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CHRONIC PULMONARY DISEASE IN  
SOUTH WALES COALMINERS

I.—MEDICAL STUDIES.

A.—REPORT BY THE COMMITTEE ON INDUS-  
TRIAL PULMONARY DISEASE.

B.—MEDICAL SURVEY, by P. D'Arcy Hart and E. A.  
Aslett, with contributions by D. Hicks and R. Yates.

C.—PATHOLOGICAL REPORT, by T. H. Belt with  
assistance from A. A. Ferris.



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## PREFACE

In 1936 the Medical Research Council were asked by the Home Office and the Mines Department to investigate the problem of chronic pulmonary disease among coalminers, with particular reference to conditions in the South Wales coalfield. The Council undertook to do this, and referred the matter to the Committee on Industrial Pulmonary Disease which they had appointed some years earlier to advise and assist them in all research work under that general heading. The Committee drew up a programme, and after this had been modified in some respects in subsequent discussion it was accepted by the Council, who agreed to provide the necessary personnel and expenses. Various preliminary inquiries and arrangements had then to be made, and the actual field investigations began in December, 1937. In planning and carrying out the work much valuable help was given by the Mines Department and its officers; a contribution to the cost was also made from the Miners' Welfare Fund.

It was obvious that no advance could be made in the understanding of so difficult and complicated a problem, on which much work had already been done, except by a comprehensive study from all angles; and as this could be made only step by step it would necessarily last for a considerable period. The work was accordingly still in progress on the outbreak of war in 1939, but the Council decided to make every effort to carry it through to the stage of completing the original programme. This took longer than had been expected, partly because research of this kind naturally raises new issues as it proceeds, and partly because of delays directly or indirectly due to war conditions. The main field investigations were, however, completed early in 1941. Thereafter some further time was required in which to collate and assess the large amount of evidence obtained.

The problem was two-fold. Firstly, there was the question as to the nature of the pulmonary diseases and their occupational and geographical distribution in the South Wales coalfield; this involved elucidation of the form of disabling chronic pulmonary disease which was believed to exist amongst these miners but which, not coming within the accepted definition of silicosis, did not qualify for compensation. Secondly, there was the question as to the environmental conditions concerned in the causation of the disease, and as to whether improved preventive measures might be made possible by better knowledge of these conditions. Thus the first part of the problem was largely medical, while the second part called for a study of various factors in the occupational environment.

For the medical work, the Council appointed Dr. P. D'Arcy Hart to their scientific staff and also obtained a loan of the services of Dr. E. A. Aslett from the Welsh National Memorial Association. An account of the findings of these investigators and their collaborators, together with the results of pathological work by Dr. T. H. Belt, assisted by Dr. A. A. Ferris, forms the bulk of the present volume. On the basis of the evidence thus presented, the Committee on Industrial Pulmonary Disease have prepared a covering report giving their conclusions and recommendations.

It is intended to issue a second volume, reporting on the environmental investigations, within a few months. It is also hoped later to institute further investigations, of a limited but intensive kind, into certain specific questions which have been indicated as a result of the work already done.

The Council gratefully acknowledge the co-operation which they have received during the investigation from the Mines Department, from the colliery owners, from the trade union representatives and from the coalminers concerned. They also wish to express their appreciation of the services of the Committee and of all those who took part in the scientific work, a list of whom is given on a later page.

MEDICAL RESEARCH COUNCIL,  
c/o London School of Hygiene and Tropical Medicine,  
Keppel Street, London, W.C.1.

28th February, 1942.



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## CHRONIC PULMONARY DISEASES IN SOUTH WALES COALMINERS.—I. MEDICAL STUDIES

### A.—REPORT BY THE COMMITTEE ON INDUSTRIAL PULMONARY DISEASE

1. The problem of pulmonary disease in the coalmining industry was considered by the Committee soon after their appointment in 1930, and it was recognised that this problem differed in various ways from that of silicosis in surface industries such as metal grinding on sandstone, manufacture of refractory bricks and of pottery, and the quarrying and dressing of sandstone. In these industries there was exposure to the inhalation of dust containing high proportions of silica as quartz or flint, and such exposure had continued in much the same way for many years. In the coalmining industry one class of occupation was comparable with the surface industries just mentioned, namely, the driving of hard headings through strata composed of various kinds of rock, which very frequently included varieties of sandstone with high proportions of quartz; in this occupation cases of silicosis were met with which resembled in all important features those seen in the surface industries, but the number of men engaged in this class of work in coalmines formed only a small proportion of the total number employed underground. In recent years an increasing amount of attention has been directed to the occurrence of pulmonary trouble in the coalmining industry, and information regarding it became more definite when the provisions of the Workmen's Compensation (Silicosis) Acts were extended in 1929 to include certain processes in mines involving "drilling and blasting in silica rock". Information became much more precise when, in 1931, certification for compensation under this Act, now extended as regards the processes, was carried out by the Silicosis Medical Board, because certification by the Board had certain important advantages, including central control, with agreed uniform standards, and facilities for having radiological examinations made in cases of claims for disablement or post-mortem examinations carried out in fatal cases. Besides these measures to assist in accurate diagnosis, the members of the Board, each of whom had a wide experience of the diagnosis of silicosis, had the advantage of working in panels of two members, with the opportunity of obtaining the opinion of the Chief Medical Officer in cases of doubt or difficulty. The further extension of the provisions of the Various Industries (Silicosis) Amendment Scheme, 1934, to include "any operation underground in any coal mine" brought within the purview of the Medical Board all wage-earners employed underground in coalmines, subject to the important condition that, before the Medical Board could examine a workman, or investigate a fatal case, a claim had to be made for compensation on the grounds of disablement or death due to silicosis. Thus the experience of the Medical Board in regard to coalminers was limited, even since 1934, to workers underground in respect of whom claims for compensation had been made.

2. In March, 1936, the Chief Medical Officer of the Silicosis Medical Board informed the Committee that the claims for compensation made by coalminers in South Wales were increasing in number, and that the proportion of cases in which the Medical Board refused certificates was also increasing. Thus, the total claims in 1933, 1934 and 1935 were 234, 316 and 398, respectively, and the proportions of refusals in these three years were 23 per cent., 39 per cent. and 52 per cent., respectively. Several possible explanations were brought forward to account for these facts, and the character of the mines, methods of working and the occurrence of "slants" were considered, but no satisfactory explanation could be found for the preponderance of claims for

compensation, and of cases diagnosed as silicosis, in South Wales as compared with other coalfields. From the statistics available from the Medical Board three points emerged: first, an increase, year by year, in the number of cases of silicosis; second, the large proportion of these cases which arose in the South Wales coalfield; third, the finding that by far the greater proportion of this increase was derived from the anthracite mines in this area. In addition to these remarkable facts in regard to the geographical distribution of certified cases of silicosis in coalmines, there remained the problem of the increasing proportion of refusals among the claimants: the problem, that is to say, of the existence of a type of disabling pulmonary disease amongst South Wales coalminers which was apparently due to employment but which did not come within the definition of silicosis.

In May, 1936, the occurrence of disablement from silicosis and other lung troubles amongst coalminers was debated in the House of Commons. Following the debate the Home Office brought the subject to the notice of the Medical Research Council, and it was suggested that some of the affected workmen should be medically examined. Arrangements were made for the Committee to meet in Cardiff and to invite for interview some of the disabled workmen, representative medical practitioners from mining districts, and others who could give information regarding the nature of the men's employment in so far as it was related to the pulmonary disease affecting them. The meeting was held on the 17th June, 1936, and, while much information was obtained, the Committee wished to consider the subject further and to discuss with the Silicosis Medical Board the medical reasons for refusing certificates to certain disabled workmen. The Chief Medical Officer and the two members of the Cardiff panel of the Medical Board attended a meeting of the Committee on the 16th July, 1936, when the chest radiographs, together with the working histories, of a number of disabled coalminers were examined and discussed. The members of the Medical Board expressed the view that there was amongst South Wales coalminers a type of pulmonary disease which was disabling but which did not come within the radiographic definition of silicosis, and that this disease was due to employment and was prevalent. The Committee considered that they were not warranted in suggesting that the definition of silicosis laid down by the International Conference held at Johannesburg in 1930 should be altered; since that time, however, much further information had been acquired, and it might yet be shown that other mineral dusts could give rise to disabling pulmonary disease as a result of exposure during work. The Committee were satisfied from what they had seen and heard from the Medical Board and other sources that a sufficient amount of disablement due to pulmonary trouble was occurring amongst workers in the coal industry in South Wales to call for a thorough scientific investigation from the aetiological, clinical and radiological points of view, and they recommended that such an investigation be undertaken by the Medical Research Council.

In October, 1936, the Committee submitted to the Council a scheme which might form the basis for such an investigation, including both the medical and the environmental aspects. The Council accepted the recommendation of the Committee and agreed that an investigation should be made.

3. The problem which faced the Committee was this. For the period 1931-37 the average annual number of new cases of certified silicosis per thousand workers employed underground was 5·23 in anthracite mines in South Wales, 0·99 in non-anthracite mines in South Wales, and only 0·06 in coalmines in Great Britain excluding South Wales; clearly, South Wales, particularly its anthracite area, had the highest rates. In addition, there was the problem of the existence of a type of disabling pulmonary disease amongst South Wales coalminers which

was apparently due to employment but which did not come within the definition of silicosis. It was clear also that the condition generally designated silicosis in South Wales differed in certain respects from the type which results from exposure to dust containing a very high proportion of quartz. Not only did there seem to be differences in the radiological picture, but experience had shown that clinical tuberculosis, which is so frequent a terminal feature of silicosis affecting rock drillers in quartz reefs, sandstone workers, pottery workers and sandblasters, was by no means prominent in South Wales. Moreover, it had for a considerable time been apparent—and this evidence was endorsed by the experience of the Silicosis Medical Board—that the bulk of the cases of pulmonary disability, and of certifiable cases of silicosis, was contributed by colliers working at the coalface. In the coalfields of Great Britain other than in South Wales, the cause of the relatively infrequent cases of certifiable silicosis seemed to have been traced, with few exceptions, to work in hard headings, i.e., in highly siliceous rock, the risk of which was well recognised; serious pulmonary trouble, of the type prevalent in South Wales, had not so far been reported to a material extent among coal-getters as opposed to hard-heading workers. Such a distinction could not be ignored, and in latter years an explanation had been sought in conditions which might prevail in the South Wales anthracite area to a greater extent than in other coalfields. Thus, slants rather than shafts were characteristic of the anthracite area, and in the same area there was more shot-firing than is customary in other coalfields. It had been suggested that bronchitis resulting from the chill experienced in "spake" journeys up the slants, or the irritant effect of explosive fumes due to shot-firing, might be the antecedent factor which allowed the air-borne dust at the coalface to exert a far more deleterious effect than it would otherwise have done.

4. It appeared, however, to the Committee that, before turning to possible factors in causation, the nature of the problem in South Wales must in the first instance be much more clearly defined than was possible on existing information, and that a detailed examination of the distribution of all forms of pulmonary abnormality which might be due to occupation was essential, in order to ascertain beyond doubt the relation of incidence to type of occupation, and to determine whether or not these abnormalities were prevalent in varying degree throughout the whole of the South Wales coalfield or were restricted to the anthracite area.

This inquiry into the incidence of pulmonary abnormality was undertaken by Dr. P. D'Arcy Hart, a member of the scientific staff of the Medical Research Council, and by Dr. E. A. Aslett, who was seconded for this purpose by the Principal Medical Officer of the Welsh National Memorial Association.

Before the inquiry could be begun, much preliminary work was necessary in order to decide the best line of procedure. The available statistical material was reviewed by Dr. A. Bradford Hill, while H.M. Inspectors of Mines supplied the Committee with information about a number of mines, some having a high, and others a low, incidence of certified silicosis, and this information was fully discussed with representatives of the Mines Department. At the same time, contact was made with mine owners, mine managers and the South Wales Miners' Federation, since their co-operation was clearly essential.

As a result, it was decided to make in the first instance a radiological and clinical investigation of the entire population, including workers above as well as below ground, at one colliery (A.3) in the anthracite area, the records of which showed a high incidence of certified silicosis. This investigation was to be extended subsequently to other mines in South Wales, the scope and precise form of the further inquiries being determined in the light of the experience already gained. The medical investigation was started in December, 1937. In addition to the medical survey, it was decided to obtain information, so far

as practicable, about the concentration and nature of the dust to which the miner might be exposed, as well as about other environmental factors which might possibly have some influence on the incidence of pulmonary disease. The study of the dust and other environmental factors required the help of a number of other investigators, each with some experience of a particular aspect of the problem.

5. This first Report of the Committee deals with the medical part of the inquiry, and precedes the report by Dr. Hart and Dr. Aslett on their medical survey, and one by Dr. T. H. Belt, assisted by Dr. A. A. Ferris, on the pathology of the pulmonary diseases encountered in South Wales. To the report on the medical survey, Mr. Donald Hicks, Officer-in-Charge of the Coal Survey Laboratory at Cardiff, and Major R. Yates, at that time H.M. Inspector of Mines, Swansea Division, have contributed descriptions of the coalfield in South Wales, the structure of the coal seams and the different occupations of the miners—information which has an important bearing on the problem as a whole.

