased especially at the left upper zone. There were occasional ronchi over both bases. The heart sounds were pure and of good quality. E.S.R. 37 mm. in one hour.

Sputum Examination.

Ten consecutive sputa were negative for the tubercle bacillus and fungus infection.

Radiograph (Fig. IX).

There are well-defined nodular changes in the mid zone of the right lung with areas of coalescence at the upper and lower zones.

In...../

In the left lung a pneumothorax is present at the lower zone. Fibrous adhesions are visible. The remainder of the lung is occupied by a dense massive fibrosis.

Diagnosis.

Massive fibrosis with localised pneumothorax.

Conclusion.

Probably the chief difference between the classical silicosis of the Copperbelt and the anthraco-silicosis of coal miners is the relative rarity of emphysema. As a result death from cardiac failure, especially in the African miner, is extremely rare - indeed I have not encountered a single case here where death has been due to cardiac failure in an African miner with silicosis.

Tuberculosis on the other hand is a frequent complication of silicosis in the African miner. In 200 cases of certified silicosis in African miners 46 of these were complicated by tuberculosis and as has been pointed out previously, once established in an African the disease is rapidly fatal. In addition, the number of African miners with silicosis who return to their villages and subsequently develop tuberculosis must be considerable.

To sum up, the analysis of the complications of

silicosis..../

silicosis in the Copperbelt is in sharp contrast to pneumoconiosis in coal miners where "miner's asthma" is so common (Cummins 1934) and where death is due to emphysema and right heart failure. In silicosis of the copper miners the miner, especially the native, dies more frequently of recognisable tuberculosis.

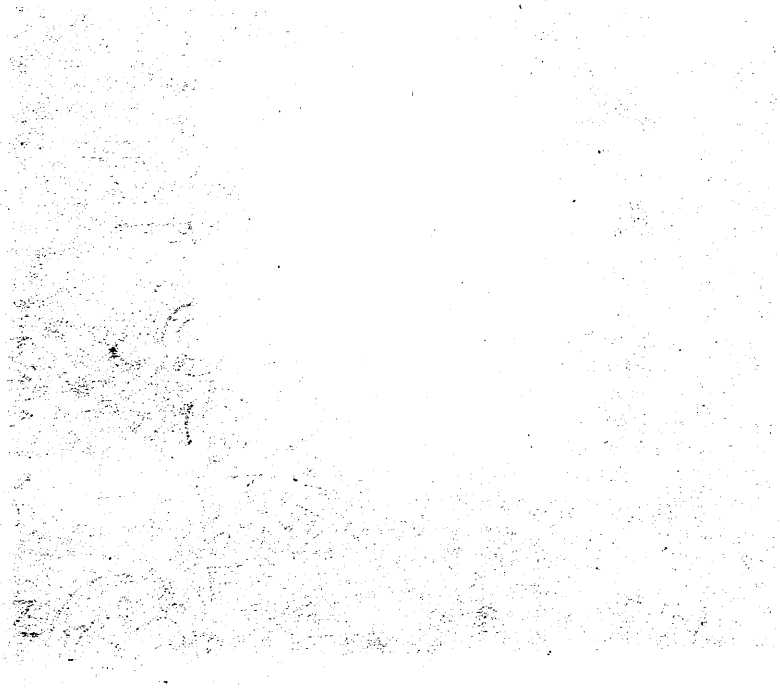


Figure I.
Tuberculosis complicating silicosis.

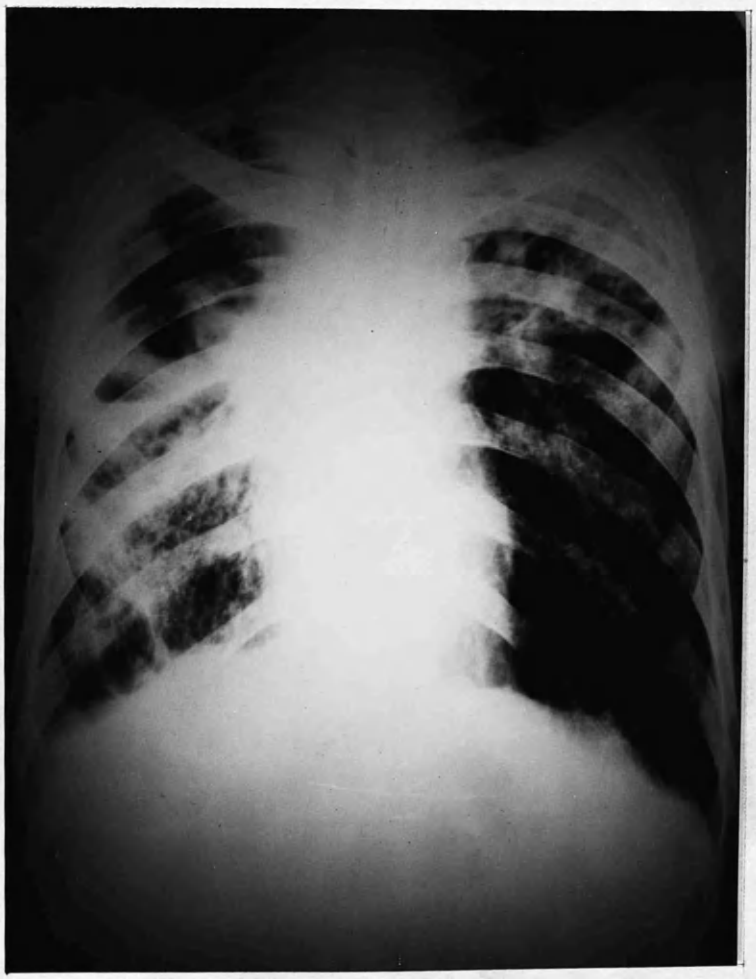
From an African with 122 months machine service at Mufulira.

Figure II.
Generalised Arborisation
with partial small mottling.

From an African with 40 months machine and 90 months underground other/at Mufulira.
service

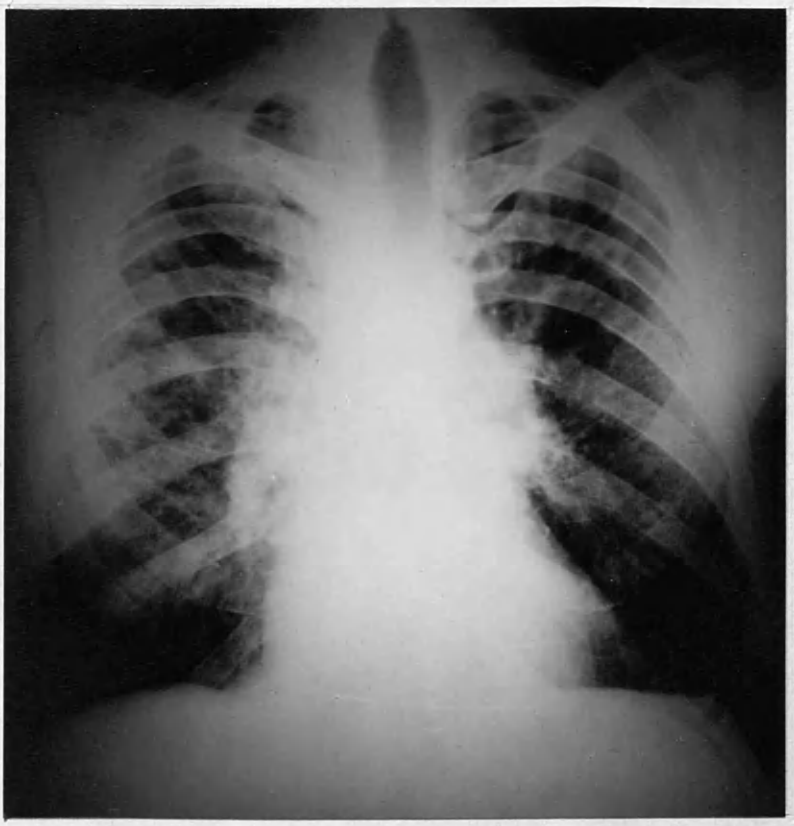
Figure III.

Tuberculosis complicating silicosis.



From the same African as Figure II.
The tuberculosis developed after
his return to his village and
without further mining service.

Figure IV.
Generalised Arborisation
with partial small mottling.



From a European with 60 months machine service at Roan and 320 months underground other service on the Rand gold mines.

Figure V.
Tuberculosis complicating silicosis.

From the same European as Figure IV. There is now an extensive tuberculous infiltration involving the greater part of the right lung.

Figure VI.
Tuberculosis complicating silicosis.

From an African with 74 months machine and 37 months underground other service at Mufulira.

Figure VII.
Massive Fibrosis.

From an African with 136 months machine service at Mufulira.

Figure VIII.
Apical Emphysema.

From an African with 96 months machine service at Mufulira.

Figure IX.
Pneumothorax.

From an African with 80 months machine and 41 months underground other service at Mufulira.

Pathology.

The classical type of silicosis, similar to that found in the South African gold fields, is encountered in the Northern Rhodesian copper mines and the description which follows is of that particular form of the disease.

In South Africa a study of the pathology has been done by Simson, Strachan and Irvine (1930) and Simson and Strachan (1935).

The three essential conditions for the development of silicosis are :-

a) Silica in the form of silicon dioxide must reach the lungs.

b) The particle size must be 10 microns or less.

c) There must be a sufficient amount of such particles inhaled over a sufficient period.

All the inhaled particles do not reach the alveoli and in fact possibly only a small fraction do so. Many are arrested in the naso-pharynx which acts as a filter.

The trachea and bronchi are lined with ciliated epithelium which secretes a viscid mucus. Particles of dust deposited on this epithelium tend to be expelled by the action of the cilia propelling the mucus with its dust deposits towards the trachea whence they are expelled

by...../

by coughing. Of those dust particles which reach the alveoli some are removed by coughing and the remainder dealt with by phagocytosis. These phagocytes originate from the alveolar cells; they ingest the dust particles and carbon pigment and pass into the lymphatic system. The lymphatic channels of the lungs may be divided into a superficial and a deep group. The superficial group lies in the connective tissue under the pleura and the deep group lies in relationship to the walls of the bronchi and vessels. They drain into the broncho-pulmonary and tracheo-bronchial lymph nodes respectively.

The phagocytes with their ingested dust particles and carbon pigment follow the lymphatic flow, some being arrested in the lymphatic nodes and others passing to the hilar glands; ultimately the phagocytes degenerate and leave behind the silica particles and dust pigments and fibrosis is set up at the site of their arrest.

From these beginnings the ultimate picture of the classical silicotic nodule is produced. The essential feature is a nodule composed of dense connective tissue arranged in a laminated fashion and containing dust cells. These discrete nodules may come together when the intervening alveoli collapse and an irregular composite nodule is formed.

At...../

At the site of arrest of the "dust cells" there is a proliferation of fibroblasts which are formed from the preexisting connective tissue cells. The fibroblasts lay down collagenous fibres which ultimately assume the characters of adult tissue.

Such is the sequence of events in simple silicosis due to the action of silica particles alone. In infective silicosis the lesions result from the combined action of silica particles and infection which is invariably tuberculous.

The classical silicosis found in the Northern Rhodesian copper mines is in some ways similar to the silicosis found in the coal fields of Britain, but there are certain essential differences, the chief of which are :-

a) The pneumoconiosis of coal workers does not predispose to the development of pulmonary tuberculosis to such a degree as does classical silicosis.

b) Emphysema is much more marked in the pneumoconiosis of coal workers.

c) The nodules of classical silicosis are more densely fibrosed and are laid down in laminated fashion.

d) Pigmentation is much less in classical silicosis.

Gough (1949) has admirably demonstrated the

presence...../

presence of gross focal emphysema in coal workers' pneumoconiosis, by his large section technique. In this and his work on pneumoconiosis in coal trimmers (1940) he has demonstrated the focal character of the lesions. This focal distribution has also been demonstrated by Heppleston (1947). The views of the two above workers diverge from those held by Belt and Ferris (1942) who in their description of pneumoconiosis in similar workers found it to be diffusely disseminated throughout the lungs.

The macroscopic appearances of an established silicosis present the following features. In the Africans from whom most of our pathological material is obtained the striking feature is the frequency with which one encounters pleural adhesions even in cases of early simple silicosis. When the combined disease is present then the adhesions are much more widespread. The lungs tend to be bulky and apical emphysema is sometimes seen. The root glands are usually deeply pigmented and moderately enlarged and fibrotic. The pleura is pigmented and palpable subpleural plaques up to 5 mm. may be present. The cut surface of the lungs shows increase in pigment aggregated in discrete islets which are palpable and tend to develop first in the upper lobes. There may be areas

of.../

of massive pigmented fibrosis which are easily palpable.

The following photomicrographs were prepared from cases selected from 62 post mortems and illustrate the histo-pathological changes in the lungs found in the miners in the industry here from the earliest dust accumulation till the development of a fully formed silicotic nodule. The early accumulation of dust is seen in the connective tissue surrounding the bronchioles and their accompanying blood vessels, subpleurally and in the hilar glands. Photomicrographs of both simple and infective silicotic lesions are shown.

a) Simple Silicosis.

Figures 1 and 2 show the earliest dust accumulation. Small collections of dust can be seen in the connective tissue surrounding the bronchioles and in the walls of the bronchioles. Slight fibrous reaction is present but there is no evidence of nodulation.

In Figure 3 there is a similar distribution of the dust and the small vessels in relation to the bronchioles are involved. There is evidence of early fibrosis.

Figure 4 shows a further advance with definite but still relatively slight fibrous reaction. This section illustrates the perivascular distribution. As yet there is no nodule formation.