6. At the anthracite colliery selected for detailed investigation, a total of 560 men was examined. Each man was examined radiologically and clinically, and special clinical tests were used in a number of instances, e.g. examination of the sputum, tuberculin tests, and measurement of lung volume. The whole of the information was collated with the occupational history in each case. It was soon apparent that the collier working at the coalface provided the fundamental problem. The subsequent investigation at fifteen other mines in South Wales, both anthracite and non-anthracite, was, therefore, confined to colliers, 1,392 of whom were examined; it was limited to a radiological examination and an occupational history. Finally, 470 coaltrimmers employed in ships loading coal at four of the five main coal-shipping ports in South Wales were examined in the same way, as well as 33 long-term workers on the surface screens and 60 hauliers from two bituminous coalmines, for comparison with screens workers and hauliers in the anthracite mine A.3.

7. The careful summaries which have been given at the end of the chapters in the report by Dr. Hart and Dr. Aslett will make the course of the investigation clear, and it is unnecessary for the Committee to recapitulate them. There is, however, one aspect, viz., the classification and interpretation of the radiographs, upon which the Committee wish to lay stress. As has already been indicated, the radiographic appearances commonly found in the lungs of coalminers seem to differ in certain respects from those typical of "classical" silicosis. The X-ray classification adopted in the present investigation is as follows: (a) normal, (b) reticulation, (c) nodulation, (d) coalescent nodulation, (e) massive shadows, (f) multiple fluffy shadows, and (g-h) indefinite; categories (c-f) are grouped together as consolidation, and (d-f) as major consolidation. X-ray photographs are, of course, but shadows, and the interpretation of these in terms of actual pathological change in the tissues of the lung, i.e. the translation of shadow into substance, is by no means easy. While the pathological fibrosis which occurs in the different types of X-ray consolidation has been described in the work of earlier investigators, the interpretation of the fine diffuse shadows to which the name "reticulation" has been given was at first a matter of some doubt. This doubt has, however, been dispelled by the studies of Dr. Belt and Dr. Ferris; for, in addition to clarifying further the pathology of the more severe types of fibrosis, they have shown that X-ray reticulation corresponds to a widespread, though not necessarily great, increase in the reticular connective tissue in the lungs which results from the accumulation of dust particles, and that this causes a loss of elasticity in the tissue of the lung and a resulting liability to emphysematous change. They have also shown that, in addition to coal particles, an accumulation of siliceous particles is present not only in the more grossly fibrotic or consolidated lungs but also in those showing only reticulation.

8. As a result of the medical and pathological investigations described below, the Committee have reached the following conclusions :—

(i) The pulmonary abnormality encountered amongst the South Wales coal-miners is not restricted to the anthracite area but can be found in the whole coalfield, though the incidence and severity vary greatly in different regions.

The appearance of reticular shadows ("reticulation") in radiographs of the chest is the earliest radiological sign of any abnormal change in the lungs, while nodular or coalescent shadows indicate a much greater development of fibrotic tissue. The evidence makes it extremely probable that reticulation represents the first of a series of pathological changes which may culminate in gross fibrosis.

As with all diseases dependent on the accumulation of dust, the severity of the pathological changes is closely related to the duration of exposure to the dust hazard, i.e. to the length of the working life in the dusty occupation. Other factors, such as the character and concentration of the dust, will be considered in a further Report of the Committee.

The clinical evidence of respiratory disability, as shown by such symptoms as breathlessness or liability to cough, runs, in general, parallel to the X-ray changes. Such disability is to be found most frequently, and usually in its most pronounced form, in those cases showing massive X-ray shadows; it is observed both less frequently and, as a rule, less severely in those showing reticulation only. The incidence of disability in the group showing only reticulation falls mainly on men in the second half of life, and even amongst these, while some give clear evidence of an associated respiratory disability, many others reveal no clinical symptoms at all.

(ii) Although hard-heading workers, driving through rock containing a high proportion of quartz, are subject to a special and well-recognised risk of developing silicosis, the number of such men is too small in the South Wales coalfield to provide more than a small fraction of the cases of pulmonary abnormality. There is also some evidence that shot-firers in South Wales run a high risk, but the bulk of the cases of pulmonary abnormality is unquestionably derived from the colliers working at the coalface, while the risk to other underground workers such as hauliers and repairers who do not work at the face appears to be less. X-ray changes and some degree of pulmonary disability of a type similar to those shown by colliers, but less frequent in incidence, are also found amongst surface workers on the screens and coaltrimmers at the docks, i.e. amongst those who are exposed to dust derived from the coal but not under the conditions which prevail at the face.

(iii) The character and rank of coal in the South Wales coalfield change gradually from north-west to south-east. The highest rank of anthracite, with about 5 per cent. of volatile matter, is found in the north-west, and, proceeding towards the south-east, the volatile content steadily increases, the coal changing in character to lower-rank anthracite, steam coal, and finally, in the south-eastern and eastern parts of the coalfield, to bituminous coal, with up to 36 per cent. of volatile matter.

On the basis of the X-ray abnormalities found in colliers, the collieries may be divided arbitrarily into four groups, showing respectively "high", "medium", "low-medium" and "low" incidences of these abnormalities. The incidence changes from "high" in the anthracite area to "low" in the bituminous coal area. Reticulation is the commonest X-ray abnormality amongst the younger colliers in both anthracite and non-anthracite mines. Amongst the older colliers it is also the most prominent abnormality in the low incidence mines, but in the high incidence mines it is exceeded in frequency by consolidation. The incidence of certified silicosis suggests that there is a sudden change in passing from the anthracite to the non-anthracite areas, but the X-ray evidence shows that the change is not abrupt but gradual throughout the coalfield, sharp though the contrast may be between the anthracite

area at one end and the bituminous area at the other. The incidence of pulmonary abnormality among the colliers is evidently related to the rank of the coal mined. This relationship may, however, be not direct but secondary, for it may be that the real causative factor, possibly the amount or character of the air-borne dust to which the miner is exposed, is itself correlated with the rank of the coal. Within the anthracite area itself there are also distinct variations in the incidence of X-ray abnormalities, and these appear to be related to the depth of the workings and to the temperature and moisture at the coalface; here again these relationships may be indirect.

(iv) The pulmonary abnormality found among hard-heading workers corresponds closely to the type of silicosis shown by those who have been exposed to dust containing a high proportion of quartz. On the other hand, the following distinctive features are found amongst the mining population in South Wales other than hard-heading workers, most typically in colliers but also to some extent in screens workers and coaltrimmers :—

- (a) There are differences in the X-ray appearances from those seen in the silicosis of quartz workers.
- (b) While having some points in common with classical nodular silicosis, the pathological changes have special characteristics.
- (c) Clinically recognisable tuberculosis does occur terminally, but local medical opinion suggests that cardiac failure and non-tuberculous respiratory affections are more frequent modes of death. This opinion is supported by the fact that sputum examination for tubercle bacilli, made in the majority of men who had expectoration at colliery A.3, proved negative, while a tuberculin test on nearly the whole age group 30-39 at the same colliery failed to show that X-ray reticulation or consolidation was associated with definite hyper- or hyposensitiveness to tuberculin. Although overt tuberculosis may be far less common than in silicosis in other industries, the report by Dr. Belt and Dr. Ferris shows that careful microscopical examination may sometimes reveal evidence of tuberculosis in the lungs of men who have died without having shown definite X-ray or clinical evidence of this disease during life. It is therefore impossible to discount the tubercle bacillus as a contributory factor, except in the case of dust-reticulation, which, in its uncomplicated form, is uniformly lacking in histological evidence of infection.

From the information available it would appear that this type of pulmonary abnormality is largely confined in Great Britain to the South Wales coalfield—the progressive decrease in incidence among colliers in passing from the anthracite to the bituminous coal area certainly points in this direction—whereas the silicosis hazard faced by hard-heading workers is not restricted to this coalfield. It is of interest to note from contemporaneous investigations made in the U.S.A. and U.S.S.R. that in these countries also occupational pulmonary disease is less frequent in the bituminous coalmines than in the anthracite.

(v) The primary and fundamental cause of the pulmonary abnormality found in this investigation is the inhalation of air-borne dust. This is shown by the fact that colliers at the coalface, surface workers on the screens and coaltrimmers at the docks, all of whom are exposed to dust, are liable to develop the same types of X-ray change, though to a varying degree, while other surface workers who are not exposed to dust escape these changes.

(vi) Neither exposure to the chilling effect of spake journeys up the slants, with resulting bronchitis, nor the irritant effect of explosive fumes, can be a primary or essential cause of the pulmonary fibrosis, for these reasons :—

- (a) The present investigation has given no unequivocal evidence that spake journeys do in fact result in bronchitis, great though the chill may be in coming up the slant.

- (b) The characteristic changes in the lungs can develop in workers on the screens and in coaltrimmers who are not exposed to spake journeys nor to explosive fumes.
- (c) The incidence and severity of pulmonary abnormality decrease gradually in passing across the coalfield from west to east. There is no evidence of the abrupt change which might have been expected from the fact that both slants and the use of heavy shot-firing during the coal-getting shifts are characteristic of the western or anthracite region but not of the eastern, bituminous area.
- (d) A medium incidence of pulmonary abnormality was found in some of the steam coal collieries in which there is no spake riding; similarly, an unsatisfactorily high incidence of pulmonary abnormality can occur in anthracite mines in which there is no systematic shot-firing at the coalface.

Although the Committee are unable to regard spakes or explosive fumes as primary factors, they are not prepared to exclude them as contributory factors, since the type of pathological change which may result from chronic bronchitis or from the irritant effect of the nitrous fumes liberated in shot-firing is such as to interfere with the normal processes of dust elimination from the lungs. The concentration of nitrous fumes in the air at the coalface is, however, very low, as will be shown in a subsequent report by Mr. Ivon Graham and Dr. Runnicles.

9. In the light of the evidence now available, the Committee wish to make certain recommendations:—

(i) The pulmonary abnormality found in hard-heading workers has the general characteristics of the disease found in workers in other occupations where the exposure is to dust with a high quartz content, as in stone-masons; therefore it is correct to apply the term "silicosis" to it.

The abnormality found in South Wales in other classes of colliery workers, and most typically in colliers at the coalface, differs, however, in certain respects from that found typically in hard-heading workers, and the Committee feel that a less specific term than "silicosis" should be employed for it. Dust at the coalface includes both coal dust and mineral dust other than coal, derived from the coal seam itself and from the immediately adjacent strata; the dust which arises from handling coal at the screens or in coaltrimming also contains mineral matter other than coal. Since everything points to the dust being the fundamental cause of the abnormality found typically in colliers at the face, but the relative parts played by the different components of the dust are not yet elucidated, the Committee consider that the term selected should not prejudge the issue as to the exact causation of this condition.

Although the Committee recognise certain distinctions between the pulmonary abnormality found typically in colliers and that found typically in hard-heading workers, they believe that differentiation between the two conditions is impracticable in routine work, and that one term is preferable to cover both. They, therefore, recommend the use of the comprehensive term "pneumo-koniosis of coal workers" for all the pulmonary conditions described as due to dust in workers engaged in any operation underground in coalmines, in screens workers at collieries and in coaltrimmers at docks.

(ii) At present "silicosis" is defined for purposes of the Compensation Schemes in this country as "fibrosis of the lungs due to silica dust", the standard of diagnosis being based on the classification adopted at the International Conference at Johannesburg in 1930. This standard requires two conditions to be fulfilled before a certificate of silicosis can be issued for compensation purposes, viz., pulmonary disability and definite X-ray nodulation or consolidation. Certificates have had to be refused in a number of cases of coalminers which did not fulfil these conditions in spite of the fact that the pulmonary



disease was disabling and apparently occupational in origin. The Committee, therefore, consider that in the case of coal workers this standard is too restrictive. The X-ray criterion demanded is based essentially on experience of silicosis in other occupations, and excludes those cases of pulmonary disability in which the radiographs show only reticulation. Yet the present investigation has, in the view of the Committee, established the fact that such cases are true instances of occupational disease and ought to be so regarded. If the standard of diagnosis for purposes of compensation were widened so as to include these cases, and the nomenclature correspondingly altered as indicated in (i) above, the Committee believe that all cases of pneumokoniosis of occupational origin in the groups of coal workers under consideration would be covered.

The Committee accordingly recommend, for purposes of compensation, that the X-ray standard required for the diagnosis of the "pneumokoniosis of coal workers" should include reticulation as well as nodulation and consolidation. For this purpose, reticulation is defined in the accompanying reports—on p. 48 (radiographically) and on p. 221 (pathologically). Reproductions of X-ray photographs and of photomicrographs illustrating reticulation are included.

The general criterion on which the diagnosis should be based should remain unchanged, viz. that the two conditions of pulmonary disability and radiological evidence of a definite character must be fulfilled before a diagnosis can be made. In this way, breathlessness caused, for example, by emphysema or cardiac disease not of occupational origin would be ruled out by the absence of the requisite radiological evidence.

The Committee submit that the most effective way of dealing with compensation for the "pneumokoniosis of coal workers" would be to bring it under one legal designation. Any enactment made for this purpose should cover screens workers at collieries and coaltrimmers at docks as well as underground workers in coalmines.