In..../

In Figure 5 there is a dust cell aggregate with definite fibrosis.

Figure 6 demonstrates early nodule formation with accumulation of dust cells and scattered fibroblasts. The fibrosis is not hyaline or whorled.

Figure 7 shows a stage further in nodule formation with aggregates of dust cells and fibroblasts. There is distinct fibrosis which is not whorled but the centre of the nodule is less pigmented and the collagen bundles are swollen.

Figure 8 demonstrates definite nodule formation. The collagen fibres and fibroblasts are arranged concentrically but there is no evidence of hyaline change in the areas of dense fibrosis.

The fully developed silicotic nodule is demonstrated in Figure 9. Here the focus of fibrosis is fairly sharply demarcated from the surrounding area containing pigmented dust cells. The centre of the nodule consists of dense fibrous tissue with few cells and little pigment. There is definite whorl formation.

Figure 10 represents a larger field and shows several small silicotic islets lying in relation to the respiratory bronchioles and alveolar ducts. There is generalised fine emphysema.

In..../

In simple silicosis the changes in the root glands may develop earlier than in the lung substance. The glands become enlarged, deeply pigmented and show the presence of typical nodular fibrosis before such changes take place in the lungs.

b) Infective Silicosis.

Where there is fibrosis due to the action of silica dust alone there may be super-imposed fibrosis due to added infection. Such lesions, may, however, be infective from the outset. Where such infection exists the resultant lesions form areas of massive fibrosis. Where this infective element is present there are certain differences in the formation of the nodules. There is a more cellular reaction in the early stages and in the fully developed nodule there is evidence of central necrosis.

Figure 11 shows conglomerate nodules of the infective type with evidence of central necrosis. (This is better demonstrated in the actual section).

Figure 12 illustrates massive fibrosis of the infective type. There is marked pleural fibrous thickening and subpleural fibrous formation. The nodular character of the lesions is less clearly defined. Generalised fine emphysema is also shown.

The separation of the simple from the infective

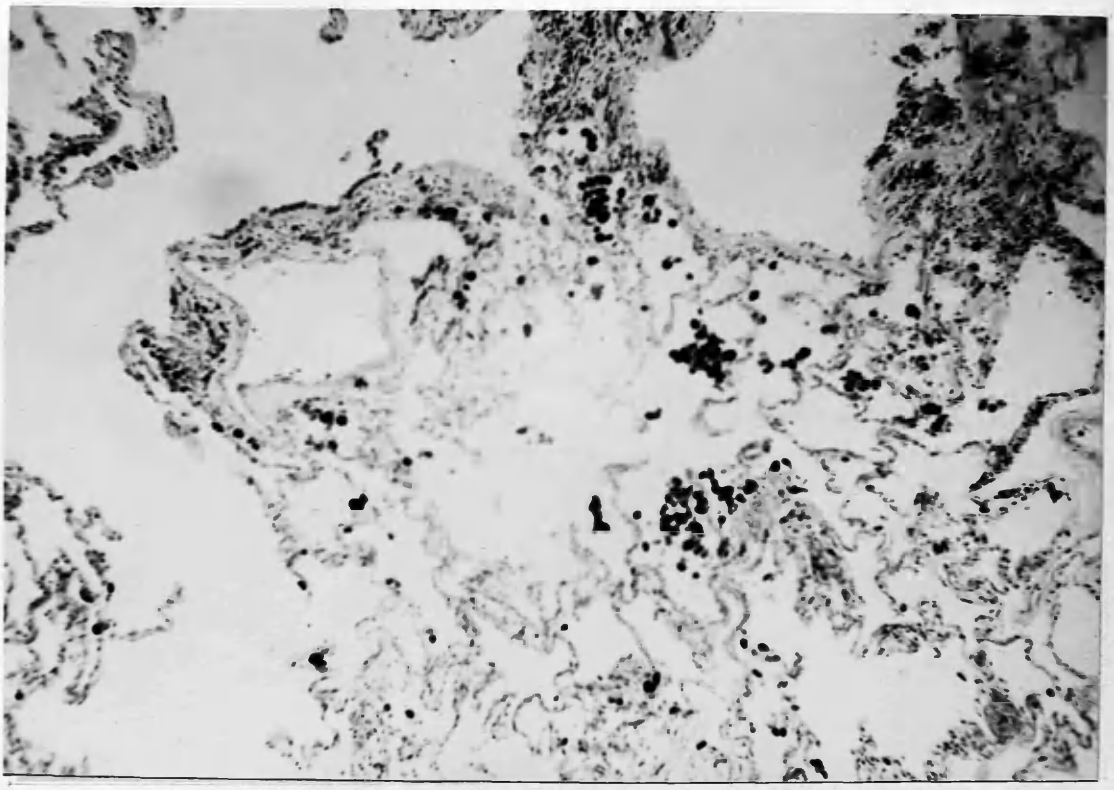
type.../

type of silicosis is not clear cut as the lesions of silicosis and tuberculosis are essentially similar and it is often impossible to be certain of the nature of a given lesion. Silica may cause almost every type of cellular reaction caused by tuberculosis, such as necrosis and giant cell formation.

In suggesting that the majority of lesions with massive fibrosis have a tuberculous element present, the difficulty in assessing the histology should be stressed.

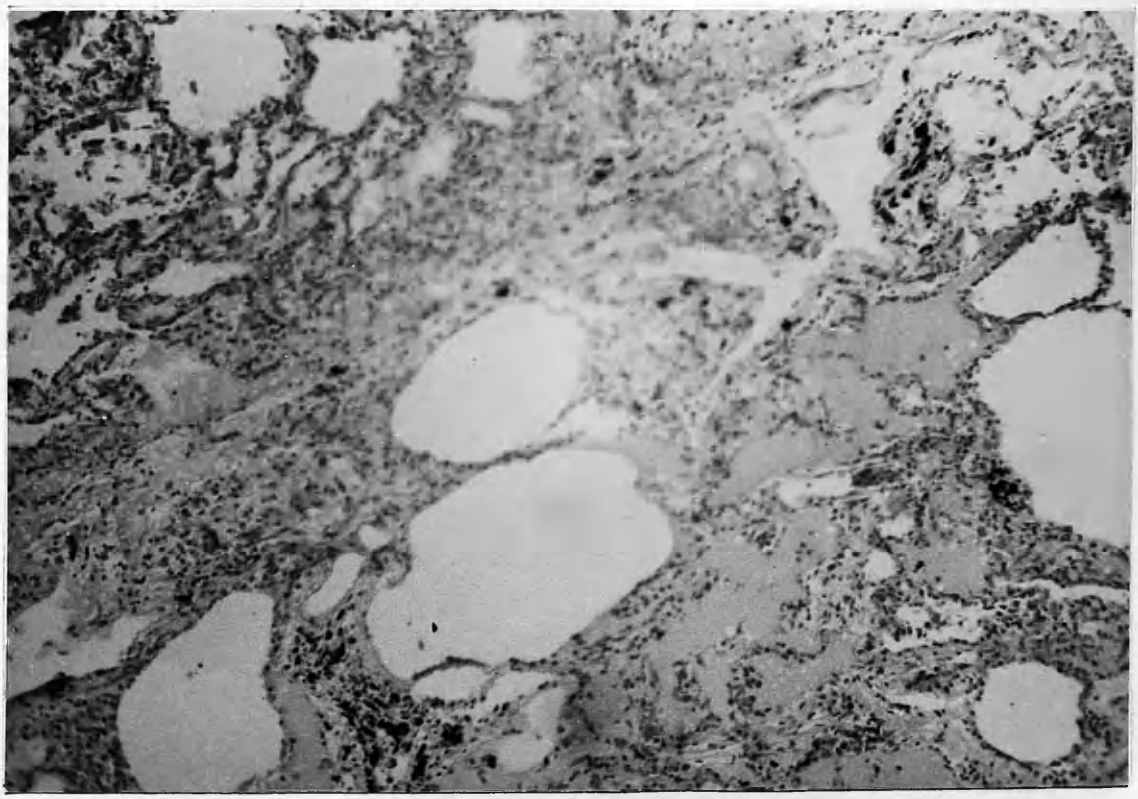
In considering the above photomicrographs it will be seen that in the majority of cases there is a definite correlation between the pathological findings, the radiographic appearances and length and degree of dust exposure. Case 10 however is an exception for this native had only six years machine service at Mufulira and yet developed generalised small mottling in that time. Such cases suggest that in the development of silicosis a personal idiosyncracy may exist.

Figure I.
Haematoxylin and Eosin x 200.



From an African with 3 years underground other service at Mufulira. (X-ray - normal thorax).

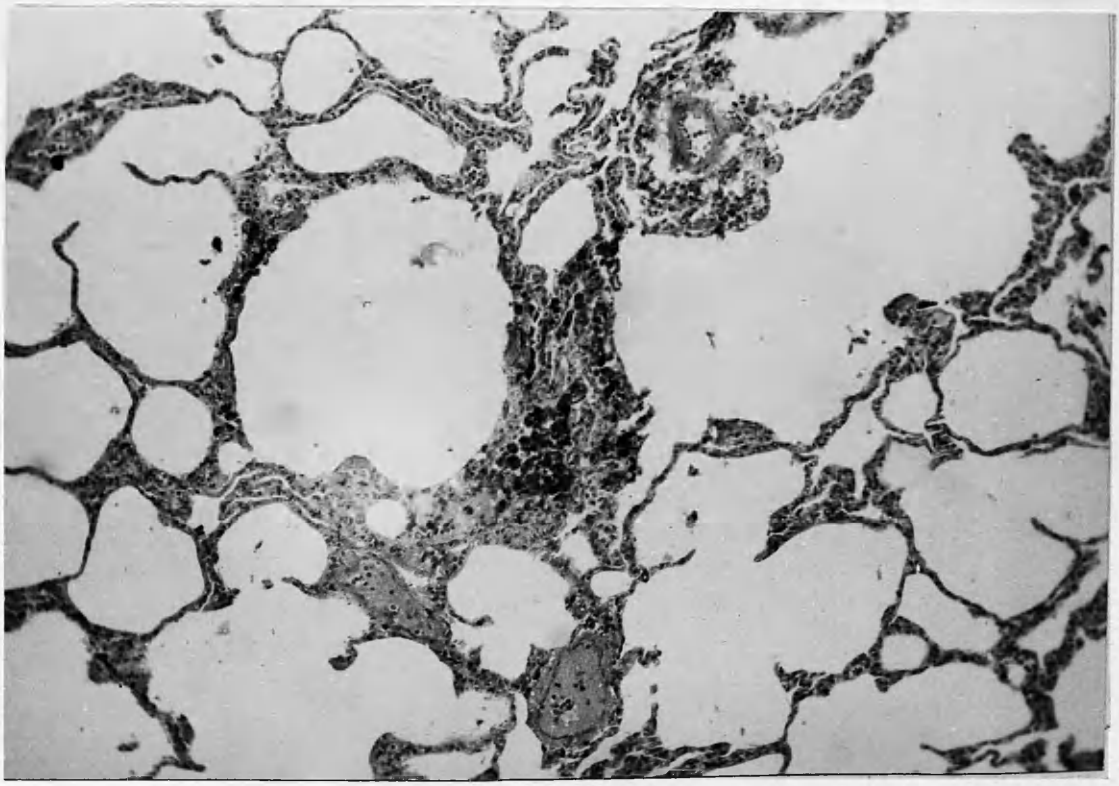
Figure II.
Haematoxylin and Eosin x 200.



From an African with 3 years machine service at Nkana. (X-ray - normal thorax).

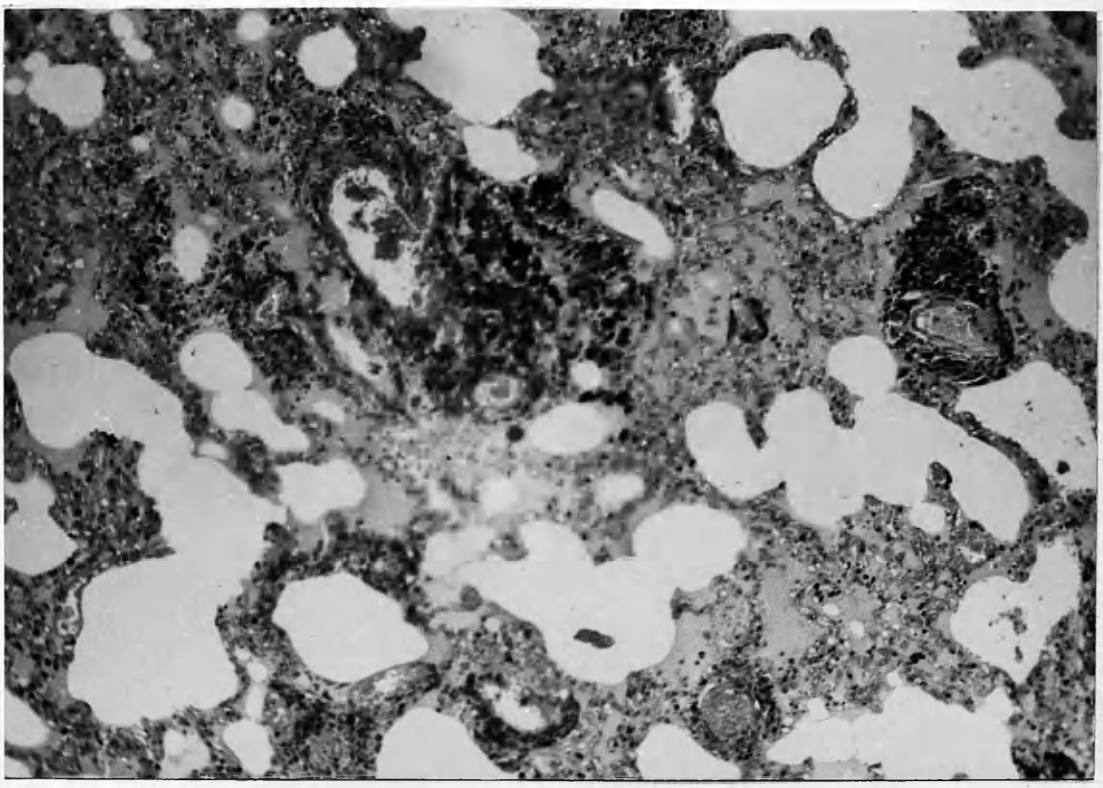
Figure III.