(iii) Nothing in this report should divert attention from the serious danger to which hard-heading workers and others who drive through highly siliceous rock may be exposed. Consideration might be given to limiting the number of years to be spent by any man on this class of work.

(iv) The investigations which have been made on dust and other environmental conditions in the South Wales coalmines, and the correlation of the results with the facts established by the medical survey, will form the subject of a further report by the Committee. Some suggestions as to possible preventive measures can, however, be made from the medical survey alone.

Efforts have been made for a number of years to protect men against chill whilst spake-riding to the surface, by the provision of special clothing or by other means. Although these efforts may have been based on an over-estimate of the possible results of the chill, the Committee believe, for the reasons given in paragraph 8 (vi), that they should be encouraged. Whatever means may be adopted, however, there must be nothing to hamper a man from jumping clear in the event of a derailment.

Shot-firing has two undesirable features. In the first place, it gives rise to irritant gases which, in spite of their low concentration, may yet in the long run act as a contributory factor in pulmonary disease. This the Committee regard as probably the minor feature. The major feature, in the Committee's opinion, is the large amount of dust to which shot-firing gives rise.

When a shot is fired, an excessive amount of dust is temporarily dispersed into the air. Since it is not yet possible to say which component, or components, of the dust are actually harmful, shot-firing in the coal must be regarded as potentially as harmful as shot-firing in roof-rippings at the face. For this reason, the Committee recommend that, if practicable, shot-firing in the coal and in face-ripping should be done on the back shift and not on the coal-getting shift, for it is but common prudence to expose as few men as possible to the

risk of abnormally high concentrations of air-borne dust. Such a change was made at one anthracite colliery some years ago without, it is understood, any disadvantage to the general working of the mine. The fewer the men exposed to such high concentrations of dust, the more possible may it prove for them to wear respirators during these particular operations, e.g. firemen or shotmen approaching workplaces after shots have been fired.

In addition to this immediate liberation of dust following shot-firing, dust is dispersed into the air by the subsequent moving of the excessively shattered coal or rippings brought down. While moving of the coal is an essential part of the collier's work, it would be well, when practicable, to relegate the operations of clearing and packing the debris of ripping, as well as the actual shot-firing of ripping, to a back shift when the collier is away.

At best these measures cannot be more than partial remedies and will not by themselves eliminate the disease. The root cause of the trouble is the dust which is inevitably produced in the normal processes of coal-getting, even in the absence of shot-firing; shot-firing merely accentuates the dust. It is clear that reduction of the concentration of dust to limits which can be considered safe must be the main objective. Much work has been done, both in Britain and elsewhere, on the problem of dust suppression in mines, and although in this country it is mainly the risk of coal-dust explosions which has stimulated the work, South Wales has a problem of at least equal importance in the prevalence of pneumokoniosis. Much can be done by careful attention to methods of mining and of ventilation, but the extensive trials that have been made of mist projectors and water sprays by mining investigators in this country are a clear indication that more specific measures may also be of great service. The problem of the reduction of dust is one that demands the application of the full resources of mining technique if it is to be solved. During the course of the present investigation the use of a simple water spray gave results of some promise at the coalface, but consideration of this experiment will be deferred until the question of dust is dealt with more fully in the environmental reports.

(v) The question has frequently been asked whether, from the medical point of view, there would be any advantage in the initial and periodical examination of all coalminers in South Wales. From the aspect of pneumokoniosis the Committee suggest there would be undoubtedly many advantages. Firstly, such examinations would make it possible to transfer men to more suitable work before they became unfit; secondly, they would facilitate the detection of tuberculosis and the removal from the mines of men in an infective stage of this disease; thirdly, over a long period of time, they would provide a means for observing the effects on health of any preventive measures carried out in the mines.

10. At the start of this inquiry the Committee undertook that no names should be divulged. While this obligation prevents the individual mention of those who have helped them, they wish to express their gratitude to mine owners, mine managers and their staffs, to the officials of the South Wales Miners' Federation and of the coaltrimmers' trade unions in South Wales, and to the men themselves, for their active co-operation and unflinching courtesy. Without such assistance it would have been impossible to conduct the inquiry successfully. No information that might be helpful was withheld; all made useful suggestions. Unavoidable disturbance of the normal routine in the collieries was willingly accepted by the managements, and the help which the local officials of the Miners' Federation gave in explaining to the men what was required of them, and the purposes of the investigations, proved invaluable. Assistance was as readily given by the Mines Department and by H.M. Inspectors of Mines. The Committee also wish to express their high appreciation of the careful and critical studies made by the investigators—medical and non-medical—in relation to this inquiry, and of the excellent radiographic work done by Messrs. Portable X-Rays, Ltd.

## CHRONIC PULMONARY DISEASE IN SOUTH WALES COALMINERS

### List of Principal Medical and Scientific Investigators concerned in this Inquiry

(*Note.*—The whole scheme of research has been directed by the Committee on Industrial Pulmonary Disease, appointed by the Medical Research Council. A list of this Committee has been given on p. ii.)

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# CHRONIC PULMONARY DISEASE IN SOUTH WALES COALMINERS.—I.

## B.—MEDICAL SURVEY

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## PART I. INTRODUCTION

## CHAPTER 1

**The Problem of Chronic Pulmonary Disease in the South Wales Coalfield**

The prevalence of chronic pulmonary disease has long been one of the health problems of the coalmining industry.\* In 1929 it was officially recognised that this pulmonary disease included a form of silicosis due to industrial employment, and compensation under the Workmen's Compensation Act became payable in certain cases to men in this industry, the occupation range covered being later considerably extended.† Since that time the number of cases receiving compensation in the coalmining industry has mounted rapidly year by year until pulmonary disease from this source has come to dominate the silicosis problem of the country.

The figures in Table I (p. 6), from the official Workmen's Compensation Statistics, show strikingly this increasing prominence over a period of five years. From columns (2)-(4) it can be seen that the total number of disablement cases of silicosis on compensation in Great Britain as a whole has increased from 1,245 in 1933 to 2,517 in 1938. The increase is accounted for mainly by the coalmining industry, cases in which have risen from 229 in 1933 to 1,279 in 1938 (and this rise is known from unpublished data to have continued since), though some of the other industries have shown smaller rises. Similar trends are evident when only the new disablement cases (bracketed figures) for each of these years are considered; and here the contrast between coalmining and the other industries is even more striking, for the annual number of new cases in the coalmining industry has been more than trebled during the five years, while in each of the other industries tabulated the annual new cases have declined. From columns (5)-(7) of Table I it can be seen that the total disablement cases on compensation in the coalmining industry in 1933 held fourth place among the individual industries tabulated, and formed 18·4 per cent. of the total for the whole country; in 1938 they were the highest, and formed 50·8 per cent. of the total. Similarly, the new disablement cases in 1933 were 28·1 per cent. of the total for the whole country, while the percentage was as high as 66·7 in 1938.

Fatal cases have been purposely excluded from Table I. Some indication of the relative frequency of deaths attributed to silicosis in the different industries is given by Bridge (1938) in an analysis based upon data from death certificates, supplied by the Registrar-General, and upon investigations of occupational histories of deceased persons, carried out by the Factory Department of the Home Office. In this analysis, 41·2 per cent. of the deaths attributed to silicosis in England and Wales in 1938 were assigned to the coalmining industry.

While the decline in the annual number of new cases of silicosis receiving compensation between 1933 and 1938 for most industries suggests improved preventive control, the very considerable rise for the coalmining industry over this period cannot be taken as indicating a real increase in dust-produced disease; it is probably due largely or entirely to increased recognition of disease already present. None the less, the trends of the absolute and relative figures of

\* Coalminer or colliery worker is defined as a man employed in the coalmining industry either below ground or on the surface at a colliery.

† The chief enactments and schemes relevant to silicosis compensation in the coalmining industry are as follows: Workmen's Compensation Act, 1925, extended by Workmen's Compensation (Silicosis and Asbestosis) Act, 1930; Various Industries (Silicosis) Scheme, 1928, replaced by Various Industries (Silicosis) Scheme, 1931, the latter extended by Various Industries (Silicosis) Amendment Schemes, 1934 and 1939; Silicosis and Asbestosis (Medical Arrangements) Scheme, 1931. See also p. 189, footnote.

Table I demonstrate that efforts to solve the pneumokoniosis problem in Great Britain have now to be directed particularly to the coalmining industry.

The increasing magnitude of this problem in the coalmining industry is evident also in the amount paid in compensation (see Home Office, 1933, 1935, 1938). The total amount thus paid, under the "Various Industries Schemes," to silicosis cases from this industry (including here fatal cases) was in 1933 approximately £24,000 out of £109,000 paid for the whole country. In 1938 the corresponding amount was £138,000 out of a total of £231,000.

The foregoing statistics are concerned with coalmines as a whole and do not distinguish between anthracite and non-anthracite mines. During the past ten years attention has become focussed upon the anthracite mines as the chief source of chronic pulmonary disease among the coalminers of Great Britain. These mines are confined to the western half of South Wales, being situated in the counties of Pembroke and Carmarthen and in the western parts of the counties of Brecon and Glamorgan.

The statistics given in Tables II-V, derived from official sources, demonstrate this selective geographical localisation of pulmonary disease.

The analyses of occupational mortality in the Registrar-General's Decennial Supplement for England and Wales for 1921 show the high mortality from respiratory disease of various kinds among coalminers in the western counties of South Wales, but anthracite and non-anthracite miners are not differentiated. This distinction is, however, made in the occupational mortality tables of the Decennial Supplement for 1931; some data from this source are assembled in Table II (p. 7) in order to show the distribution of deaths, and the comparative mortalities, from lung and heart diseases in various parts of the British coalfields. It may be seen that in absolute number of deaths (columns (a)) anthracite miners, being the smallest of the populations at risk, have, for each of the categories of diseases, the smallest figure of the three groups. When, however, the actual deaths are related to the standard deaths (columns (b)) in the form of Standardised Mortality Ratios (S.M.R., columns (c)), which take population and age differences into account, this table shows that the anthracite miners of South Wales have a mortality from tuberculosis and other respiratory diseases, and also from cardiac diseases, in excess of non-anthracite miners of the area, and considerably in excess of miners elsewhere in the country. This excess of mortality is insignificant for "all other diseases," used as a control category.

Since 1929, when compensation for silicosis first became payable to men employed in the coalmining industry, statistics relating more specifically to pneumokoniosis have been available. From the point of view of this inquiry, the usefulness of such figures dates from June, 1931, when the special Medical Board for Silicosis took over the function of granting certificates for disablement or death due to this disease, for purposes of compensation in the cases of workers underground in coalmines. Table III (p. 8), derived from reports and records from the Mines Department and Inspection Divisions, shows the distribution and incidence of certified silicosis among coalminers in various parts of Great Britain at the beginning of the present study. It will be seen that in the years 1931-37 the absolute number of new cases from South Wales as a whole was more than six times that from the remainder of Great Britain, and that the number of cases from the anthracite mines of South Wales was greater than from its non-anthracite mines. When these figures are related to their respective populations, to give comparative incidence-rates, the geographical differences are even more striking. The incidence-rate of certified silicosis in the anthracite mines is more than five times that in the other mines of South Wales, and nearly 100 times the rate for Great Britain other than South Wales. There is thus a double contrast: (1) between anthracite and non-anthracite mines within the South Wales

coalfield, and (2) between non-anthracite mines in South Wales and non-anthracite mines in the rest of Great Britain.

Table IV (p. 8) is an amplification of the first two lines of Table III. Instead of the average incidence of certified silicosis in the anthracite and non-anthracite groups of South Wales mines, the percentage of mines with "high," "medium" and "low" incidences in each group is compared. It can be seen that as many as half the mines in the anthracite group have high or medium incidences (26·7 per cent. and 24·4 per cent., respectively), whereas such incidences are the exception (1·4 per cent. and 4·3 per cent., respectively) in the non-anthracite groups. These facts must be borne in mind when selecting a series of representative mines for examination.

It must be emphasised that the designation "low" incidence of certified silicosis is arbitrary and relative, and that the average incidence even in this subdivision of the South Wales non-anthracite group is considerably higher than the average for the mines of Great Britain excluding South Wales. On the other hand, it is important to note from Table IV that within the anthracite area there are mines with a comparatively low incidence of certified silicosis as well as mines with a very high figure.

Table V (p. 9) represents a further limited extension of the comparison between statistics of certified silicosis in anthracite and non-anthracite mines. In this table the distribution and incidence of cases among certain occupational classes of miner are compared for each group of mines. The comparison is limited to the Swansea Division of the South Wales coalfield, which contains all the anthracite mines and about one-fifth of the population of the non-anthracite mines. The figures in the table must be treated with caution, since the occupational subdivision of cases is very rough (see notes to Table V) and the employed populations on which the incidence-rates are calculated are quite small in some instances. With these reservations, the following tentative conclusions may be drawn: (1) In the anthracite mines of the Swansea Division colliers\* have provided far more cases of certified silicosis than has any other occupational class, and they have been responsible for two-thirds of the total; in the non-anthracite mines, on the other hand, while colliers have been one of the largest sources of cases, the great excess over all other occupational classes just noted for the anthracite group is not evident. (2) In each group of mines the *incidence-rate* is much greater among hard-heading men† than among any other occupational class; this is not in conflict with the presence of an excess of colliers among the *cases* in the anthracite group (referred to in (1) above), which is a more important consideration. (3) The incidence-rate of certified silicosis among colliers in the anthracite group of mines is nine times that among colliers in the non-anthracite group; by contrast, there is little difference between the rates among hard-heading men in the two groups.