Haematoxylin and Eosin x 200.



From an African with 4 years underground other service at Mufulira. (X-ray - slight increase in linear striation).

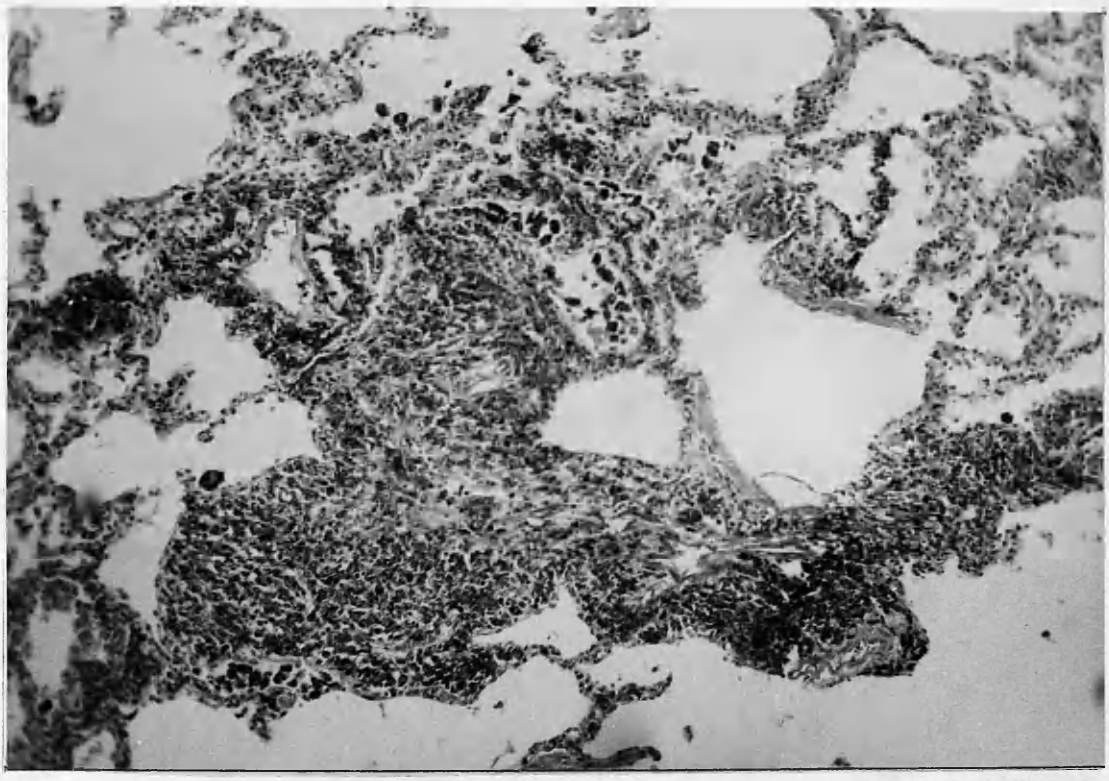
Figure IV.
Haematoxylin and Eosin x 200.



From an African with 20 years machine service at Roan. (X-ray - mdderate increase in linear striation).

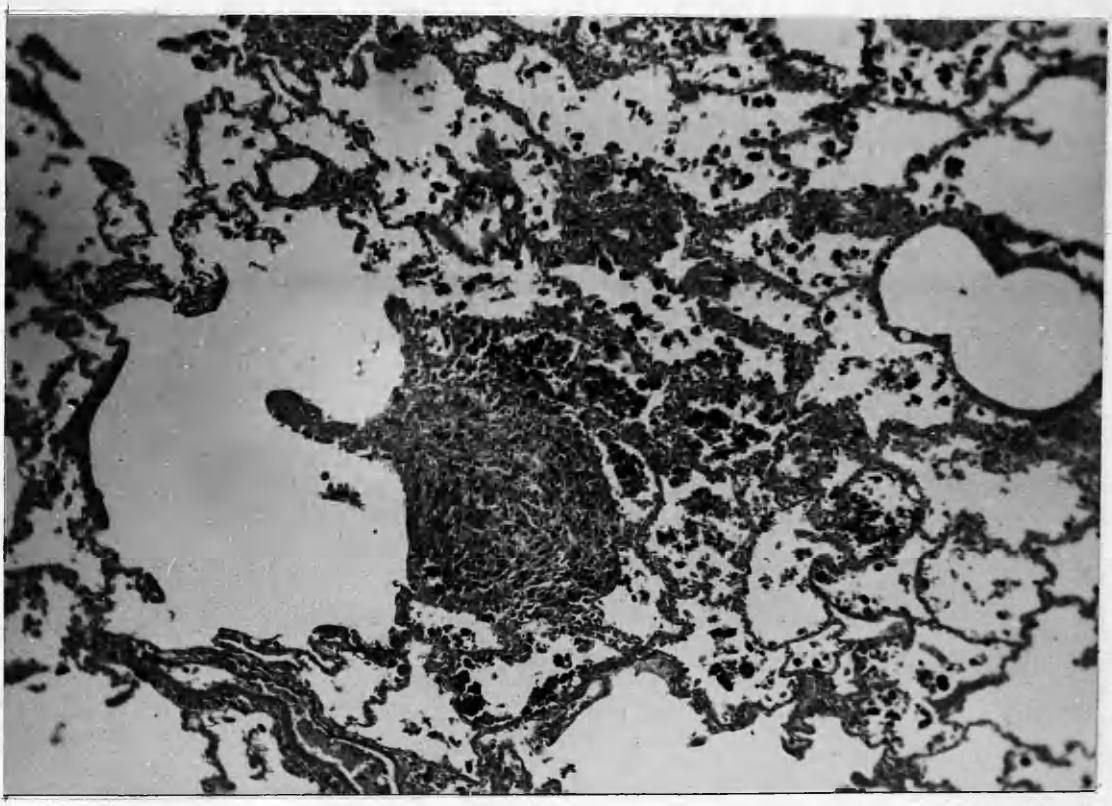
Figure V.

Haematoxylin and Eosin x 200.



From an African with 6 years underground other service at Mufulira. (X-ray - moderate increase in linear striation).

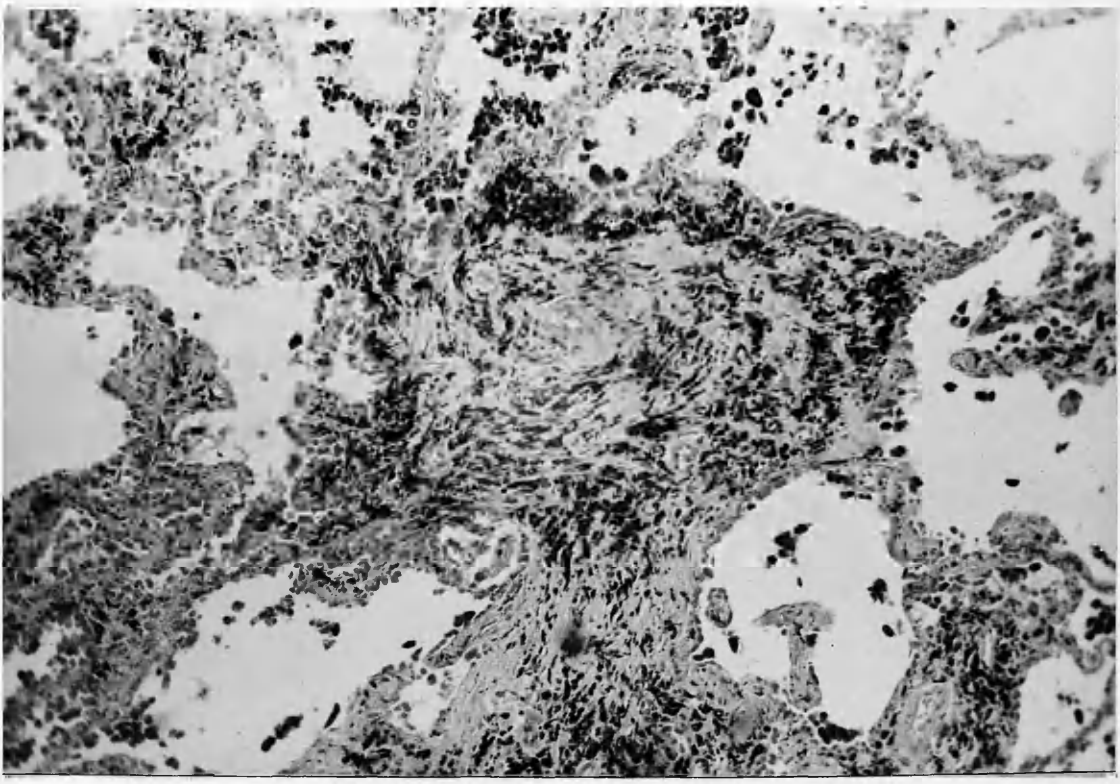
Figure VI.
Haematoxylin and Eosin x 200.



From an African with 7 years machine service at Mufulira. (X-ray - moderate increase in linear striation).

Figure VII.

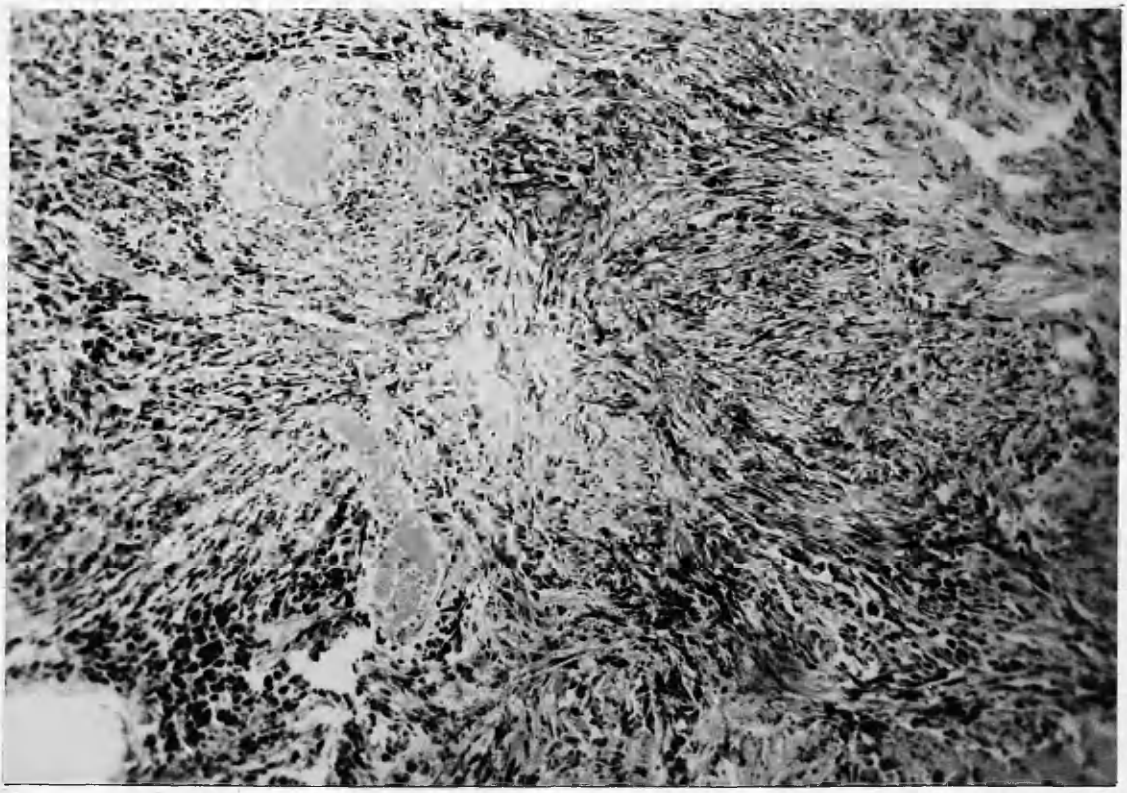
Haematoxylin and Eosin x 200.



From an African with 19 years machine and underground other service at Roan. (X-ray - well marked increase in linear striation).

Figure VIII.

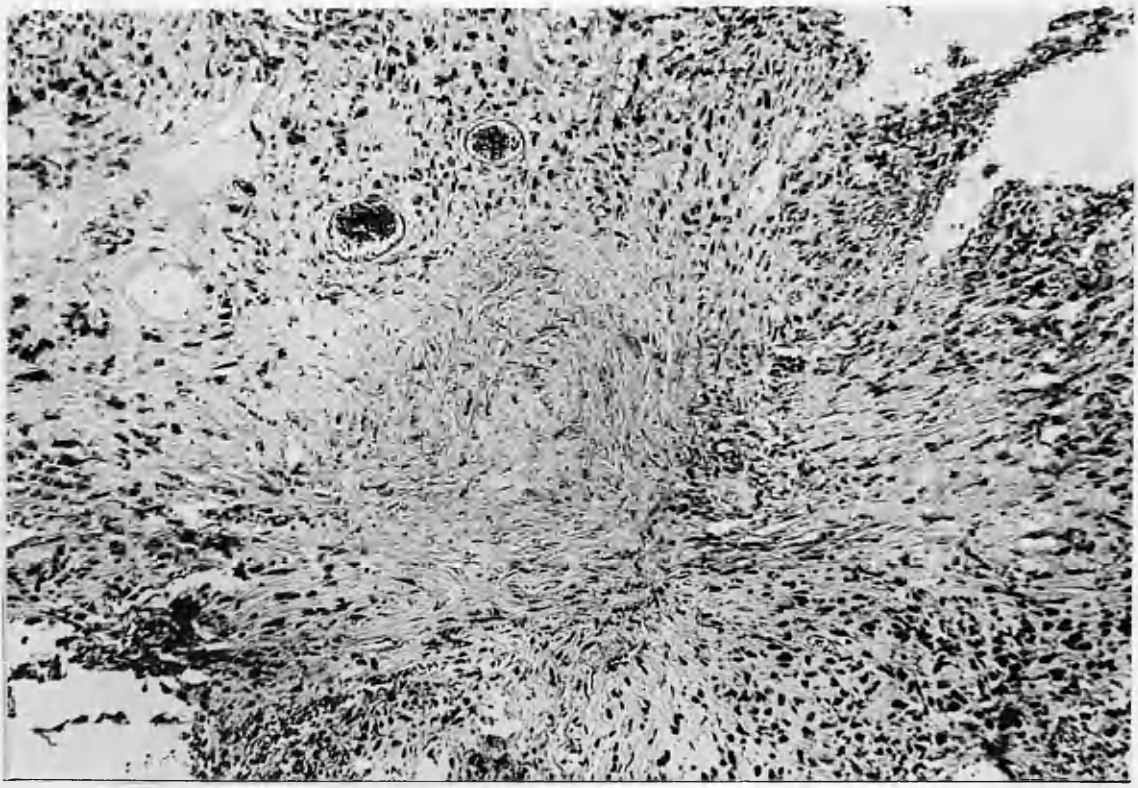
Haematoxylin and Eosin x 200.



From a European with 20 years machine and underground other service at Mufulira. Had also 10 years underground other service on the Rand. (X-ray - generalised arborisation with partial small mottling).

Figure IX.

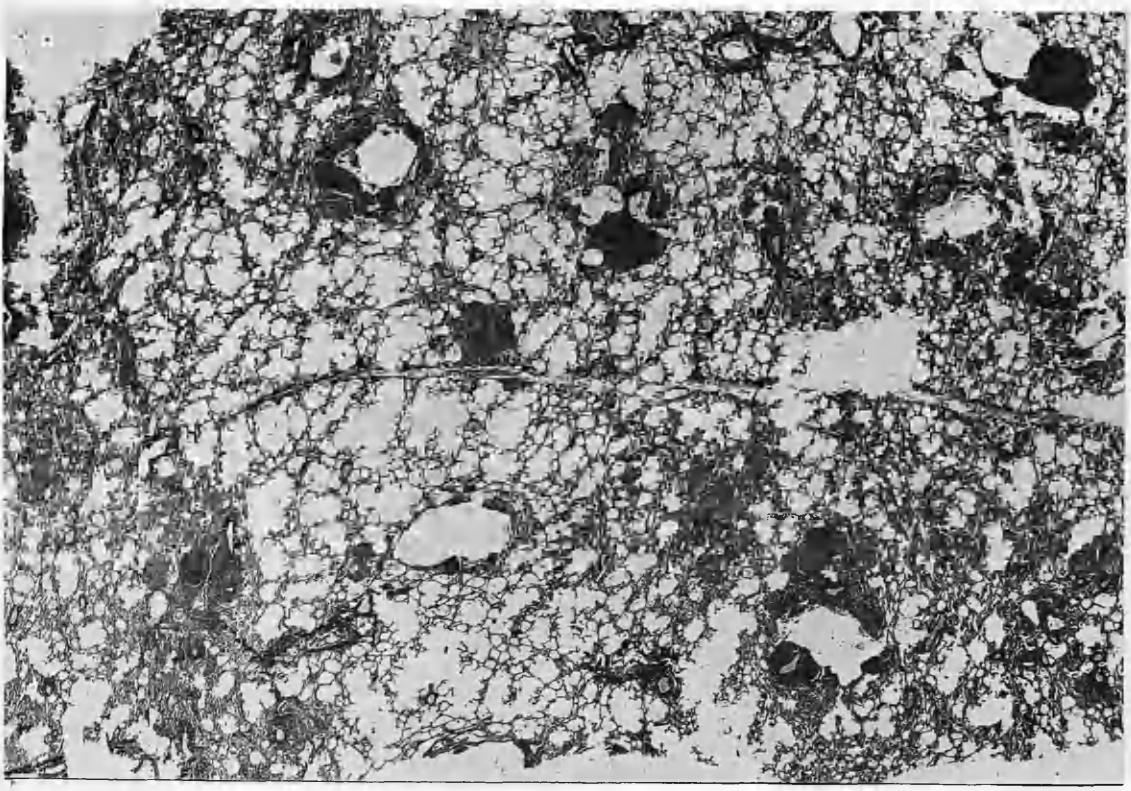
Haematoxylin and Eosin x 200.



From an African with 9 years machine service at Mufulira. (X-ray - generalised small mottling).

Figure X.

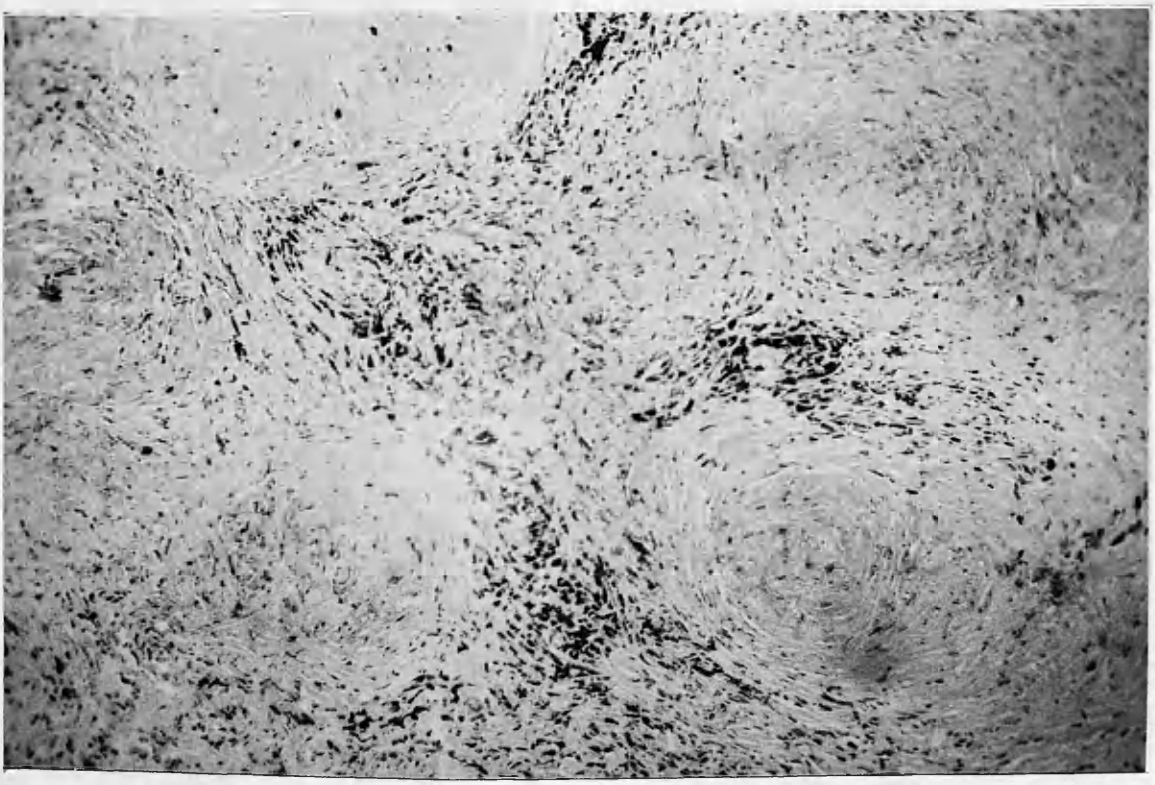
Haematoxylin and Eosin x 8.



From an African with 6 years machine service at Mufulira. (X-ray - generalised small mottling).

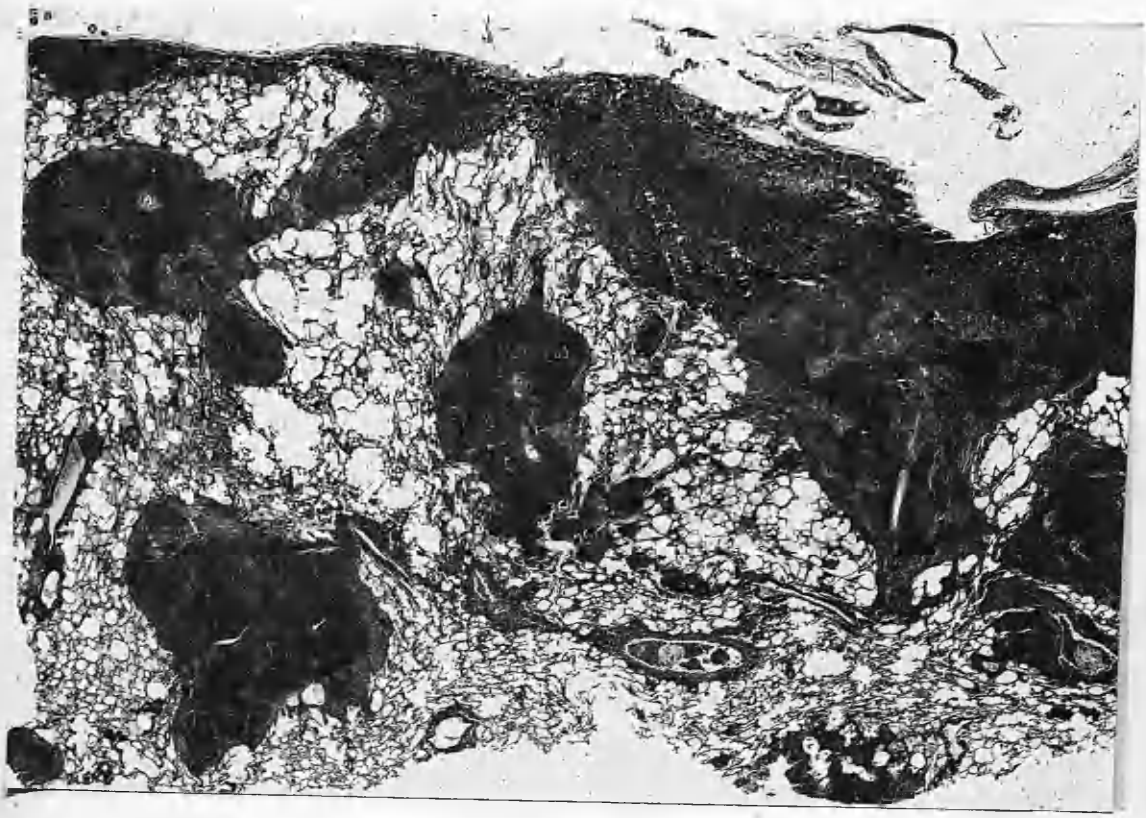
Figure XI.

Haematoxylin and Eosin x 200.



From a European with 12 years underground other service at Mufulira and 25 years as a coal miner. (X-ray - generalised arborisation with partial small mottling - infective).

Figure XII.
Haematoxylin and Eosin x 200.



From an African with 10 years machine service at Mufulira. (X-ray - medium mottling with massive fibrosis).

DIFFERENTIAL DIAGNOSIS.

Radiographic examination of the chest, properly carried out is the most accurate method at our disposal for the diagnosis of silicosis. Difficulty in the diagnosis only occurs when it is based on the radiographic appearances alone. There are many diseases in which the radiographic findings may be indistinguishable from those of silicosis.

This difficulty in diagnosis will not arise if the radiograph is examined in conjunction with a detailed clinical examination and a detailed occupational history. Such a history does not end with a knowledge of the approximate period exposed to a dust hazard but must include an intimate knowledge of the various occupations followed and the extent (both time and intensity) of the dust hazard in each.

Some of the more common conditions which simulate the radiographic findings of silicosis are considered below.

(1) Bronchogenic Carcinoma.

Metastatic carcinoma of the lungs can simulate nodular silicosis especially if the metastatic nodules are numerous and widely dispersed throughout both lung fields. Primary bronchogenic carcinoma may also cause

difficulty.../

difficulty in diagnosis.

Silicosis and primary bronchogenic carcinoma have frequently been observed together. This has led to the belief that silica, acting as an irritant to the bronchial epithelium may cause cancer. This is the view expressed by Anderson and Dible (1938).