All the foregoing statistics are crude and incomplete. The mortalities from respiratory disease (Table II) include, of course, other conditions besides those due to dust or otherwise of industrial origin. On the other hand, the incidences of certified silicosis (Tables III-V), whilst referring more specifically to the pneumoconioses, apply only to conditions satisfying certain limited diagnostic and legal criteria; moreover, the initiation of the process leading to the granting of a certificate of silicosis to a coalminer for purposes of compensation is dependent upon the volition of the individual applicant and not upon regular routine examinations. Finally, the occupational grouping of Table V must be regarded as very crude, since for the silicosis cases it is based upon the major occupations followed during the lives of the certified workmen, whereas for the population at risk it is based upon the actual occupational distribution of employees at one given time.

\* A collier is defined as a coalminer engaged in getting, hewing, winning or filling coal at the coalface. The definition includes assistant colliers.

† For definition of hard-heading man, see pp. 30-31.

Nevertheless, in spite of their defects, the statistics of Tables II-V show that the main problem of pulmonary disease in British coalminers lies in South Wales, more particularly, though by no means entirely, in its anthracite mines. They suggest, further, that—at least as regards certified silicosis—the chief source of cases in the anthracite mines is the collier. Such information must, however, be regarded as only a preliminary to the solution of the problem of industrial lung diseases in the coalfield. The present investigation was therefore instituted with the following three objects: (a) to determine—more accurately than by means of mortality or certification statistics—the character, distribution and incidence of chronic pulmonary disease in various classes of mining occupation and in different parts of the South Wales coalfield; (b) to discover whether pulmonary conditions due to employment exist that do not come under the present definition of silicosis for purpose of certification, and if so whether they are disabling; and (c) to elicit the causes of these various industrial pulmonary diseases, and especially of the high incidence of certified silicosis in the anthracite area.

The investigation has comprised a field survey in South Wales and certain special laboratory inquiries. The former has consisted of examinations carried out at 16 representative collieries (eight anthracite and eight non-anthracite) out of the approximately 200 mines employing more than 100 men underground in this coalfield, and at four of the five principal coal-exporting ports of South Wales. These examinations have been of two main kinds: (a) medical, comprising an X-ray examination and the recording of the man's working history, together with, in one mine, a detailed clinical examination, and (b) environmental, involving analysis and measurement of the concentration of the air-borne dust, examination of the coal and rock strata, estimation of nitrous fumes, and measurement of the humidity and ventilation; the environmental studies have related mainly to conditions at the coalface. The observations have also included the pathological examination of autopsy material from miners in South Wales. The present report is concerned with the medical part of the field survey and a report on the post-mortem material follows it; the environmental part of the inquiry will be published separately.

#### SUMMARY OF CHAPTER I

(1) Since 1929, when compensation for silicosis first became payable to men employed in the coalmining industry, the number of disablement cases among coalminers has increased rapidly, until pulmonary disease in this industry has come to dominate the silicosis problem of Great Britain. In 1938, 51 per cent. of all disablement cases, 67 per cent. of new disablement cases, and 41 per cent. of deaths attributable to silicosis were from the coalmining industry. In that year, too, over half the total amount paid in compensation for silicosis related to this industry, and the proportion is still increasing.

(2) Mortality statistics show an excess mortality from respiratory disease among coalminers in South Wales over miners elsewhere in the country, and among South Wales anthracite miners over South Wales non-anthracite miners.

(3) Compensation statistics show similarly that the main problem of certified silicosis lies in the South Wales anthracite mines, the incidence-rate there being, in 1931-37, more than five times as high as in the rest of South Wales, and nearly 100 times the rate for the coalmines in Great Britain other than South Wales. In some anthracite mines, however, the incidence of certified silicosis is comparatively low.

(4) Compensation statistics also suggest that in anthracite mines the collier is the main source of certified silicosis, though the incidence-rate is at its highest among hard-heading men.



## PULMONARY DISEASE IN WELSH COALMINERS

TABLE I

*Number of silicosis cases (fatal cases excluded) receiving compensation in different industries in 1933, 1935 and 1938 (under Section 47 of the Workmen's Compensation Act, 1925, as amended by the Act of 1930)*

Compensation Scheme.  (1)	Disablement cases receiving compensation ; total, and new cases, in each year.*						
	Number.			Percentage.			
	1933 (2)	1935 (3)	1938 (4)	1933 (5)	1935 (6)	1938 (7)	
Refractories Industries Scheme	270 (13)	274 (8)	262 (9)	21·7 (2·9)	15·8 (1·8)	10·4 (1·4)	
Sandstone Industry Scheme ..	242 (76)	350 (75)	372 (69)	19·4 (17·0)	20·2 (16·6)	14·8 (10·7)	
Metal-grinding Industries and Various Industries Schemes.	China and Earthenware Industry.	241 (99)	282 (69)	249 (47)	19·4 (22·1)	16·2 (15·3)	9·9 (7·3)
	Metal Industries ..	46 (16)	61 (17)	56 (14)	3·7 (3·6)	3·5 (3·8)	2·2 (2·2)
	Coalmining Industry ..	229 (126)	545 (217)	1,279 (430)	18·4 (28·1)	31·4 (48·0)	50·8 (66·7)
	Builders, etc. .. ..	94 (45)	123 (28)	110 (21)	7·6 (10·0)	7·1 (6·2)	4·4 (3·3)
	Miscellaneous† .. ..	123 (73)	101 (38)	189 (55)	9·9 (16·3)	5·8 (8·4)	7·5 (8·5)
	<b>Total .. .. .</b>	<b>1,245 (448)</b>	<b>1,736 (452)</b>	<b>2,517 (645)</b>	<b>100·0 (100·0)</b>	<b>100·0 (100·0)</b>	<b>100·0 (100·0)</b>

\* The unbracketed numbers and percentages are the total cases of disablement (i.e. new cases + cases continued from previous years) in which compensation was paid in the given year; the bracketed figures are the new cases only.

† Including Metalliferous Mines.

Source.—Home Office (1933, 1935, 1938).

TABLE II

Comparative mortalities, from respiratory and cardiac diseases, of coalminers underground in various parts of the British coalfields in 1930-32

(1) Coalfield.	(2) Respiratory tuberculosis.			(3) Other respiratory diseases.			(4) Heart diseases.			(5) All other diseases.		
	Actual deaths.	Standard deaths.	S.M.R.	Actual deaths.	Standard deaths.	S.M.R.	Actual deaths.	Standard deaths.	S.M.R.	Actual deaths.	Standard deaths.	S.M.R.
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Anthracite mines of South Wales	70	68	103	117	50	234	101	67	151	221	207	107
Non-anthracite mines of S. Wales	389	495	79	537	396	136	728	560	130	1,627	1,647	99
Coalmines in remainder of England and Wales (all non-anthracite).	1,423	1,807	79	1,547	1,351	115	1,706	1,839	93	5,288	5,543	95

## Notes to Table II

- Column (1). Here, and throughout this report, Monmouthshire is included in South Wales.
- (2). Category 23 of International List of Causes of Death (1929). Note that when silicosis and tuberculosis are returned together on a death certificate, the classification is tuberculosis; category 23, therefore, includes cases of silicosis *plus* tuberculosis.
- (3). Categories 104-114 of International List.
- (4). Categories 90-95 of International List.
- (5). Deaths from all causes *less* deaths from suicide and accident and *less* deaths recorded in columns (2)-(4).
- (a). Deaths registered at ages 20-65 for occupational groups 4 and 5 (all underground workers in coalmines) of Table 4A of Registrar-General's Decennial Supplement for 1931.
- (b). Calculated standard deaths, i.e. deaths that would have been experienced had the group population been subject to the contemporaneous age-mortality rates (at ages 20-35, 35-45, 45-55 and 55-65) of the total national male population.
- (c). Standardised Mortality Ratio, i.e. actual deaths per 100 standard deaths.

Source.—Registrar-General (1931, Tables 4A, 4D).

TABLE III

*Cases and incidence of certified silicosis among coalminers underground in various parts of the British coalfields in the years 1931-37*

Coalfield. (1)	Total number of new cases.* (2)	Average number of men employed underground.† (3)	Average annual incidence-rate per 1,000 employed underground.§ (4)
Anthracite mines of South Wales ..	749	22,033	5.23
Non-anthracite mines of South Wales	608	94,351	0.99
Coalmines in remainder of Great Britain.‡	200	507,755	0.06

\* Total number of new cases of coalminers certified (under the Various Industries (Silicosis) Schemes, 1931 and 1934) during the period June, 1931, to December, 1937, to be disabled (totally or partially) or to have died from silicosis.

† Average number of men employed underground in December of each year from 1931 to 1937.

§ Column (2) divided by column (3) and multiplied by  $\frac{1,000}{6.5}$ .

‡ All non-anthracite except for a few typical anthracite mines in Scotland.

Source.—Mines Department (1931-37, and unpublished records).

*Additional data.*—For 1940 the total number of new cases was as follows:—South Wales anthracite mines, 267; South Wales non-anthracite mines, 176; remainder of Great Britain, 41. For the two South Wales subdivisions the new cases were thus about twice the annual average for 1931-37, whereas for the remainder of Great Britain they were approximately the same (House of Commons, 1941).

TABLE IV

*Numbers and percentages of mines with "high," "medium" and "low" incidences of certified silicosis among (i) the anthracite, and (ii) the non-anthracite mines of the South Wales coalfield*

South Wales coalfield.†	Incidence of certified silicosis.*							
	Number.				Percentage.			
	High.	Medium.	Low.	Total.	High.	Medium.	Low.	Total.
Anthracite mines‡ ..	12	11	22	45	26.7	24.4	48.9	100.0
Non-anthracite mines ..	2§	6	130	138	1.4	4.3	94.3	100.0

\* Average annual incidence of certified silicosis per 1,000 employed underground for the 7½ years 1931-38. On the basis of this rate, each mine has been classed arbitrarily as having high, medium or low incidence of certified silicosis:—

"High": annual rate of cases 8.0 or more per 1,000 employed underground.

"Medium": rate 7.9 to 3.5.

"Low": rate less than 3.5.

† Mines employing less than 100 men underground have been excluded. In certain cases the figures of two or more mines have been pooled.

‡ All work exclusively seams of Lower Coal Series (see Chapter 2).

§ Both mines work Red Ash or Tillery seam, which occurs at base of Pennant Coal Series (see Chapter 2).

Source.—Mines Department (unpublished records, based upon records of Medical Board for Silicosis).

TABLE V

*Cases and incidence of certified silicosis among various occupational classes of underground worker in (i) the anthracite, and (ii) the non-anthracite mines of the Swansea Division of the South Wales coalfield*

Occupational Class. ‡ (1)	Total cases 1931-39.*		Number employed 1937.†		Average annual incidence-rate per 1,000 employed 1931-39.‡	
	Anthra- cite.	Non- anthra- cite.	Anthra- cite.	Non- anthra- cite.	Anthra- cite.	Non- anthra- cite.
	(2)	(3)	(4)	(5)	(6)	(7)
Collier, or assistant .. ..	719	71	11,014	9,479	8.2	0.9
Hard-heading man .. ..	111	75	188	145	73.8	64.7
Borer, ripper or repairer, or assistant.	125	42	2,733	2,377	5.7	2.2
Fireman or shotsman .. ..	50	8	942	475	6.6	2.1
Haulier or rider .. ..	19	5	3,091	2,407	0.8	0.3
Others .. ..	15	3	2,628	3,312	0.7	0.1
All underground occupations..	1,039	204	20,596	18,195	6.3	1.4

\* Total number of cases of silicosis certified from June, 1931, to May, 1939, classed by occupations. Subdivision into occupational classes is made from rough and often incomplete working histories supplied by colliery companies. The basis is the occupation mainly followed during the life of the workman, and not necessarily that followed at the time of certification. Where more than one occupation has been important, precedence for purpose of assigning the class is given in the following order:—Hard-heading man, collier, repairer, labourer.

† Estimated number employed in 1937 in the particular classes of occupation. The estimate is based upon employment figures, subdivided by occupation, obtained for a typical week for certain mines, and accounting for 16,794 of the 20,596 employed underground in 1937 in the anthracite mines of the Swansea Division, and for 9,531 of the 18,195 employed underground in 1937 in the non-anthracite mines of this Division; it is assumed that the occupational figures obtained for these samples apply proportionally to the corresponding full totals.

‡ Column (2) divided by column (4), and column (3) divided by column 5, and each multiplied by  $\frac{1,000}{8}$ .

‡ Some mining occupations are explained in Chapter 3.

Source.—Swansea Divisional Inspector of Mines (unpublished records).