Meiklejohn (1949), in his study of silicosis in the Potteries, records thirteen cases of primary bronchogenic carcinoma in three hundred and fifty-nine persons with simple silicosis. Two cases were also observed in two hundred and forty-one persons who died of silicosis accompanied by tuberculosis. He also records, however, eleven cases of bronchogenic carcinoma among one hundred and fifty cases in which there was no evidence of silicosis. On this evidence he does not subscribe to the theory that silica is an aetiological factor in the production of bronchogenic carcinoma. Similarly Smith (1939) quoting from the triennial report of the Silicosis Medical Bureau, Johannesburg, for the years 1935-1938 describes an analysis of three groups consisting of European males who had never worked underground, a group of non-silicotic European miners and a final group of silicotic European miners, in which the incidence of primary cancer of the lung was 1.27, 0.74 and 0.72

respectively.../

respectively. On this evidence he concludes that primary cancer of the lung is not more common in silicotic miners than non-silicotic miners.

Our experience here has not been sufficient to express an authoritative opinion but such as it is, it supports the view that the inhalation of silica is not an aetiological factor in the causation of primary bronchogenic carcinoma.

However, primary bronchogenic carcinoma does occur in association with cases of incipient or overt silicosis and may lead to difficulty in diagnosis. One such case is described below.

Case report.

Examination March, 1948.

European.

Age 57.

Clinical findings.

Occasional dry unproductive cough. Dyspnoea on exertion. No loss of weight. No other complaints.

Physical findings.

Percussion note resonant throughout. R.M. vesicular and air entry moderately good. Generalised prolongation of expiration. No adventitae. Sputum negative for tubercle bacillus.

Occupational..../

Occupational history.

141 months underground timbering at Roan Antelope.

151 months general underground work at Broken Hill mine (lead, zinc and vanadium and not scheduled) Northern Rhodesia.

Radiograph. (Fig. I).

Throughout both lungs the linear markings are increased and associated with a generalised arborisation which extends to the periphery.

The right hilum is increased in extent and density. The left hilum is within normal limits.

There is a diffuse hazy opacity at the right upper zone suggestive of infective silicosis.

Post mortem October 1948.

This confirmed the presence of carcinoma and the lungs showed an increase in pigment but no evidence of silicosis or tuberculosis.

Diagnosis.

Primary bronchogenic carcinoma present in the right hilum extending into the right lung. Section showed the structure of a squamous carcinoma.

(2) Tuberculosis.

Miliary tuberculosis - active or healed - often presents a radiograph with appearances similar to those

of.../

of silicosis. Tuberculous bronchopneumonia also can present very similar appearances to those of infective silicosis.

The nodulation seen in tuberculosis tends to be less dense. The nodules are usually smaller and the edges ill-defined. However, on the radiograph alone it is quite impossible to differentiate the two conditions. Fig. II illustrates a case of tuberculosis in which there is a tuberculous bronchopneumonia of the right lung and a haematogenous spread in the left. He had no underground service but had 54 months unscheduled surface service at Mufulira. Diagnosis was confirmed post mortem.

Fig. III illustrates a case of tuberculous bronchopneumonia. This case also had no underground service nor was he employed in a surface scheduled occupation. The radiograph shows a bilateral disseminated tuberculous bronchopneumonia. There is cavitation at the right upper and lower zones. The cavity at the right lower zone shows a fluid level. Sputum was positive for the tubercle bacillus.

Fig. IV. demonstrates a case of healed calcified tuberculosis. This man has to date 171 months underground timbering at Nkana. The radiograph shows a generalised

arborisation.../

arborisation and superimposed there are disseminated throughout both lung fields discrete, dense, healed tuberculous foci. This radiograph is comparable to that shown in Fig. V. Here, however, the nodules are more numerous and more widely spread. This radiograph is fairly typical of a long standing and slowly produced silicosis where, due to the affinity of silica for calcium, the silicotic nodules have calcified increasing their density. Mavrogordato (1922) has described fatty changes in fully developed silicotic nodulation. Calcification of such silicotic lesions may take place in long standing lesions, even in the absence of infection. The occupational history of this case was 130 months machines at Nkana and 120 months machines on the scheduled Rand mines.

(3) Haemosiderosis.

Due to the recent work of Scott, Lendrum and Park (1947) our knowledge of this condition has been greatly enhanced. They showed that in cases of mitral stenosis of long duration there is frequently demonstrable in the radiographs of such cases a diffuse nodulation similar to that produced by silicosis. Scott and his colleagues believe that those shadows are due to the deposition of haemosiderin in the alveoli.

Fig. VI demonstrates this condition.

Fig..../

Fig. VII is a contact print of the right upper zone showing the fine pin-head mottling. The occupational history of this man at the time of the radiograph was 84 months timbering at Nkana. He has been invalided from mining service.

(4) Sidero-Silicosis.

This type of silicosis is illustrated in Fig. VIII. This man had two hundred and forty months underground service in the haematite mines of Cumberland before coming to work in the Northern Rhodesia Copper Mines. Craw (1947) states that the physical properties of iron ore cause a very dense shadow and the nodulation in the radiograph illustrated shows such dense shadows. In addition the edges of the nodules are irregular and are not of a uniform density. According to Craw silicosis in the haematite mines of Cumberland has ceased to be a problem and radiographs such as illustrated are not now seen.

(5) Radio-Opaque dusts.

There also occurs pure siderosis where the radiographic appearances of nodulation are due to the radio-opaque iron oxide particles in the lungs. Doig and McLaughlin (1936) report the occurrence of such fine nodulation in electric arc welders. Such a condition

is..../

is included in the benign pneumoconioses. Another example of this is baritosis due to the inhalation of barium sulphate. Lanza (1938) stated that this condition is compatible with complete freedom from any symptoms. Radiographic findings similar to those of silicosis have also been described in metal grinders (Buckell et al, 1941), silver polishers (McLaughlin et al, 1945), and boiler scalers (Harding, Tod and McLaughlin, 1946).

(6) Mycotic infections.

Many of these fungus infections may simulate the radiographic appearances of silicosis but the nodules are less discrete and have fluffy margins. Chief among these are sporotrichosis and moniliasis. Actynomycosis may present the radiological appearance of a massive infective silicosis.

(7) Boeck's Sarcoidosis.

Although essentially a systemic disease, frequently the only demonstrable manifestation is pulmonary. When this is so the sarcoidosis may show, radiographically, multiple nodulation throughout the lungs, very similar to the nodulation of silicosis. Hilar lymphadenopathy may or may not be present. Where these appearances are present in an industrial worker exposed to a dust hazard diagnosis may be difficult.

Confirmation of the diagnosis of sarcoidosis depends on histology - Scadding (1950).

(8) Asbestosis.

Normally the radiographic appearance of asbestosis is easily distinguishable from silicosis as there is usually no nodular fibrosis. The classical description is that the lung fields have a ground-glass appearance. This hazy appearance affects the lower zones of the lungs most commonly, in contradistinction to silicosis where the mid and upper zones are primarily affected. A further characteristic of the radiological appearance of asbestosis in an advanced state is the irregular blurred outline of the cardiac and diaphragmatic outlines.

(9) Hydatid disease.

Fig. IX demonstrates the radiographic appearances of hydatid disease of the lungs. It will be noted that the opacity is circular and the outline is sharp and well defined. Such an appearance should not give any difficulty in diagnosis but I have seen a case where the radiograph showed bilateral subapical hydatid cysts which were very similar to a silico-tuberculosis.

(10) Other diseases.

Recently there has been described a disease due to the inhalation of beryllium or one of its compounds.

The..../

The radiographic appearances may be granular, reticular or nodular and the last may have a striking resemblance to the radiographic appearances of silicosis. The disease is associated with extreme dyspnoea, loss of weight and cough with a latent period varying from months to years prior to onset. There is also extreme toxaemia and Hardy and Tabershaw (1946) report a 35 per cent mortality in their series.

Polycythemia vera should also be mentioned in the differential diagnosis of silicosis because in that condition, due to vascular engorgement, the vascular shadows are greatly increased but there should be little difficulty in the differentiation of the diseases.

Bronchiectasis, which may be a complication of silicosis, has no specific radiological appearance and in fact should not be included in a differential diagnosis, but the case described below is included because the clinical manifestations of cough and dyspnoea were present in an underground worker. The case was atypical in that there were relatively few physical findings in the lungs with the exception of a few localised rales at the left base and sputum was not copious. A bronchogram (Fig. X) showed definite bronchiectasis at the left lower zone.

In...../

In conclusion the following important factors in the diagnosis of silicosis are emphasised :

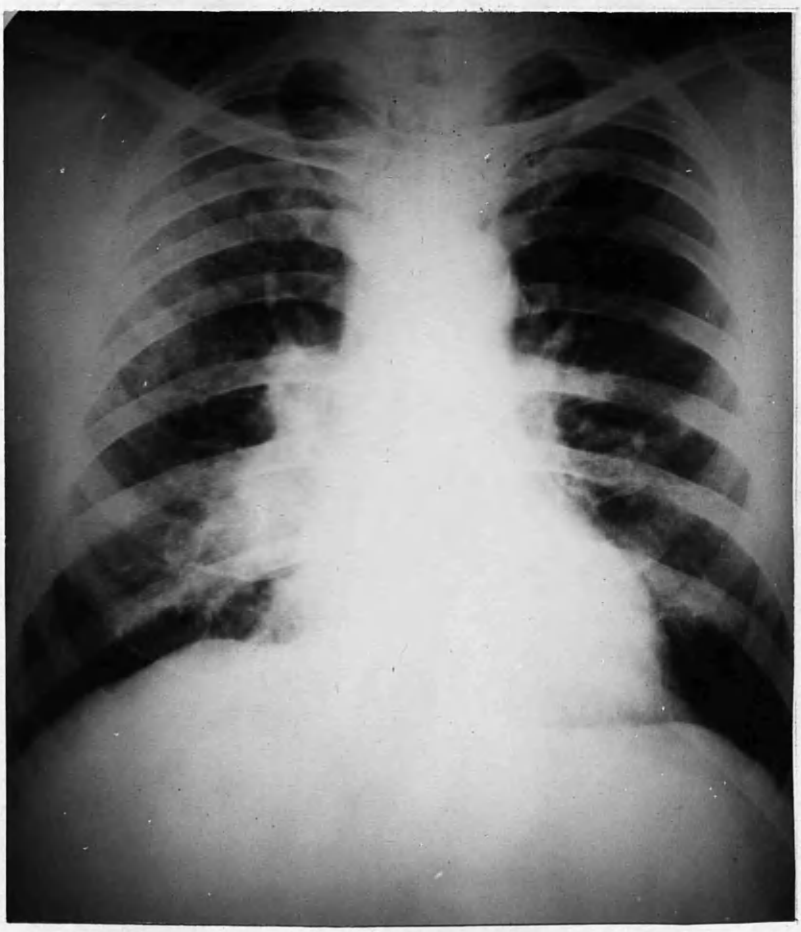
(1) Diagnosis should never be based on the radiographic appearances alone.

(2) A detailed clinical examination is necessary.

(3) An intimate knowledge of the occupational history is imperative.

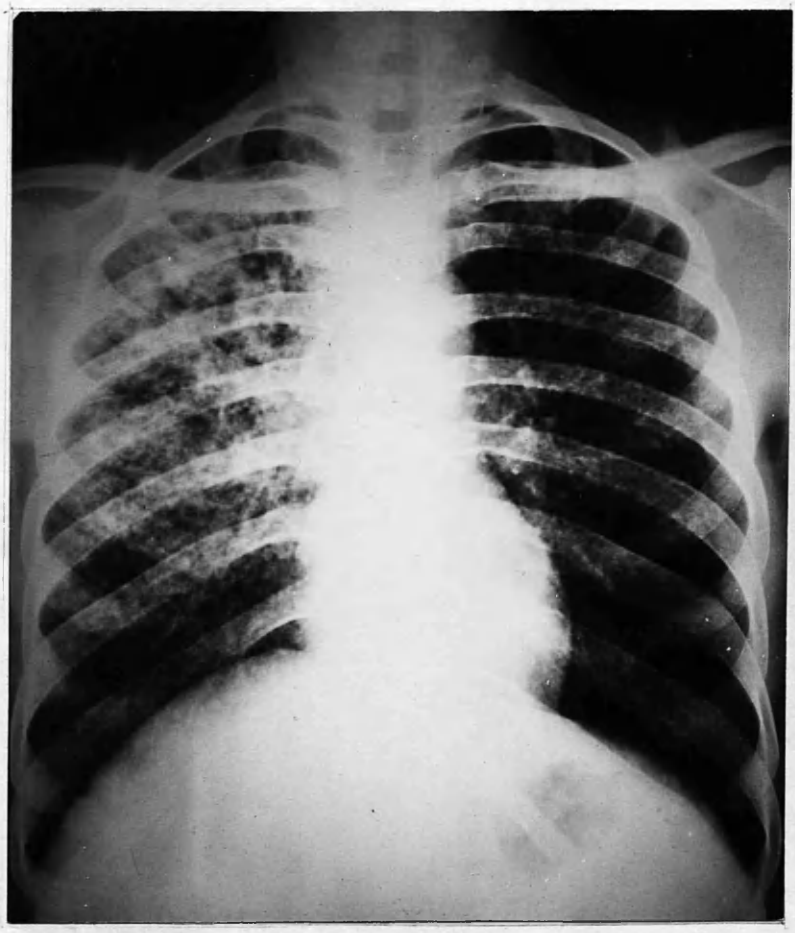
(4) The radiograph should be as near technical perfection as possible.

Figure I.
Bronchogenic Carcinoma.



From case of a European miner who had twelve years underground service at Roan and twelve years underground at a non-scheduled mine. Post mortem confirmed the presence of carcinoma but showed no evidence of silicosis or tuberculosis.

Figure II.
Acute Miliary Tuberculosis.

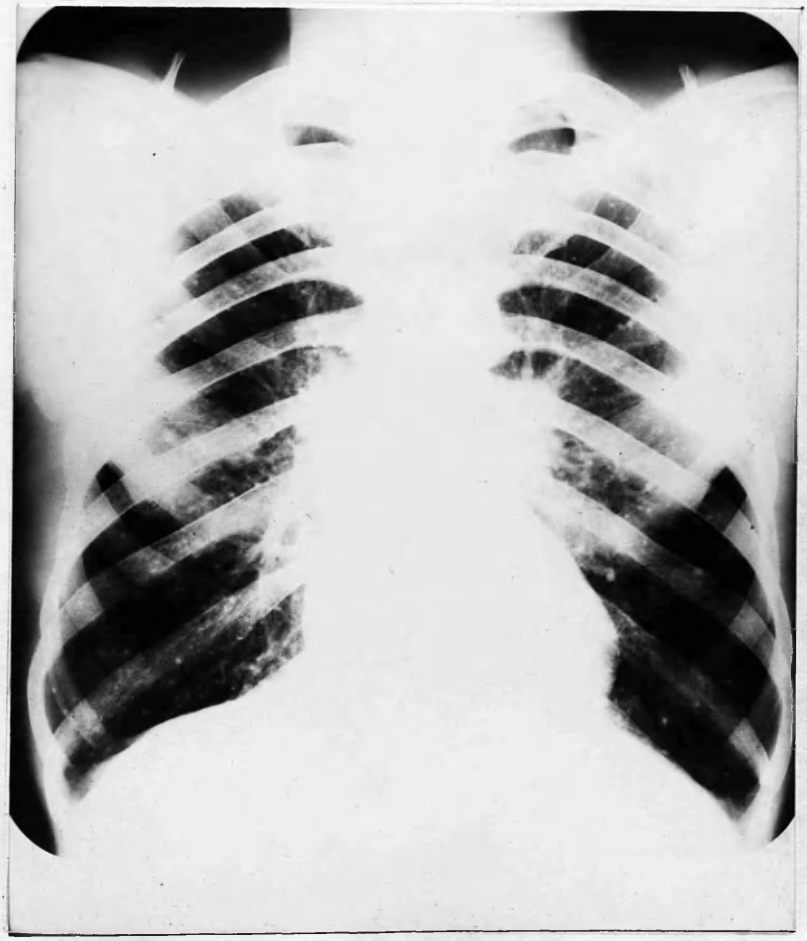


From case of a native unscheduled surface worker at Mufulira. He had no underground service. Diagnosis confirmed post mortem.

Figure III.
Acute Bilateral Tuberculous.
Broncho-pneumonia.

Illustrates bilateral tuberculous broncho-pneumonia from a case of a native mine worker with no underground or surface scheduled service. Sputum positive for tubercle bacillus. There is cavitation at the right upper and lower zones. The cavity in the lower zone shows a fluid level.

Figure IV.
Healed Calcified Tuberculosis.



Case of a European miner with fourteen years underground service at Nkana. There is generalised arborisation with multiple healed calcified tuberculous foci disseminated throughout both lung fields.

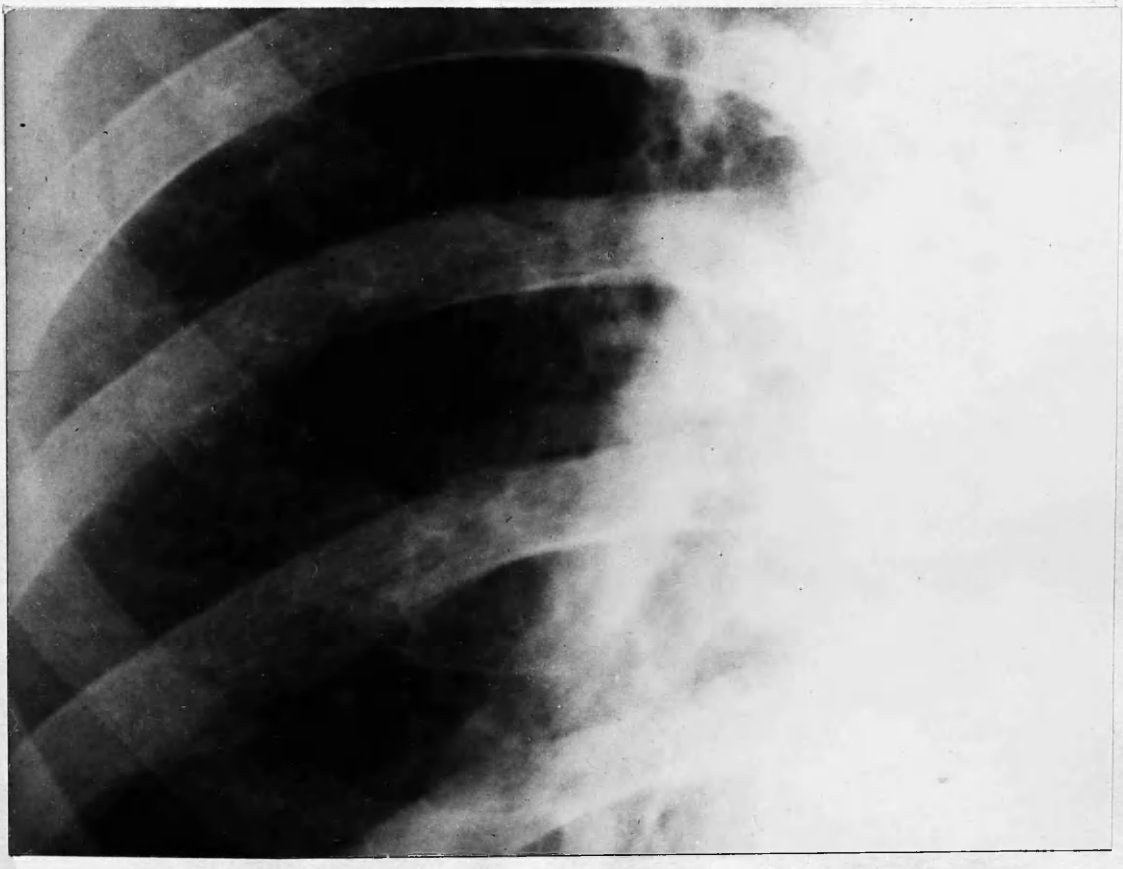
Figure V.
Generalised Small Mottling
with Calcareous Changes.

From a case of a European miner with a total of eleven years underground service at Nkana and eleven years underground service on scheduled Rand mines. This illustrates the calcareous changes that may take place in silicotic nodulation.

Figure VI.
Mitral Stenosis.

From a case of a European miner with seven years underground service at Nkana. This illustrates the fine mottling in mitral stenosis due to the deposition of radio opaque haemosiderin in the lungs.

Figure VII.
Mitral Stenosis.

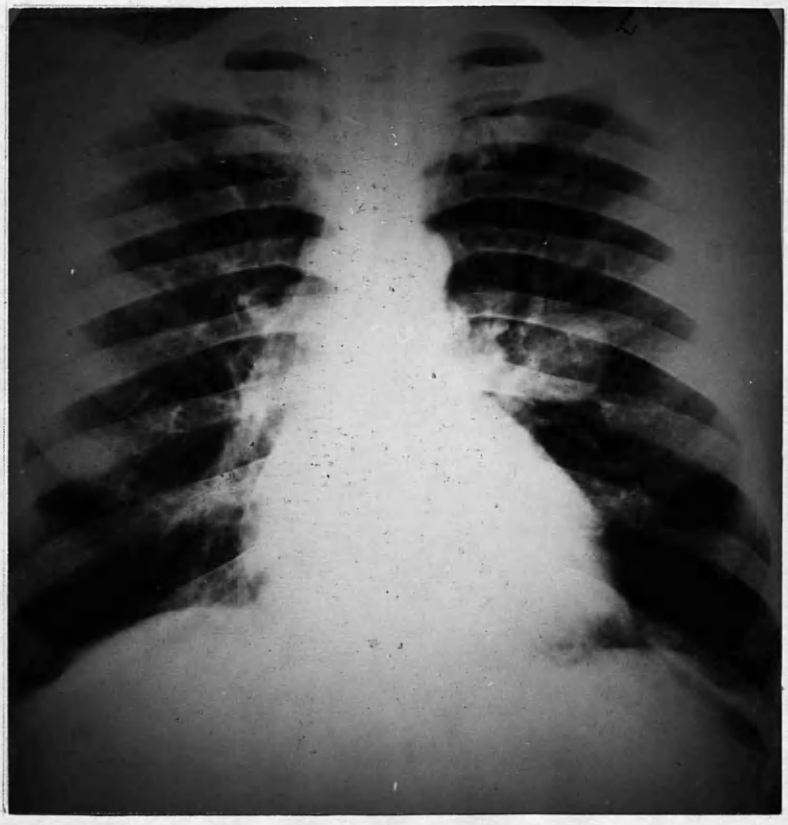


Contact print of the right mid zone of Fig: VI.

Figure VIII.
Sidero-Silicosis.

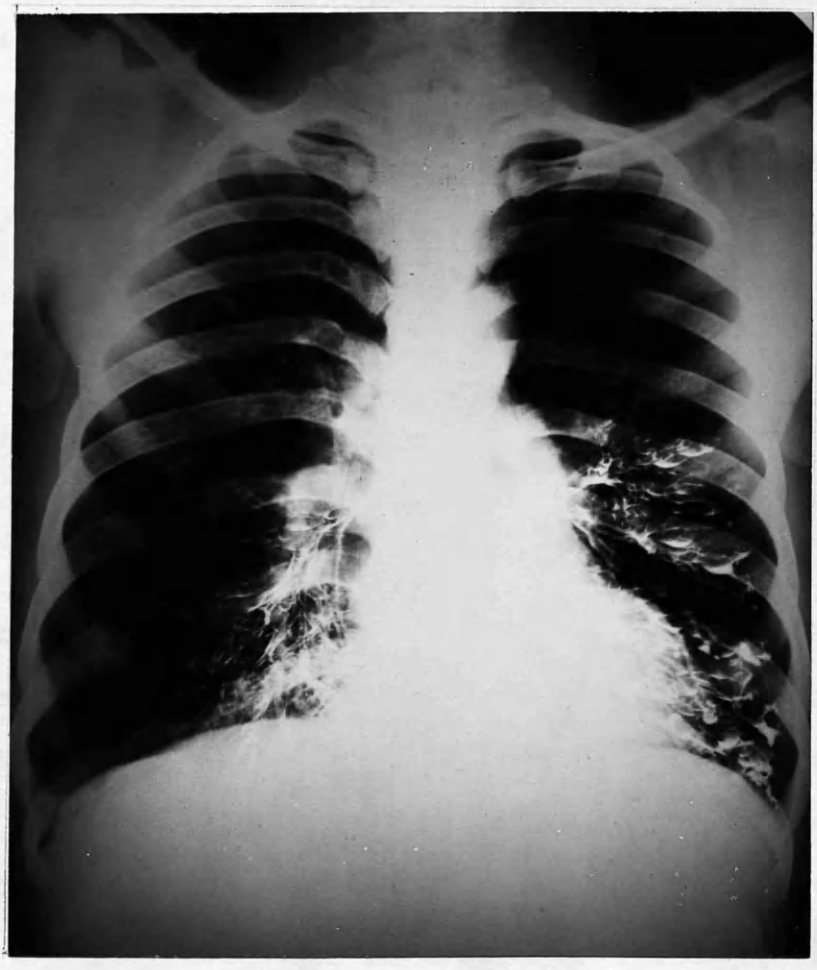
From a case of a European miner with twenty years service in the haematite mines of Cumberland.

Figure IX.
Hydatid Cyst.



From a case of a native miner with three years underground service at Nkana. The cyst lies in the left mid zone and presents a circular opacity with clearly defined edges.

Figure X.
Bronchiectasis.



Bronchogram from a case of a native miner with three years underground service at Roan showing left lower zone bronchiectasis.

DUST PREVENTION AND VENTILATION.

General.

The provision of adequate ventilation in the form of large volumes of fresh air throughout the working places in the mines is the chief factor in the reduction of the amount of harmful dust inhaled by the miners. The system employed and the standards achieved are referred to in the section on ventilation and dust sampling.

Methods employed in decreasing the amount of dust produced in the various mining operations here, are described below.

All pneumatic drills used in the four Copperbelt mines, with a few exceptions, are front vented with an axial water-feed. The introduction of front venting prevents large quantities of compressed air passing down the drill with the water. This aerated water carries dust and on release from the drill hole the bubbles of air burst and the dust is disseminated into the atmosphere. This does not occur with the front vented drills now in use. The tungsten carbide tipped drills now in use tend to produce less fine dust than ordinary steel drills because they retain a sharp cutting edge much longer.

In grizzleys, secondary blasting takes place

during...../

during the working shift but each grizzley has air and water blasts which remove and lay the dust considerably before the miners re-enter to resume work.

In primary blasting the schedules are so arranged that four hours elapse before the lashing crews enter the ends.

Before and during the lashing process the ore is well soaked with water to lay the dust. This also applies to mechanised scraping.

Although all these secondary measures are important factors, the mainstay of the reduction of the concentration of dust in the working places is an adequate ventilation system.

In the past few years each of the four mines has developed such a system and in so doing have done much to reduce the risk of silicosis. A mining expert from the British Ministry of Fuel and Power (Winstanley, 1949), after very full study of the data on the spot, recently wrote, "There is no doubt, on the evidence submitted, that between 1944 and 1949 the quantity of air circulated in each mine and the arrangements for directing the ventilation into the working places and to dust producing operations, have been substantially improved and have materially reduced dust concentrations in the air

in..../

in the mines, and consequently they have reduced the risk of miners developing silicosis".