## CHAPTER 2

### A Short Description of the South Wales Coalfield\*

The South Wales coalfield extends from Pontypool in the east to St. Bride's Bay in the west, a distance of nearly 90 miles. Its width from north to south varies from 20 miles in parts of Glamorganshire to about two miles in Pembrokeshire. The total area within the outcrop† of the lowest seam is approximately 820 square miles, which includes 90 square miles of undersea

\* By Donald Hicks, M.Sc., A.I.C., Officer-in-Charge, Coal Survey Laboratory, Cardiff.

† "Outcrop" is defined as the cropping out of a seam or stratum at the surface, or as the edge of the seam or stratum thus cropping out.

coalfield in Swansea Bay and Carmarthen Bay. The boundary of the coalfield as defined by the base of the Lower Coal Series is shown in Fig. 1. The small part of the coalfield which is in Pembrokeshire is not shown.

Structurally the coalfield is a pear-shaped basin, with the strata dipping inwards from all sides. The dip is gentle along the northern and eastern outcrops but steep on the southern outcrop. Along the main outcrops of the coalfield the coal is mined from slants\* driven in on the seams, but further in from the outcrops the coal is mined from shafts; consequently the coal in most of the field is obtained from shafts which have been sunk through the measures to the productive seams. Up to the present the anthracite, which occurs in the north-western part of the coalfield, has been mainly mined from slants. Some of these slants have been in operation for many years, and the workings are at a considerable distance "inbye" and at considerable depths below the surface. Beyond a distance of two miles or a little more from the mouth, mining from slants is difficult and uneconomical, but it has not yet been found necessary in the anthracite field to sink many deep shafts further away from the outcrops.†

The development of the field as a whole has been assisted by subsidiary folding along an east-west axis. In some areas this has had the effect of bringing many workable seams to within reasonable distance of the surface. These seams would have passed to depths which it would have been impossible to reach had the dip of the beds from the rim of the coalfield towards its centre been maintained.

The coalfield is intersected by a large number of deep valleys. This has had an important effect on mining development, particularly in the centre and eastern areas. By sinking shafts in the bottoms of the valleys it has been easier to reach the very productive seams which occur in the lower part of the measures. Seams higher up in the measures outcrop on the steep faces of these valleys, and some of these seams have been, and still are, worked to a small extent from slants, levels or shallow pits.

\* "Slant" is defined as a roadway driven from the surface at an angle to the horizontal, in order to enable a seam to be mined.

† Note by P.D'A.H. and E.A.A.: Although anthracite has been mined for some hundreds of years, large-scale development of the industry has taken place only in the last 60 years and notably in the last 40 years. This is shown by the following table of outputs:—

*Annual coal outputs*  
(in thousand tons)

	<i>Anthracite, South Wales coalfield.</i>	<i>Total, South Wales coalfield.</i>	<i>Total, United Kingdom.</i>
1865 .. ..	509 (1864)	12,656	98,151
1870 .. ..	400 (approx.)	13,664	110,431
1890 .. ..	1,221	29,415	181,614
1895 .. ..	1,761	33,040	189,661
1900 .. ..	2,203	39,328	225,181
1905 .. ..	2,789	43,203	236,129
1910 .. ..	4,032	48,700	264,433
1915 .. ..	4,393	50,453	253,206
1920 .. ..	4,232	46,249	229,532
1925 .. ..	5,567	44,630	243,176
1930 .. ..	5,568	45,108	243,881
1935 .. ..	5,874	35,025	222,249

Sources.—Royal Commission upon Coal, 1871; Royal Commission on Coal Supplies, 1905; South Wales Coal Annuals.

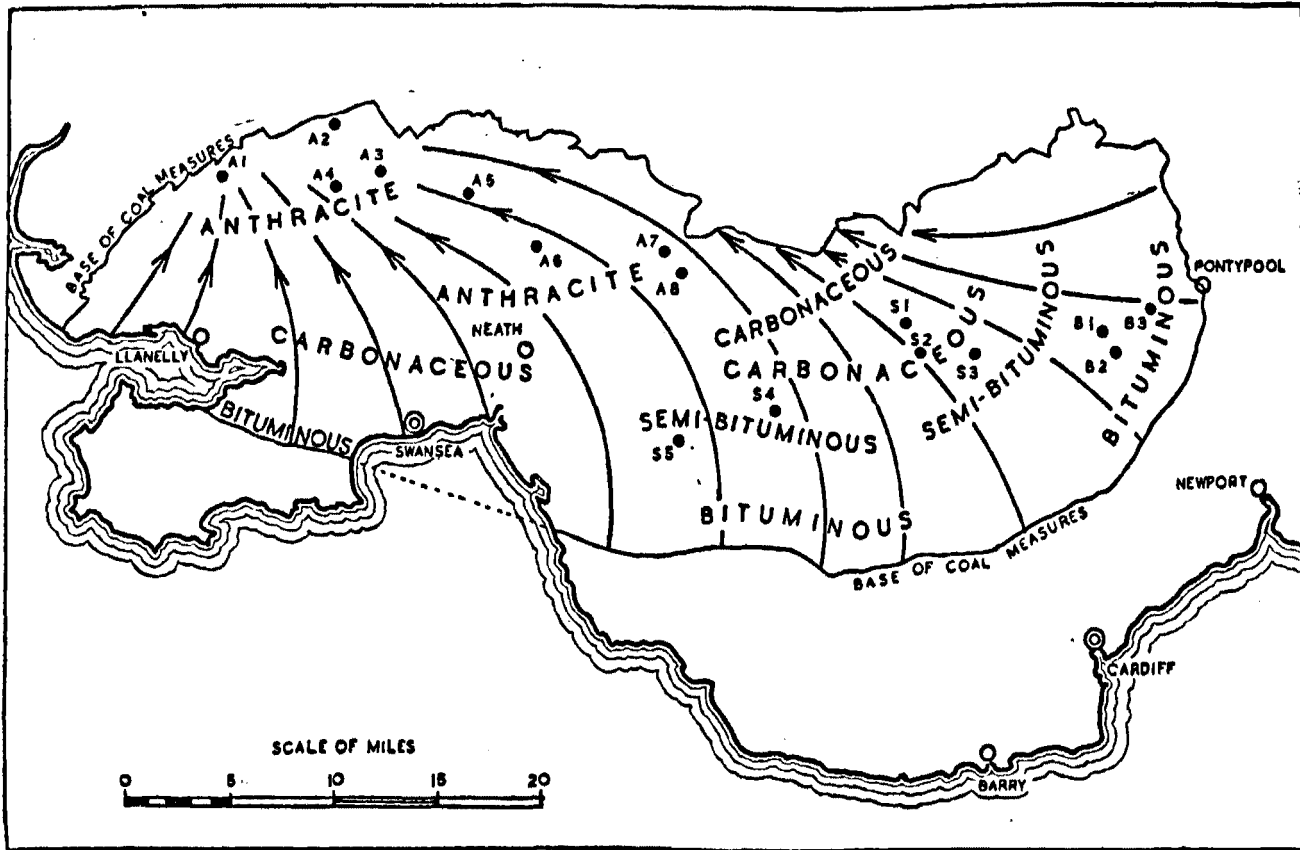


FIG 1 —Map of the South Wales coalfield, showing the directions of the change of rank of the coal, and the position of the 16 collieries of the inquiry (anthracite, A.1—A.8; carbonaceous, S.1—S.3; semi-bituminous, S.4—S.5; bituminous, B.1—B.3).

## 12 . PULMONARY DISEASE IN WELSH COALMINERS

The coal measures\* of South Wales have been divided on a lithological basis into :—

3. Supra-Pennant Series or Upper Coal Series.
2. Pennant Series.
1. Lower Coal Series.

The Lower Coal Series is present over the whole of the field, and the Pennant over a very large part of the field. The Supra-Pennant Series is present in a few isolated areas only.

The Lower Coal Series is predominantly an argillaceous division and consists of beds of shale, fireclay and sandstone, and a number of workable coal seams of excellent quality. Most of the output of the South Wales coalfield, including all the anthracite, is now obtained from seams in the Lower Coal Series. The great majority of the productive seams in the Lower Coal Series occur in its lower part, which may be defined arbitrarily as that part of the measures from the lowest seam up to and including the Two Feet Nine seam or its equivalent.

The Pennant Series consists chiefly of thick massive sandstone. Shales are not absent but they are subordinate. In the eastern part of the field the coal seams in this Series are few and unimportant. The Series thickens in a westerly direction and workable coal seams appear, some of which have been, and still are, worked in the area between Neath and Llanelly, particularly in the Swansea area.

The junction of the Pennant and Lower Coal Series is marked by the No. 2 Rhondda seam and its correlatives—the Tillery, Red Ash, Brithdir, and Ynisarwed seams. The collieries that mine this seam are often referred to locally as House Coal Pits. The correlation of this seam is fairly well established, but there is not everywhere a sharp lithological change at this horizon, thick beds of sandstone developing below it in some areas.

The Mynyddislwyn seam forms a convenient base to the Supra-Pennant Series, which is a succession of shales, fireclays and soft sandstones, with some coal seams. The Mynyddislwyn seam is worked at a few collieries, but at present none of the seams which occur above it is worked.

Sufficient data have not yet been collected to show whether the above main subdivisions of the South Wales coal measures, based on lithology, are reflected in the petrographic and chemical composition of the coal seams themselves in the vertical sequence.

The positions of the 16 collieries chosen for the medical and environmental field surveys of chronic pulmonary disease which form the subject of this study are shown in Fig. 1. As a group they form a small selection of the 200 collieries employing more than 100 men underground which are now working (see Mines Department, 1938). Although the number of collieries chosen is small, it will be seen from Fig. 1 that they are well spaced geographically, and, as is shown later, the selection also embraces the full range of types of coal which are mined in South Wales.

Fig. 2 gives the vertical sections of the coal measures at these collieries. The three divisions of the measures, namely, the Lower, Pennant and Supra-Pennant Series are shown. Each vertical section gives the horizons† of the main workable seams. At some of the collieries not all the seams shown have yet been worked, although they have been proved.

Collieries A.1, A.2, A.3, A.4, A.5, A.7 and A.8 are slants driven in from the outcrops. The seams at these seven collieries, shown in Fig. 2, have been proved

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\* "Coal measures" are defined as the whole series of rocks formed by the seams of coal and the intervening strata of shales, sandstones, etc.

† "Horizon" is a plane of stratification assumed to have been at one time horizontal and continuous.

by cross measure drivages and general mining operations. At the other nine collieries the seams have been proved during the sinking of the shafts and by subsequent mining.

To indicate the position of the seams in the Lower Coal Series relative to the coal measures as a whole, the horizon of the base of the Pennant is shown, although it has not always been encountered in the colliery. For example, at A.1, the Brondini seam, which is the equivalent of the No. 2 Rhondda seam, outcrops on the hillside above the colliery. At A.5, the Red Vein is worked from a slant driven in on this seam, but the measures in this locality have been proved by a borehole, the record of which is summarised in Fig. 2. Colliery A.7 is a slant, but the measures between the White and the Cnapiog seams have been proved in this and in neighbouring slants, while the sequence from the White to the Ynisarwed is exposed on the hillside nearby. The horizon of the No. 2 Rhondda on the hillsides above collieries A.8, S.1 and S.4 is well defined.

Because the Supra-Pennant occurs in isolated areas, it is not possible to show the Mynyddislwyn seam in more than three of the sections.

No attempt is made in Fig. 2 to show the correlation of the seams included, except the fairly well established correlation of the Nine Feet seam and its equivalents—Black Vein, Upper and Lower Rhas Las, Harvey, Big and Stanllyd.

The seams underlined in Fig. 2 are those of most importance in the occupational histories of the men examined in the medical survey, and have been the sources of the environmental studies. They are a group of seams which, generally speaking, are fairly close together and, with the exception of the Red Vein, are in the lower part of the Lower Coal Series. At some of the collieries only one seam has been of any importance in the occupational histories of the men examined. For example, at collieries A.1 and A.2, the Lower Pumpquart, and at A.5 and A.6, the Red Vein, are the only seams that are relevant to the inquiry. Moreover, at nine of the collieries the Nine Feet seam, or its equivalent, is included among the more important seams.

All the South Wales seams have a wide range of physical and chemical properties. As part of the physical and chemical survey of the national coal resources, officers of the Fuel Research organisation of the Department of Scientific and Industrial Research have examined the Nine Feet seam and its correlatives over most of the coalfield, and have also examined a large number of samples of other seams in the Lower Coal Series. From the results of this survey certain generalisations can be made.

One measure of the rank of a coal is the percentages of carbon and hydrogen in the coal substance, calculated on a dry mineral-matter-free basis (see King, Maries and Crossley, 1936). The percentages of carbon and hydrogen in 250 samples, each representing the full thickness of the seam, taken at points spread over the coalfield, have been plotted, and the results all fall in a well-defined band. This band is often referred to as the "coal band." The South Wales Lower Coal Series "coal band" is shown in Fig. 3 (p. 16). The extremes of carbon and hydrogen of seams in the lower part of the Lower Coal Series are 86.0 per cent. of carbon, and 5.3 per cent. of hydrogen (lower rank coals), and 94.5 per cent. of carbon, and 2.5 per cent. of hydrogen (high rank coals). There is very little anthracite with less than 2.8 per cent. of hydrogen.