Ventilation.

Each mine has a ventilation department supervised by a senior ventilation officer. The duty of this department is the supervision of the ventilation of the mine and the taking of dust samples.

Ventilation generally is supplied by downcast and upcast shafts and auxiliary fans and the average minimum quantity of air per minute per person is approximately 220 cubic feet on all four mines, ranging from 197 cubic feet at Roan Antelope to 300 cubic feet at Mufulira. Air is distributed by means of metal and canvas tubing and after ventilation is liberated by means of return airways to the upcast shafts. There is no one employed in these return airways.

The following tables show the total and individual air supply on the four mines. These figures are of recent origin.

Table I...../

TABLE I.

Total quantity in cubic feet per minute of air passing through the four mines.		
MINE	CUBIC FEET OF AIR PER MINUTE.	
	DOWNCAST	UPCAST
Nkana	610,000	654,000
Nchanga	327,000	356,000
Roan Antelope	860,000	900,000
Mufulira	737,000	762,000

The apparent discrepancy in the quantity of downcast and upcast air is due to the liberation of compressed air underground.

TABLE II.

Minimum quantity of air in cubic feet per minute per person underground.	
MINE	CUBIC FEET PER MINUTE PER WORKER.
Nkana	238
Nchanga	186
Roan Antelope	197
Mufulira	301

The above tables show that ventilation is very adequate on all four mines. This shows a remarkable improvement in ventilation in recent years when, due to the

war.../

war and the demand for increased production and inability to obtain materials, ventilation did not have the high priority of to-day. This is well illustrated in Table III which shows the comparative number of auxiliary fans in use in 1944 and 1949.

TABLE III.

MINE	1944 Fans in use.	1949 Fans in use.
Nkana	71	175
Nchanga	33	96
Roan Antelope	48	258
Mufulira	39	204

Airborne dust contains less silica than the rock from which it is produced in mining operations and Table IV shows the averages at the four mines and are from recent samples.

TABLE IV.

Free and total silica content of dust concentrations in the four mines.		
MINE	PERCENTAGE FREE SILICA.	PERCENTAGE TOTAL SILICA
Nkana	21	40
Nchanga	55	71
Mufulira	38	56
Roan Antelope	31	50

Dust Sampling.

Dust sampling is done by means of the Denvers

konimeter.../

konimeter and a standard technique is employed in preparation, treating and counting, thus giving comparable counts on the four mines.

The konimeter is used because it allows more frequent counts to be taken and a larger number of working places to be visited. The thermal precipitator is not in general use in the Copperbelt, but it has been found that there is a correlation between the results given by the two instruments.

Dust sampling takes place daily and the samples are taken at the level of the workman's face and a foot from his mouth.

All particles from 5 microns to 0.2 microns are counted. There is no size grading of particles below 5 microns.

A recent survey of the four mines showed that the average combined dust count for all mining operations is little over 200 particles per cubic centimetre.

The equivalent average dust concentrations at working points in the scheduled gold mines on the Witwatersrand was 180 particles per cubic centimetre (Lambrechts, 1945).

SUMMARY and CONCLUSIONS.

1. The history and development of legislation in the Northern Rhodesian copper mines is described.

2. The aetiology of silicosis is reviewed.

3. The organisation and daily working of the Northern Rhodesia Silicosis Medical Bureau is reviewed.

4. Details of the initial and periodic examinations by the Medical Bureau are given.

5. The results of the clinical survey of one hundred and fifty silicotics are recorded in detail.

6. A study of the erythrocyte sedimentation rate in silicosis and silico-tuberculosis showed that the normal value of the erythrocyte sedimentation rate in Africans is higher than in Europeans. In simple silicosis in both Europeans and Africans a slightly raised value was recorded and in the presence of infection there was a definite rise. It is considered that a raised sedimentation rate has a certain value in assessing the presence of infection in silicosis.

7. A comparison of clinical manifestations with the radiological stages of silicosis showed a striking lack of correlation particularly in the absence or the presence of only a slight degree of dyspnoea. This is a marked contrast to the usual picture in coal miners' pneumoconiosis where the patient is more dyspnoeic than ill.

8..../

8. A radiological classification of silicosis is presented and discussed. The classification contains twenty-one main groups.

9. The occupational incidence among 4,844 African underground workers disclosed that machine boys developed abnormal radiographic appearances sooner than the underground other group. The occupational incidence of 150 African cases of silicosis occurring in the four copper mines disclosed that machine boys had the highest incidence. The factor of individual susceptibility is discussed. The possibility of increase in linear striation being non-specific is mentioned.

As a result of the annual turnover of native labour, interruption of underground service and subsequent intermittence of exposure to harmful dust, the total exposure in such native miners is considerably reduced and consequently the risk of their developing silicosis is correspondingly lessened and the time taken to develop the disease proportionately increased.

In general, with the introduction of excellent ventilation and greatly improved mining methods and resultant reduction of dust concentrations, the incidence rate of silicosis has been reduced on the four copper mines.

10..../

10. The complications of silicosis occurring in this series are recorded and discussed. The relationship between massive fibrosis and tuberculosis in silicosis occurring in copper miners is discussed.

The majority of the natives of Northern Rhodesia are acquiring a degree of immunity to infection by the tubercle bacillus, as shown by the presence of healed calcified lesions in 80 per cent of chest radiographs. When natives, however, develop pulmonary tuberculosis, they have little resistance to the established disease and die rapidly of an acute caseating lesion.

11. Representative sections from 62 post mortem cases are presented and a comparison is attempted between radiological and pathological material.

12. Illustrative cases presenting the difficulty in differential diagnosis of silicosis are given.

13. Methods of dust prevention and dust sampling are detailed and discussed.

14. A full appendix gives details of payments for contraction of silicosis and details of the occupations mentioned in the text and illustrative tables of the composition of the rocks in the four mines.

APPENDIX.

Compensation Payments for Contraction of Silicosis.

No account of silicosis in Northern Rhodesia would be complete without a note about the arrangements for payment of compensation to employees in the copper mines who contract the disease and it may be said at once that the law of Northern Rhodesia which provides for such payments (it is an Ordinance quite separate from the Workmen's Compensation Ordinance) provides also for payment of compensation to workers exposed to the risk of silicosis who contract simple tuberculosis provided they have been employed as miners for not less than one year and are certified to have tuberculosis within one year of ceasing to be so employed.

This payment of compensation for what is not, in my own view, as I have stated previously, an industrial disease, is not the only important difference between the compensation arrangements of the United Kingdom and those of Northern Rhodesia. In an unpublished memorandum prepared by the British Ministry of National Insurance for the Commission which reported on future silicosis legislation in Northern Rhodesia reference is made to compensation in Britain for silicosis discovered before 5th July, 1948, being governed by the various "Schemes"

under.../

under the Workmen's Compensation Acts, while silicosis discovered subsequent to that date is dealt with under the National Insurance (Industrial Injuries) Act and the following note is added :-

> "These two systems differ in certain fundamental respects. The Workmen's Compensation Schemes provide for the payment by employers of compensation in respect of loss of earning capacity. Benefit under the Industrial Injuries Act, on the other hand, is dependent on the degree of disablement - that is, on the loss of health and strength - and is paid out of a State Insurance Fund, made up of contributions from employers and workers and from the Exchequer".

Under the British Workmen's Compensation Acts, compensation is payable upon any of three types of certificate being given by the Silicosis Medical Board; these are certificates of suspension, certificates of total disablement and certificates of death. There is, however, the qualification, in respect of the first type of certificate mentioned, that no claim for compensation will lie if the Medical Board suspends but certifies that general physical capacity for employment has not been impaired by silicosis. Under Northern Rhodesian law,

early...../

early (first stage) silicosis is compensable in the absence of any reduction of physical capacity by silicosis; South African law makes a like provision. The nature of the certificates which must precede any compensation payment show that cessation of work in the hazardous occupation must accompany any such payment, a condition which applies under present Northern Rhodesian law but which is likely to disappear in Northern Rhodesia at an early date. Ordinarily, under the British Acts here under reference, compensation is payable by the individual employer, a circumstance which now applies in Northern Rhodesia where, however, forthcoming legislation seems likely to provide for it to be payable from a general fund maintained by contributions from the employers. The basis upon which employers will contribute in Northern Rhodesia seems likely, however, to be similar to the basis used in South Africa rather than the basis (variation with wage bills) which operates in England for those Schemes under the Workmen's Compensation Acts (e.g. Scheme for the Refractories and Sandstone Industries) which use a general fund. In South Africa the general fund is maintained be levies demanded by the Compensation Board in accordance with an actuarial calculation of what is likely to be required in any year and the levy on

any..../

any mine-owner may take account of the particular dust hazard in his mine or mines. In general, compensation under the English Workmen's Compensation Acts is by periodical payments but commutation to a lump sum is provided for.

Under the British National Insurance (Industrial Injuries) Act which governs cases diagnosed after July, 1948, the main differences are that the amount of compensation is strictly related to the amount of disability assessed. The assessment is designed "to represent the resulting handicap in carrying on the normal activities of life, without regard to the claimant's occupation or other particular circumstances" (unpublished memorandum already referred to) and is made in steps of five per cent. Payments are weekly and no commutation to a lump sum is permissible. Because of the progressive nature of silicosis each award is provisional until one hundred per cent incapacity is reached and the amount of the payments increases pari passu with the assessment, the maximum (i.e. for 100% disability) being fixed by law.

The South African plan of using, for compensation purposes, three defined stages of the disease silicosis is well known and has been adopted by a number of countries, including Northern Rhodesia and is un-

likely to be departed from in forthcoming Northern Rhodesian legislation. The division of the course of a slowly progressive disease into three stages is of course a quite arbitrary proceeding and the persons certified to be in any one stage will necessarily include persons having fairly widely different degrees of individual incapacity for work, but all receiving the same award.

Anyone who works under the three stage system quickly becomes aware that difficulties attach to it. Border-line cases are necessarily rather frequent. They are inescapable in a system which uses a combination of demonstrable radiographic signs with disability as the criterion of passage from one stage to another. The situation is made yet more difficult when the radiographic signs which characterize the three stages are described in the law (as in South Africa and Northern Rhodesia) in no more precise terms than "the earliest specific signs", "moderately marked specific signs" and "marked specific signs" without any guide as to what signs are really specific, and when the measure of disability which has to be applied is nothing more clear-cut than an opinion whether the individual concerned is or is not "incapacitated from performing moderate manual work".

At...../

At first sight, therefore, the present British system of making assessment of disability in steps of five per cent and of varying the amount of compensation accordingly appears attractive and equitable. It appears to have been the difficulties attaching to the three stage system which caused the majority report of the South African Commission of 1941-43 to recommend actual loss of earnings, as distinct from loss of earning power, as the factor which should govern the amount of the money award to be made. The prevision of that proposal is attractive though its being equitable is open to argument; it was not adopted.

While I have pointed above to certain attractions appertaining to the British system of rather exact numerical assessment, for the purpose of compensation, of incapacity for work, I do not support that plan. Such a system, while having the appearance of exactitude and of being well suited for application in the case of a slowly progressive disease is in fact scarcely, if at all, less arbitrary than division into three stages. I doubt the possibility of equitable assessment of human physical disability in steps so small as five per cent and when there is added the fact that to make assessed physical disability the sole measure of money benefits is to

invite...../

invite the counterfeiting of disability, my support goes wholeheartedly to a system which has regard to demonstrable damage to the lungs and which, while not excluding physical disability from any place in the assessment of an arbitrary stage, deals with the question of disability in broad terms which do not, for all their lack of verbal precision, offer any serious difficulty of interpretation to a medical man with experience and knowledge both of industrial conditions and of the psychology of industrial workers. As to the equity of the three stage system, being applied as follows in South Africa and in Northern Rhodesia, no man in any stage can get less than his due so far as concerns disability and the majority get more. Real disability from silicosis to the extent of one hundred per cent "handicap in carrying out the normal activities of life, without regard to the claimant's occupation or other particular circumstances" (Unpublished memorandum already quoted) is rare. Experience has shown that all silicotics assessed as in the third stage would be assessed, if a numerical basis were employed, as between sixty and one hundred per cent disabled. Nevertheless, the money award for all in the third stage of silicosis has been fixed as a life pension,

at least as large as that provided under Workmen's Compensation legislation for one hundred per cent disablement by accident. Working backwards from that pension, the award for all in the second stage has been fixed as three-fifths of that sum, experience having shown that all silicotics certified as in the second stage would, on a numerical basis, be assessed as between twenty-five and sixty per cent disabled. In both South Africa and Northern Rhodesia certification of silicosis in the first stage is made on the earliest appearance of specific radiographic signs, without reference to there being disability. This is regarded ordinarily by the miners themselves as equitable being (in their own words) in the nature of "compensation for an injury received". It is payable in Northern Rhodesia and in South Africa in the form of a lump sum, but the Compensation Board of each of those countries is given an over-riding discretion to pay it in instalments. This payment of compensation without physical disability is, of course, a departure from the old, underlying principle that workmen's compensation payments are made because of loss of earning power. As the years have passed, however, that principle has been less and less treated as the governing principle and for my own part, I see no inequity in requiring an employer to recompense an employée who has contracted a disease

such...../

such as silicosis in his service.

This section on the compensation of silidosis would be incomplete without mention of the remarkable if not unique arrangement, negotiated between the three independent governments of South Africa, Southern Rhodesia and Northern Rhodesia, whereby a man with service in a dusty occupation in more than one of those countries receives compensation from the Compensation Board of each country where he has served, pro rata to the length of his exposure to dust hazard there.

WORKING HOURS AND DESCRIPTION OF OCCUPATIONS.

As many of the names of underground occupations in the Copperbelt are peculiar to the area it is necessary to define them. In order to gain a sound working knowledge of these underground occupations it was found necessary to make visits underground under actual working conditions. During these visits photographs of underground workers actually at work were taken and illustrate this text. In addition it should be mentioned that all African workers are referred to as "boys" irrespective of age.

The working hours and the time of shifts are the same on all four mines with very minor variations.

The time of the three main shifts are sometimes staggered over the various shafts but are, broadly speaking, 7 a.m. to 3 p.m., 3 p.m. to 11 p.m; and 11 p.m. to 7 a.m. There is also a third or intermediate shift from 7 p.m. to 3 a.m.

Shifts.

(a) First Shift. This shift from 7 a.m. to 3 p.m. which is the main shift of the day and the one on which the largest number of people are employed, is the rock-breaking shift and, with very few exceptions, the only shift on which rock drills are in use. The rock-breaking

consists..../

consists of drilling and blasting main haulages (12' x 14'), sub-level drives (6' x 7'), stopes and raises.

(b) Second and Third Shifts. These shifts from 3 p.m. to 11 p.m. and 11 p.m. to 7 a.m. are concerned mainly with "Tramming" or the drawing off of broken ore from the stopes.

(c) Intermediate Shift. This shift is generally referred to as the lashing shift and is the shift on which the ground broken in advancing main haulages, sub-level drives and raises, is cleared out in preparation for further drilling and blasting in the following rock breaking shift. The fact that this shift starts at 7 p.m. allows an interval of four hours between blasting operations and the entry of the lashing gangs.

Occupations.

(a) Lasher. During the rock breaking shifts, main haulages and sub-level drives are advanced by drilling and blasting. It is the work of the lasher to clean out the broken ground and prepare the working place for further drilling and blasting. Lashing of main haulages is done by means of mechanical scraper loaders (Fig: 1) and sub-level drives are lashed by hand shovelling and

wheel...../

wheel barrows, (Fig: 2).

In both these processes the broken rock is sprayed with water but nevertheless the dust hazard is considerable.

(b) Grizzley Boy. At the bottom of each stope and just above the stope loading-chute, a grizzley consisting of a heavy steel grid is placed. The purpose of this grizzley is to hold back rocks which would be too large to handle through the loading chute. The job of the grizzley boy is to break up these large rocks and ensure an even flow of ore to the loading chute. Rocks are broken up by drilling and blasting or more commonly by mud blasting (Fig: 111); Fig: 1V shows a hold-up in the stope. The grizzley boy is in the act of inserting a "bomb" which he pushes up on a bamboo stick. This breaks up the rock and allows a free flow of ore to the grizzley. The chains the grizzley boys wear are to anchor them and prevent them from falling through the grizzley. This secondary blasting produces a very real dust hazard as the boys return to the grizzleys almost immediately after blasting.

(c) Trammer. When the ore has passed into the loading-chute it is the job of the trammers (Fig: V) to load the

ore..../

ore through the compressed-air-operated doors of the chutes into trucks and to convey it to the main tip at the shaft (Fig:V1). At each tipping and loading there is considerable dust in the atmosphere. Trucks are of 9 tons capacity and are usually coupled into trains of 8 and 10 trucks. These trains are hauled by electric locomotive driven from an overhead trolley wire. A tramming crew usually consists of a driver, a pole boy (who ensures that the trolley is kept on the wire), two whistle boys (who direct the trucks to the main tip) and a loading-chute boy. All these are equally exposed to the dust hazard of tramming.

(d) Timber Boy. Each European timberman has normally four to six timber boys. The timberman's work consists of installing setts and props for support, equipping service raises, installing loading chutes and grizzleys. A timberboy's work therefore takes him to all parts of the mine. Generally his risk of exposure to dust is less than that of other underground workers.

(e) Scraper Boy. In certain areas where the ore body is too flat to allow the broken ore to gravitate to the loading chutes, scrapers are installed. These scraper winches have a hauling rope and tail rope passing through a sheave block at the top of the stope. These ropes

are..../

are attached to a large steel scoop and by hauling this scoop up and down the stope, the ore is scraped down to the loading chute. Scraper boys drive the winches. Again the dust hazard here is considerable in spite of the fact that this operation is wet.

(f) Machine Boy. The normal practice is to drill main haulages and sub-levels with drifters (Figs: Vll & Vlll) and pom-poms (Fig: lX) are used for drilling up holes such as stopes and raises. With the introduction of tungsten carbide tipped drill steels, the drifters are gradually being replaced by jackhammers (Fig: X).

(g) Spanner Boy. The spanner boy is one of the team of machine boys, his reponsibility being the alteration and adjustment of the set of the drill. A spanner boy is shown in the right background of Fig: Vlll. The dust hazard of drilling is undoubtedly the greatest of all for it is in this operation that miners are exposed for long periods to continuous recently fractured fine particles of silica bearing rock. All the drilling is wet.

Figure 1.

Mechanical Scraper mucking out a sub drive.

Figure 11

Lashing boys mucking out a sub drive.

Figure 111

Grizzley boss boy placing a mud blast.

Figure 1V

Grizzley boss boy placing bomb in a draw point.

Figure V

Tramming boy loading Granby car from a stope chute.

Figure Vl.

Granby car being tipped at the main ore pass.

Figure Vll

Machine boys drilling drive face with mounted drifters.

Figure Vlll.

Machine boy drilling sub drive with mounted drifter.

Figure 1X.

Machine boys drilling a stope face with an automatic stoper (pom-pom).

Figure X.

Machine boys drilling staging holes with jack-hammer.

DESCRIPTION OF THE ROCKS FOUND IN THE COPPERBELT MINES.

Mining is carried out in the four mines in the following types of rock (Table I). The percentage free and total silica by weight is tabulated. The names of the various rocks listed below are those used locally.

TABLE I.

NAME	PERCENTAGE FREE SILICA.	PERCENTAGE TOTAL SILICA.
Granite	34-48	74-80
Basement schist	16-62	48-74
Quartzite	40-70	62-86
Ore shale	29-33	50-57
Graywacke	63	71
Dolomite	43	46
Arkose	64	81
Argillite	28	60

The following tables show the chemical analysis of the various rocks at each mine and the silica content and percentage of total excavating in the various formations :-

TABLE...../

TABLE II.

Composition of Rocks at Nkana.

Rock	% Total SiO2	% Free SiO2	% Quartz = 100% Free SiO2	% Felspars = 65-68% Combined SiO2	% Mica Chlorite = 30-45% Combined SiO2	Carbonates = No Silica	Opaques e.g. Sulphides = No Silica	Other minerals
Basement Schist	75	62	64	-	34	-	2	TR.
Footwall Quartzite	86	70	70	26	1	1	2	TR.
Footwall Sandstones & Conglomerates	64	37	37	33	15	12	2	1
Lowgrade Argillite (15')	44	25	26	3	43	27	1	TR.
Banded Ore (12')	36	20	20	16	16	42	5	1
Cherty Ore (9')	46	32	35	11	18	26	10	TR.
Porous Sandstone (4')	16	8	9	6	10	69	6	TR.
Av. Ore Horizon	39	23	25	9	26	35	5	TR.
Hanging Wall Argillite	50	26	27	14	35	20	3	1

TABLE III.

SILICA CONTENT AND PERCENTAGE OF TOTAL EXCAVATING IN THE VARIOUS FORMATIONS.

	Basement Schist	Footwall Quartzite	Footwall Sand-stones & Conglom-erates	Ore Horizon	Hanging Wall Argill-ite
% Total Silica	75	86	64	39	50
% Free Silica	62	70	37	23	26
% Total Excavating	2.46	0.27	8.89	86.96	1.42

Overall average of the free silica present in the rocks in the working places of the mine, weighted by the percentage work done in these places equals 25%.

TABLE IV.

Composition of Rocks at Roan Antelope.

Rock	Total SiO2	Free SiO2	Al_2O_3	CaO	MgO	CO_2	$Na_2O + K_2O$
Footwall Quartzite	80.10	-	8.05	1.13	0.36	0.48	6.07
Ore Shale	55.52	-	14.05	1.54	4.33	1.58	10.33
Hangingwall Quartzite	57.96	-	19.41	1.04	2.89	1.03	10.00

TABLE V.

SILICA CONTENT AND PERCENTAGE OF TOTAL EXCAVATING IN THE VARIOUS FORMATIONS.

	Granite	Basement Schist	Footwall Quartzite	Hangingwall Quartzite	Ore Schale
% Total Silica	74.5	67.0	62.5	76.0	52.0
% Free Silica	34.0	34.5	40.0	44.0	28.5
% Total Excavating	0.25	0.85	7.34	1.42	90.14

Overall average of the free silica present in the rocks in the working places of the mine, weighted by the percentage work done in these places equals 29.6%.

TABLE VI.

Composition of Rocks at Mufulira.

Rock	Total SiO_2	Free SiO_2	Al_2O_3	CaO	MgO	CO_2	Na_2O & K_2O
Argillaceous Quartzite	62	40	9.2	0.9	15.1	1.4	1.9
Quartzite & Graywacke	73	61	3.9	2.1	2.9	3.4	3.1
Quartzite & Shale	63	35	10.7	0.6	13.7	1.0	3.7
Lower Dolomite	46	43	1.3	12.9	12.0	20.6	-
Graywacke	68.5	63	1.8	1.2	3.1	1.9	0.7
Quartzite	76.5	51.5	6.8	1.8	1.3	2.9	6.5
Shale & Quartzite	77.5	53	7.6	-	5.4	-	4.6
Mudseam	62.5	40	7.9	2.7	11.4	4.3	3.1
Graywacke	63.5	41	7.6	-	7.9	-	3.4
Quartzite	66.5	45	6.8	1.5	6.1	2.4	4.1
Footwall Grit	76.5	51	7.6	-	3.6	-	5.4
Muva Quartzite	69	55	6.8	-	13.7	-	-
Intermediate Dolomite	90	74	4.3	0.3	0.2	0.5	4.1
Shale & Quartzite	32	25	2.2	18.3	14.2	29.3	1.7

TABLE VII.

SILICA CONTENT AND PERCENTAGE OF TOTAL EXCAVATING IN THE VARIOUS FORMATIONS.

		% Total Silica	% Free Silica	% Total Excavating
Argillaceous Quartzite		62	40	2.0
Quartzite & Graywacke		73	61	8.8
Quartzite & Shale		63	35	4.3
Lower Dolomite		46	43	9.4
Graywacke		68.5	63	6.2
Quartzite	Ore Horizon	76.5	51.5	26.2
Shale & Quartzite		77.5	53	5.3
Mudseam		62.5	40	-
Graywacke		63.5	41	8.4
Quartzite		66.5	45	20.1
Footwall Grit		76.5	51	8.0
Muva Quartzite		69	55	1.3
Intermediate Dolomite		90	74	-
Shale & Quartzite		32	25	-

Overall average of the free silica present in the rocks in the working places of the mine, weighted by the percentage work done in these places equals 49.21% SiO_2.

TABLE VIII.

SILICA CONTENT AND PERCENTAGE OF TOTAL EXCAVATING IN THE VARIOUS FORMATIONS AT NCHANGA.

Estimates of free and total Silica "weighted" according to the estimated work done in the individual rocks.

% Free Silica - 63
% Total Silica - 81

	Granite	Arkose Ore	Arkose Waste.
% Total Silica	80	79	81
% Free Silica	48	63	64
% Total Excavating	0.92	52.82	46.26

TABLE IX.

Incidence of Silicosis on the Four Copperbelt Mines.

1943 - 1950

Mine	Years of Service				Total all cases	Percentage of Total U/Grnd Workers at each Mine
	5 - 7	8 - 10	11-13	14-16		
Mufulira	23	67	28	-	118	3.4
Nchanga	-	2	-	-	2	0.09
Roan	-	-	1	-	1	0.01
Nkana	-	1	1+	-	2	0.04
Mixed Copperbelt Service	4	7	8	8	27	0.16
Total	27	77	38	8	150	

+ Had 14 months underground service in the Belgian Congo.

It will be seen from the above tables that the highest free silica content present in the rocks, weighted by the percentage of work done therein, is at Mufulira and Nchanga where the figures are 49.2 per cent and 63 per cent respectively. The free silica content of the rock at Roan Antelope and Nkana is considerably less - 29.6 per cent and 25 per cent.

It will be seen, when the above figures are compared with table IX showing the incidence of silicosis on all four mines, that there is a definite relationship between the number of cases of overt silicosis produced by a mine and the free silica content of the rock of.

that..../

that particular mine. Thus Nkana and Roan Antelope with a free silica content of 29.6 per cent and 25 per cent produced considerably less cases than Mufulira with a free silica content of 49.2 per cent.

Nchanga, however, with a free silica content of 63 per cent has, up to present, produced few cases of silicosis but has produced relatively more than either Roan Antelope or Nkana when its much smaller labour force is taken into consideration.

Also Nchanga has not been in production as long as the other mines; it opened in 1929 and closed in 1931 as a result of flooding. It re-opened in 1938 but only started any large scale development in 1940. This is considerably later than the other mines. The development footage is much less than any of the other three mines. I believe, that in the future, however, Nchanga will produce more cases of silicosis annually, proportionate to its labour force than any of the other three mines.

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