Seyler (1900, 1931, 1938) has used a plotting of the carbon and hydrogen as the starting point of his classification. He has defined certain "species" and "genera" by fixing limits of carbon and hydrogen. Seyler's complete classification has not been superimposed on the "coal band" plotted in Fig. 3, but the band has been subdivided into four groups, using Seyler's hydrogen horizons and his nomenclature. The four groups of coal are Anthracite, Carbonaceous, Semi-bituminous and Bituminous.

There is no break in the band at these divisions, and there is no sudden change in the properties of the coal. There is a gradual change along the band.



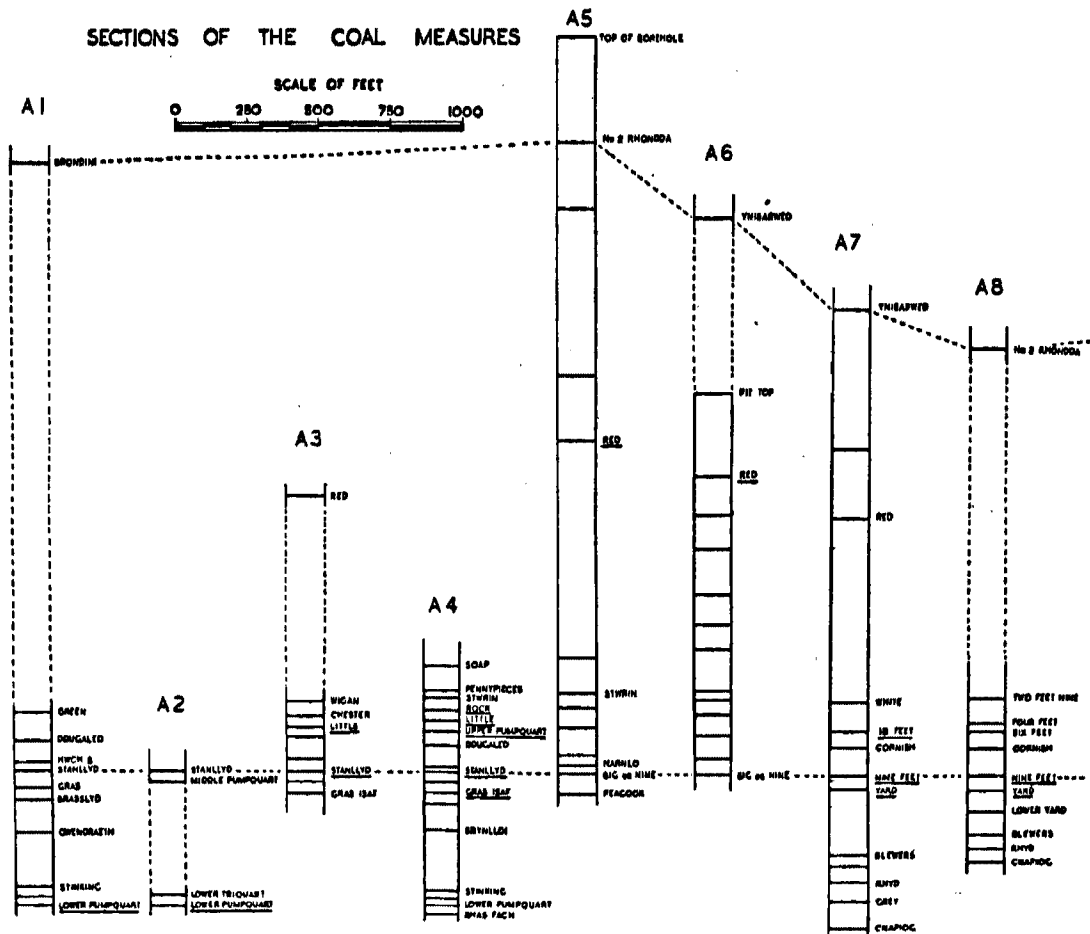
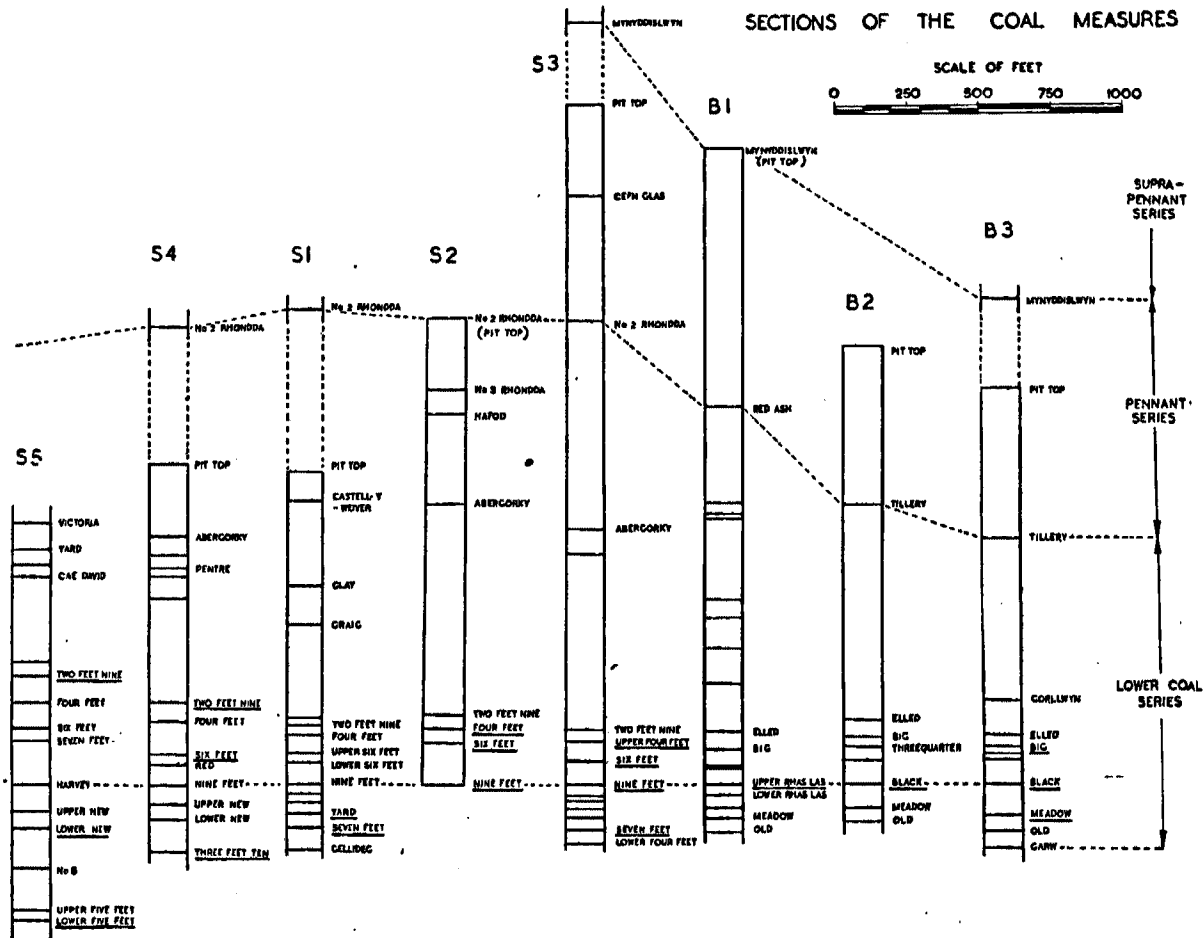


FIG 2.—Vertical sections of the coal measures at the 16 collieries.



MEDICAL SURVEY

Fig. 2.—Vertical sections of the coal measures at the 16 collieries—continued.

This fact is brought out by Seyler in his subdivision of the anthracites into Groups 1A, 1, 2, 3 and 4. From 1A to 4 there is a gradual decrease in the rank of anthracites. The carbon decreases from approximately 95 per cent. to approximately 93-92.5 per cent., and the hydrogen increases from 2.5 per cent. to 4.0 per cent. The dividing line between Groups 2 and 3 anthracites is shown in Fig. 3.

The volatile matter\* of the South Wales coals is a good first guide to their rank. The range of volatile matter of the coal in the Lower Coal Series is 5 to 36 per cent. The volatile matter increases with the decreasing carbon and hydrogen ratio. The ranges of volatile matter of the four main groups are approximately as follows: (a) Anthracite, 4-5 to 9-10 per cent.; (b) Carbonaceous, 10 to 16 per cent.; (c) Semi-bituminous, 16 to 21-22 per cent.; (d) Bituminous, 22 to 36 per cent.

The above changes in the composition of the seams take place in certain well-defined directions. Thus, if samples of the same seam taken at intervals

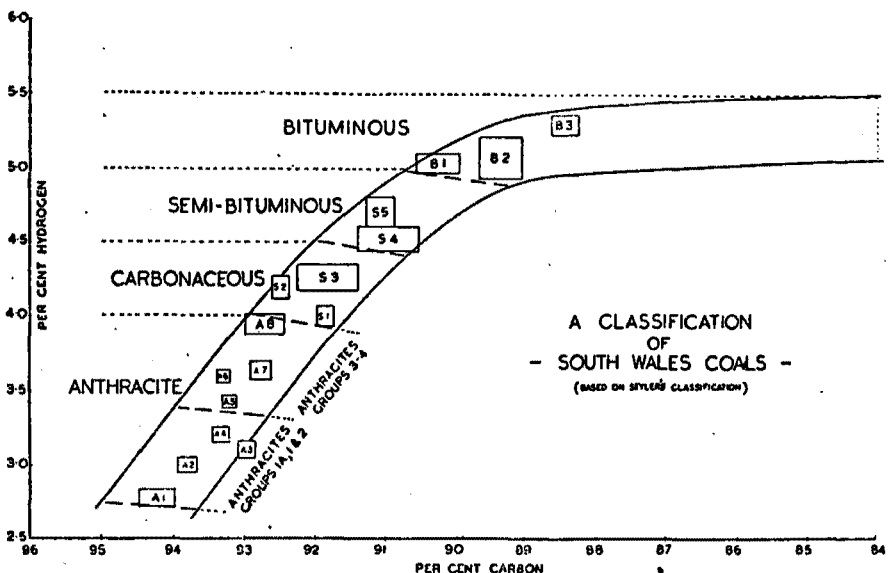


FIG. 3.—A classification of the South Wales coals, showing the approximate rank of the coal mined at each of the 16 collieries (anthracite, A.1—A.8; carbonaceous, S.1—S.3; semi-bituminous, S.4—S.5; bituminous, B.1—B.3).

along the northern edge of the coalfield are examined, it will be found that in the extreme east the coal is bituminous with a volatile matter of approximately 35 per cent., but that in a westerly direction the volatile matter gradually decreases until in the extreme west the coal is an anthracite with a volatile matter of 5 per cent. Again, if samples of the same seam are taken at intervals along a line drawn from the southern outcrop to the north-western outcrop, it will be found that the volatile matter of the coal near the southern outcrop is high, but that as the seam is traced in a north-westerly direction the volatile matter decreases, until it is approximately 5 per cent. in the extreme north-west.

From the detailed survey of the Nine Feet seam and others near it in the Lower Coal Series, referred to above, sufficient information is now available to plot a series of iso-rank lines and, conversely, the directions of the maximum

\* "Volatile matter" is that part of the coal which is driven off when it is heated under specified conditions without combustion taking place.

change of rank. The latter are shown in Fig. 1 (p. 11). The arrows point in the direction of increasing rank. The rate of change of rank is not constant along these lines. In some localities the rank changes rapidly, in others more slowly.

These directions of maximum change of rank are, so far as can be judged at present, the same for all seams in the Lower Coal Series. Although the survey of the seams is by no means complete, it can be stated that in some areas an iso-rank line for one seam is not always coincident with the same iso-rank line for another seam in the Lower Coal Series, and in certain localities there are small differences in rank between some seams and those vertically above and below them. Considering the seams in the vertical sequence at any particular point in the coalfield, there is a slight decrease in rank as one passes from the lowest seam upwards, but the magnitude of the change is by no means so great as the lateral changes described above. Thus at certain points in the field the seams in the lower part of the Lower Coal Series are Group 1 anthracites, while the seams high up in this series or near the base of the Pennant will be Group 2 anthracites. Similarly, where the anthracites in the lower part of the Lower Coal Series are Group 4 anthracites, the seams higher up or in the Pennant Series will be carbonaceous. Again, where the lower seams are carbonaceous the higher seams will be semi-bituminous. And again, the lower seams near the eastern and southern outcrops are bituminous, with a carbon content of approximately 86.0 per cent. and hydrogen 5.3 per cent., while seams higher up in the Lower Coal Series and at the base of the Pennant are lower rank bituminous coals, with some near the outcrops having a carbon content of 84 per cent. and a hydrogen content of 5.4 per cent. This is the reason why the "coal band" in Fig. 3 is drawn to the 84 per cent. carbon limit.\*

The disposition of the anthracite, carbonaceous, semi-bituminous and bituminous coals shown in Fig. 1 is a broad generalisation for the seams in the lower part of the Lower Coal Series. The collieries selected by the Medical Research Council for this inquiry can be considered in terms of this general disposition of the various types of coal, and against the background of the main directions of the changes in the rank of the coal.

It has not yet been possible to analyse all the seams underlined in Fig. 2, but a large number has been examined, and the carbon and hydrogen of the coal substance of these samples have been plotted. The points fall within the squares shown in Fig. 3. It will be seen that the coals are fairly evenly spaced in the "coal band". The collieries chosen can therefore be regarded as representative of the range of types of coal found in the South Wales coalfield.

For ease of discussion of the results of the medical survey, the collieries mining carbonaceous and semi-bituminous coals have been considered as one group, and are referred to as steam coal collieries. The subdivision of the anthracites shown in Fig. 3 has been adopted for the same reason. Groups 1A, 1 and 2 anthracites have been combined and can be referred to as high rank anthracites, and the subdivisions 3 and 4, combined, can be referred to as lower rank anthracites. The collieries have been indexed according to the chemical classification of the coal mined at them. The collieries mining

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\* Note by P.D'A.H. and E.A.A. : To avoid these additional complications due to the change in the rank of the coals in the vertical sequence, with also a possible change in the nature of the over- and underlying strata, one of the criteria of choice of collieries adopted for this inquiry has been that the seams which are of importance in the occupational histories of the men examined should be in the lower part of the Lower Coal Series. This criterion has been adhered to, except possibly in the cases of the two collieries, A.5 and A.6, where the Red Vein is the seam worked. This seam is in the upper part of the Lower Coal Series. The choice of these two collieries was made mainly for other reasons, and particularly to study a marked contrast in the incidence of certified silicosis.

anthracite have been indexed as A collieries and numbered, in order of decreasing rank, as A.1, A.2, A.3, etc. ; the collieries mining carbonaceous and semi-bituminous coal, combined and referred to as steam coal collieries, have been indexed as S collieries and numbered in order of the decreasing rank of the coal, as S.1, S.2, S.3, etc. ; and in the same way the collieries mining bituminous coal have been numbered as B.1, B.2 and B.3.

This account of the South Wales coalfield discusses only certain features which have been considered by the Medical Research Council's investigators when selecting the collieries for this inquiry, namely, the geographical position of the collieries, the composition of the coal mined at them, and the positions of the seams in the vertical sequence. Sufficient information is given to show that the 16 collieries are a fairly representative selection. They are well spaced geographically, embrace most of the types of coal found in South Wales, and work seams that are fairly close together and that are typical of the seams in the lower part of the Lower Coal Series, from which most of the output of the South Wales coalfield is obtained.

### CHAPTER 3

#### The Structure of the South Wales Coal Seams, and the Methods and the Occupational Grades of the Men who Work Them

##### A. THE STRUCTURE OF THE COAL SEAMS\*

The structure and general section of the South Wales coal seams cannot be fully described in a brief statement, because the variations in thickness and section of the seams are very great. The following account gives an outline of the structure of the seams, with illustrations of the variations in thickness of the beds of coal and other strata encountered at the working face. Some of the local names used to describe the strata are defined. The account applies generally to the coalfield, and separate descriptions are not necessary for the seams in the localities where the coal is anthracite, steam or bituminous.†

In the coal measures of South Wales there is a large number of coal seams. Some are only a few inches thick, but many have a thickness in some areas of from 5–10 ft. or even more. Fig. 4 shows the average sections of some of the important seams and associated strata at a few of the 16 collieries concerned in the present inquiry.

Up to date it has not been necessary to mine seams that are much less than 2 ft. in overall thickness, since there have been great reserves of the thicker seams. The latter—e.g. the Black Vein in Monmouthshire and its equivalent the Nine Feet seam in Glamorganshire—have been extensively mined. At collieries B.2 and B.3 the Black Vein has an overall thickness of 6–9 ft. In parts of Glamorganshire, e.g. at collieries S.3 and A.8, the Nine Feet seam is 8–9 ft. thick and, further west, the Stanlyd, which is considered to be the equivalent of the Nine Feet seam, is in some localities also a thick seam, as at colliery A.3 in Carmarthenshire, where the overall thickness is approximately 6 ft. (see Fig. 4).

Not all the seams that are extensively worked are as thick as the above. For example, at collieries A.1 and A.2 the Lower Pumpquart is 3–3½ ft. thick, at collieries A.7 and A.8 the Yard seam is 3 ft. thick, and at collieries S.4 and S.5 the Two Feet Nine seam is approximately 5 ft. thick. The following

\* This section (A) is by Donald Hicks, M.Sc., A.I.C., Officer-in-Charge, Coal Survey Laboratory, Cardiff.

† A useful summary of the description of coal-measure rocks is given by Hudspeth and Phillips (1937).

two examples illustrate the order of differences in thickness that can occur in seams in the same mine. At colliery S.1 the Two Feet Nine seam is approximately 3 ft. thick, the Four Feet seam is often 6 ft. thick, the Nine Feet seam 9 ft., the Yard seam 3 ft., and the Seven Feet seam approximately 4 ft. thick. At colliery A.4 the seams are a little thinner than at S.1, the Rock, Little and Upper Pumpquart seams being approximately 3 ft. thick, the Stanlyd 6-6½ ft., and the Gras Isaf 2-2½ ft. thick.

It should not be concluded that all the seams are single homogeneous beds of coal and that the only variation is in thickness. Many of the seams have frequently quite a complex section, and may consist of two or sometimes three or four distinct beds of coal separated by other strata. For example, at colliery S.3, the Nine Feet, Upper Four Feet and Six Feet seams each consist of two well-defined beds of coal, which are referred to as the bottom coal and the top coal; the Stanlyd seam at colliery A.3 consists of three main beds of coal, a bottom coal which is 3½-4 ft. thick, and two thinner coals above it, each about 9-12 inches thick. This complexity of structure is most common in the thicker seams. The thinner seams are often single beds of coal, as for

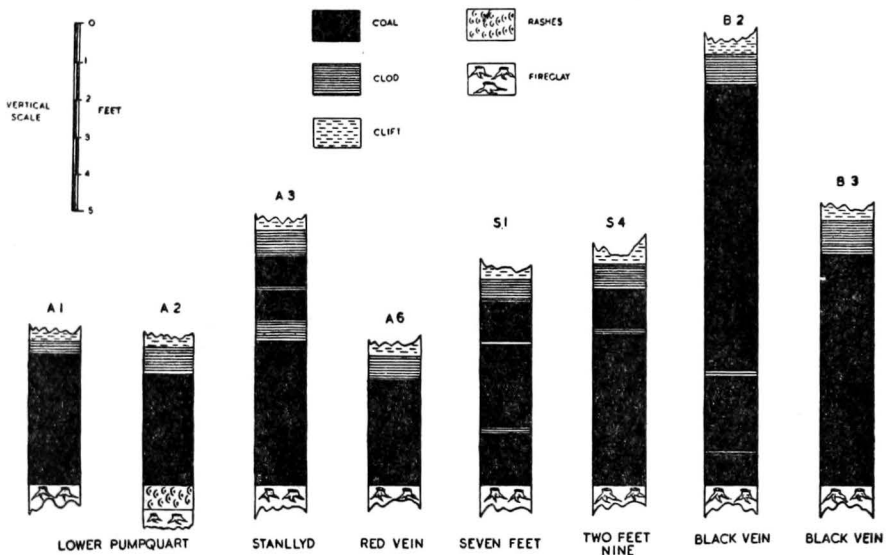


FIG. 4.—Typical sections of the seams at some of the 16 collieries.

example, the Lower Pumpquart at collieries A.1 and A.2, where this seam is 3-3½ ft. thick.

In the main, the South Wales coal consists chiefly of clarain (bright or moderately bright coal) with thin lenticles and streaks of vitrain (very bright, glassy-lustred coal). There are no pronounced bands of durain or dull coal of the nature of the "hards" of some of the English coalfields, though microscopical examination of some samples has revealed occasional thin bands of durain in some of the seams. Fusain, the charcoal-like constituent occurring in thin layers or partings, is found in most of the seams, though a few of them—e.g., the Nine Feet seam and its equivalents—contain less than 1 per cent. In seams containing relatively large amounts of fusain the latter is found often at well-defined and constant horizons. Within the beds of coal there are sometimes found thin partings or lenticles of clay-like mineral matter, and in some seams nodules of siderite and pyrites. In the mass, this is termed extraneous mineral matter, to differentiate it from the inherent mineral matter, which is a part of the organic material from which the coal seams have been

formed. As with fusain, the extraneous mineral matter in many seams often occurs at well-defined and constant horizons.

Any description of coal seams, especially for the present purpose, must include a reference to the other strata encountered at the working face. These are the various types of rock forming the floor and roof of the seams, and lying between the layers of coal in seams that consist of two or more layers. The floor of the South Wales coal seams is usually described as a fireclay. This is a general term and does not necessarily mean that the floors of all the seams are proved refractory clays. Between the fireclay floor and the main bed of coal there sometimes occurs a thin bed of rashes (or rashings) (see Fig. 4). The thickness of such beds is variable and their occurrence, even in a short length of working face, is erratic. Rashes is a term used in South Wales for a carbonaceous clay, frequently containing thin layers of coal, generally soft and friable, and with many slickensided surfaces—i.e., polished and striated surfaces indicative of movement under pressure. Immediately above the fireclay floor there is occasionally present a thin bed of inferior coal, which is sometimes referred to as an engine coal or holing coal. This is mined but it is stowed in the waste or gob—i.e. the space from which coal has been worked.\*

At the top of the seam there frequently occurs a layer of clod between the coal and the roof strata (see Fig. 4). The term clod is used to describe a hard clay or soft mudstone. It often varies in thickness even in the same underground district, and may change from one or two inches to two or three feet or more in quite a short length of face. Usually the clod is mined with the coal and it is stowed in the waste; indeed, the term clod is often applied, in South Wales, to those bands of shale which immediately overlie the coal, and which fall with the coal or are brought down easily with a pick. The clod often merges with the clift roof (see below). Generally speaking, the clod is a softer rock than the clift above it.

At the top of some coal seams in some localities, e.g. the Two Feet Nine at colliery S.4, there is a layer of bast—a hard, black, carbonaceous shale which often has the appearance of a cannel or a coaly clod. In other localities seams are overlain by a variable thickness of rashes.

Usually the roof strata of most of the seams in the Lower Coal Series are described as clift. This is a somewhat vague term and describes many types of shale, the differences in which lie chiefly in their texture and hardness, and in the degree to which they are laminated. In the main, the clifts are argillaceous rocks and, though locally they sometimes become more arenaceous†, the strata immediately above the seams in the lower part of the Lower Coal Series can rarely be described as a sandstone or what the South Wales mining engineer refers to as a "rock" roof. As a rule, the clift is left up along the working face, but in the stall roadways and coal headings at the face, part of it commonly has to be brought down systematically, so as to give the necessary headroom.

In seams that consist of two or more beds of coal, the latter are separated from one another by thin layers of rashes, or by a layer of clod (hard clay or soft mudstone) or sometimes shale (Fig. 4). These layers may be as much as 12 in. or more in thickness. They are mined with the coal, but as far as possible stowed in the waste.

How a seam is mined is partly determined by its overall thickness, its regularity, the number of beds of coal of which it consists, their quality and the thickness and nature of the bands that separate them, and the nature of the strata overlying and underlying the seam.

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\* "Gob" is a term derived from the Cymraic "agof"—a cave or hollow.

† Argillaceous—of the nature of clay; arenaceous—sandy or of the nature of sand

## B. METHODS OF WORKING THE SEAMS, AND THE OCCUPATIONAL GRADES OF THE MINERS \*

In the South Wales coalfield there is a wide variety of methods of mining, corresponding with variations in the geological and physical conditions and other factors. This section contains an outline of the important systems of work and the procedures used in their application, together with a brief description of the more important occupational classes of the miners.

### (i) *Systems of work*

The following is a brief description of the principal methods of working the seams in the South Wales coalfield; these are:—

- (a) The longwall stall system;
- (b) The longwall tophole system;
- (c) The longwall "Barry" or "Nottingham" system;
- (d) The longwall single unit and gravity conveyor systems;
- (e) The longwall double-unit conveyor system;
- (f) The pillar and stall system;
- (g) The double stall system.

The longwall stall system, over the past 30 or 40 years, has probably been the most popular method in South Wales, though, with the advent of machinery, various longwall conveyor systems have been introduced at many collieries and are being increasingly used. All the longwall systems have one principle in common, namely, that the coal is extracted along the whole length of face, in an advancing direction; the workings advance in a continuous line, and the space previously occupied by the coal is partially or wholly filled up with stone and refuse upon which the superincumbent strata settle down. This is essentially different from the older pillar and stall methods, in which there is not a continuous face and much of the coal is left behind as pillars to help support the roof. The pillar and stall methods of working are now rarely practised in the South Wales coalfield, though at two of the 16 collieries selected for this inquiry there are certain seams in which this has been the main system worked.

The method of working a seam, and the general layout of the district, are chiefly determined by the following factors: the structure of the seam (see Section (A)), the shape and size of the royalty, the dip of the strata, the presence or absence of faults and other geological disturbances, the presence or absence of water, the direction of advance of face, the ease or otherwise of controlling the roof, and, of course, the output required from the seam and district in question.

(a) *The longwall stall system.* This system is usually adopted where the dip of the strata† is not great. While it is difficult to give a limiting figure, it may be stated that the system is workable up to a dip of approximately 6 in. per yard. Judging by the histories of the selected colliers examined, the longwall stall system has been an important method in 15 of the 16 collieries chosen, and the most important or the only system in 10 of them.

Fig. 5a shows the general layout of the longwall stall system. Main headings ‡ (coal headings—to be distinguished from hard headings, see later) or levels §

\* This section (B) is based largely upon material supplied by Major R. Yates, D.S.O., M.C., H.M. Divisional Inspector of Mines and Quarries, Northern Division; late Senior Inspector in the Swansea Division.

† The downward slope, estimated by the angle of inclination to the horizontal. "Rise" is the opposite of "dip."

‡ "Heading" is a development roadway.

§ "Level" is a horizontal roadway.



are driven on the strike\* of the seam. Headings are driven at an angle off these main roads. The angles which these headings make with the main roads, and the gradients of the headings, are determined by the method of haulage. At many collieries the headings are driven to the full rise or full dip of the seam. At regular intervals stalls are turned off these headings, and they travel in the direction of the strike of the seam. The total length of the stall roads is determined chiefly by the ease with which they can be maintained. There is an economic limit to the length of the stall roads, varying from 40 to 60 yards. When this is arrived at, a new heading is opened off the main roads. This is driven parallel to the previous one and cuts off the old stall roads; fresh stalls are then opened off the new heading and the old roads are no longer used.

Usually one collier, with his assistant, is responsible for the development of the stall road. He mines the seam at the face of the stall road and the coal along the working face up to half-way between the adjacent stall roads, this area being termed his working place (see Fig. 5b). The coal headings are also developed by colliers. During the past few years, at some collieries, mining has been intensified by assigning two colliers, with assistants, to a working place; this method may be referred to as the intensive longwall stall system.

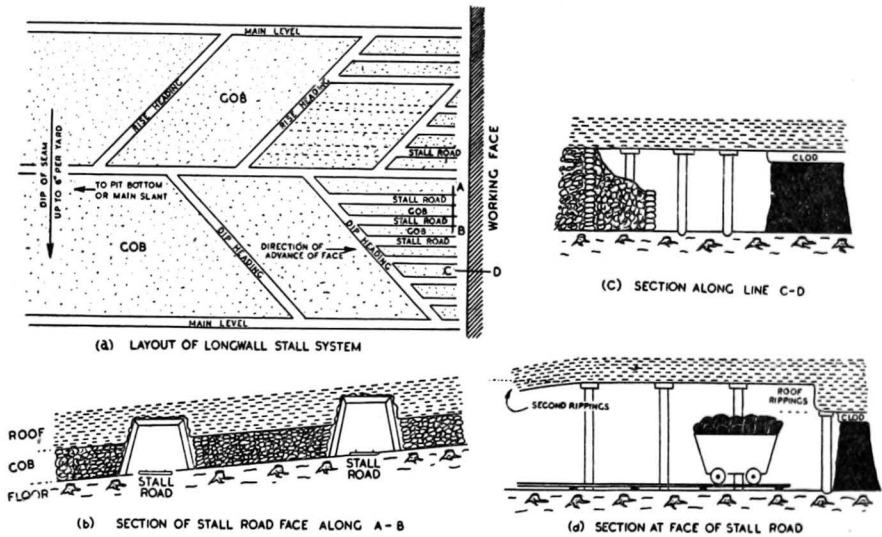


FIG. 5.—The longwall stall system of mining.

Wherever possible the whole of the seam is extracted. In the South Wales coalfield this is usually done, except in some of the very thick seams, or in seams where it is desirable to leave part of the seam unworked either because the part in question is of inferior quality, or because the top part of the seam forms a more reliable roof than the overlying strata.

To make the picture clearer some amplification is required. In a thin seam the whole of the coal is mined and any overlying clod is also brought down by the collier; the coal is filled by him into the tram which stands in the stall roadway, and the clod is packed or thrown into the gob (see Fig. 5b, 5c and 5d). This applies, for example, to the Lower Pumpquart seam at colliery A.1, which consists of  $3\frac{1}{2}$  ft. of coal above which are 4-5 in. of clod.

In order to obtain the necessary height to allow of traffic along the roads, and to cater for subsidence, it is necessary to bring down at the face of the roadways a considerable amount of the shale roof strata (clift). This operation

\* "Strike" is the horizontal course of a seam or stratum.

is generally termed first or face-ripping (see Fig. 5d). For example, on the longwall stall faces of the Lower Pumpquart seam at colliery A.1, approximately 3 ft. of the roof were brought down at the face of the stall roads and headings. The stall roads here were about 8-9 ft. wide and 6-7 ft. high, though in many seams the stall roads are ripped at the face to a height of 8 ft. or even more. Occasionally the extra height is obtained by excavating the floor of the seam instead of the roof. Depending upon the rate of advance of face, this face-ripping is usually done about once a week. The shale material or debris (rubbish) resulting from ripping is used, together with any clod mined, for making walls and packs in the gob, the object of the latter being to assist in supporting the roof (Fig. 5b and 5c). When there is insufficient material from rippings, extra rubbish may have to be brought in from other parts of the mine for gobbing purposes.

The face-ripping on the longwall stall system is generally done by the collier, and it may be estimated that ripping and the handling of rippings occupy him one or sometimes two shifts a week, or about one-fifth of his time. There are important exceptions to this, which will be discussed later.

As a result of subsidence, it may be necessary, in order to keep the roads open to traffic, to do a second or back-ripping on the roadways at a distance from the coalface. When such back-rippings are in the stall road, as for example near its mouth, they are generally done by the collier. It is impossible to generalise as to the frequency of this operation (see Fig. 5d).

As indicated above, the development and face-ripping of the subsidiary coal headings are usually carried out by the colliers. In levels and headings that are the main thoroughfares of a district, it is very essential to have plenty of room; and it is therefore often necessary to do frequent ripping of the roof, and repairs to its supports. This work on the main roads is performed by men who are described as repairers.

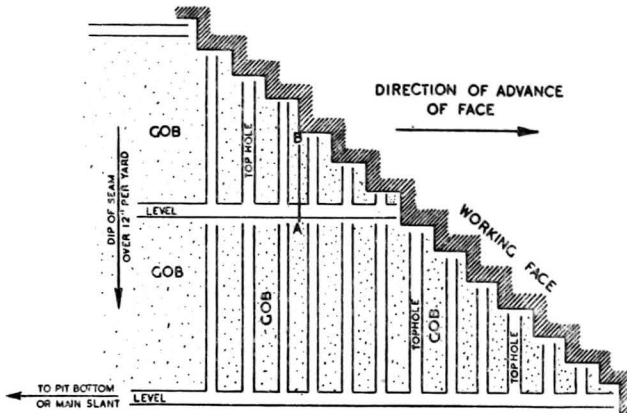
In some thick seams not all of the seam is worked along the whole face. The following examples will show how this affects ripping.

In the Nine Feet seam at colliery S.3, the top coal, or part of the top coal, has been left up to form the roof between the stall roads, but at the face of the stall roads it has been ripped down to obtain the necessary height; in this seam it has usually been unnecessary for the collier to rip the roof shales (clift). In the Monmouthshire Black Vein at colliery B.3, the bottom coal is left unmined along the working face, but is ripped up at the stall roads for extra height; again the collier does not require to interfere much with the clift roof at the face, though here he may rip down a thickness of clift a short distance back in his stall roadway. In the West district of the Black Vein seam at colliery B.2 (from which the selected colliers were taken) the bottom coal is again left unmined, but here about 2-3 ft. of clift roof is ripped at the face of the stall roads, instead of getting up the bottom coal. Finally, in parts of the Stanlyd seam at A.3, the inferior top coal (locally called "bord" coal) and overlying clod are left up along the working face, but at the face of the stall roads the collier rips down not only the bord coal and clod but also not infrequently a thickness of the clift roof strata; while in other parts of this seam the whole section, including the bord coal, is worked throughout the face, and at the stall roadheads the clift roof is ripped.

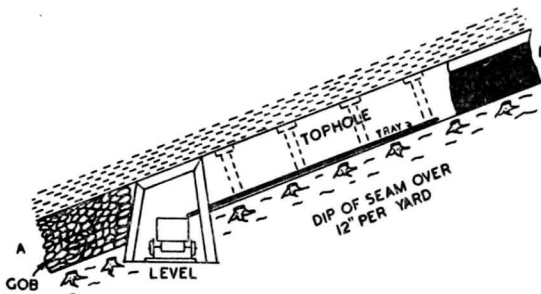
When the full sections of complex seams, i.e. those with two or more beds of coal separated by layers of clod, are mined, the intermediate clods and layers of rashes and inferior coal are thrown into the gob by the collier.

To give an idea of the extent of the working faces, the following facts may be quoted. As, however, the distance apart of the main levels and of the headings depends on local conditions, it is difficult to generalise on the subject. The levels or main roads are often 150 or more yards apart and the headings 50 yards apart, but in ground which is difficult to control the headings may be only 35 yards apart. The distance between the centres of the stall roads is approximately 12-15 yards. There are many working districts in South Wales where the total length of working face is 250-350 yards, but, on the other hand, there are some districts in which there are only a few stalls and where the length of face is as small as 50 yards. There have been instances in the steam coal and

bituminous areas where mining conditions have been good, in which the total length of face has been as much as 1,000 yards or more, but these are exceptional. Generally speaking, the size of the working districts in the anthracite collieries is smaller than in most of the steam coal and bituminous coal collieries, and the output of the anthracite collieries is frequently very much smaller than that of the average steam coal or bituminous colliery. In the anthracite field there is a large number of small units, and there are examples where the weekly output of coal from an anthracite colliery is of the same order as the daily output of many steam coal collieries.



(a) LAYOUT OF LONGWALL TOPHOLE SYSTEM



(b) SECTION ALONG LINE A-B

FIG. 6.—The longwall tophole system of mining.

At a few collieries in the South Wales coalfield, machine coal-cutters have been introduced on longwall stall faces. In such cases the system of work is somewhat similar to the above, but the collier is assisted by the machine-cutting of the coal. He fills the coal by hand into trams and does the ripping as before. Since the rate of advance of the face will be increased, more ripping has to be done at the face per unit of time. This cutter-stall system has been the most important system in the Yard seam at colliery A.8 and in the Yard seam at colliery S.1, as judged by the histories of the collieries examined.

(b) *The longwall tophole system.* When the seams are steeply inclined, as, for example, in certain parts of colliery A.2, the longwall tophole system is

adopted. This system is frequently applied when the strata are dipping at more than 12 in. per yard. It is really a modification of the longwall stall system, the topholes taking the place of stalls. The longwall tophole system has been the most important system, judged from the histories of the men examined, at colliery A.2.

The general layout of this system is shown in Fig. 6a. Levels are driven on the strike of the seam, and topholes are driven to the full rise. The collier, with his assistant, mines the coal at the face of the tophole and for some distance to the right and left of it, until he meets the men in the adjacent topholes, and so maintains a continuous face. Fig. 6a shows a stepped face. Frequently the face is straighter than this. The collier fills the coal on to metal sheets which are placed on the floor; the coal then slides down the tophole and is discharged directly into trams which stand in the levels at the mouths of the topholes (see Fig. 6b). The collier working in a tophole mines only the seam; i.e. he mines the coal and any clod or floor rashes which are associated with it, throwing the latter into the gob. He rarely rips any roof clift or floor. The roof in the gob is supported by wooden cogs but, from the very nature of the system, very little rubbish is handled except the clod and rashes.

In the levels the usual custom is to excavate the floor and sometimes rip down a little of the roof shales, in order to obtain the necessary height for traffic and to get the trams under the tophole chutes. This is illustrated in Fig. 6b.

(c) *The longwall "Barry" or "Nottingham" system.* This system is not very common in the South Wales coalfield, but it is described here because it is the method which has been extensively used at colliery S.3. It is applicable only to fairly thick seams with a good roof. The seams must be thick enough to allow the trams to be taken along the face, and the roof must be strong, because the distance between the face and the packs in the gob is commonly rather great. The trams are brought in along one road, pass along the face and out at the next road. Each panel of coal so worked is usually 40-60 yards long, and there may be two or more panels in series, to give a length of face of 180 yards or more.

The collier usually works the full section of the seam (though not in the case of the Nine Feet seam of colliery S.3). The coal is filled into trams standing along the face, and any clod, rashes or inferior coal is thrown into the gob. The system has the advantage that there are fewer roads to maintain than in the longwall stall system, though there are more than in the conveyor systems. Because the seams are thick, there is less ripping of roof to be done at the face in the roadways. In the case of colliery S.3, the necessary face-ripping is done by the colliers, of whom two, with two or three assistants, are assigned to a panel between the roads.

(d) and (e) *Longwall conveyor systems.* In the last 10 to 15 years there has been, in the South Wales coalfield, a gradual change to mechanical face-conveying, in replacement of the longwall stall system; particularly is this so in the areas where the steam and bituminous coals are mined. These newer systems are still not common in the anthracite field.

A straight face is maintained, and a panel of coal is worked to the boundary of the takings or to a natural boundary such as a big fault.

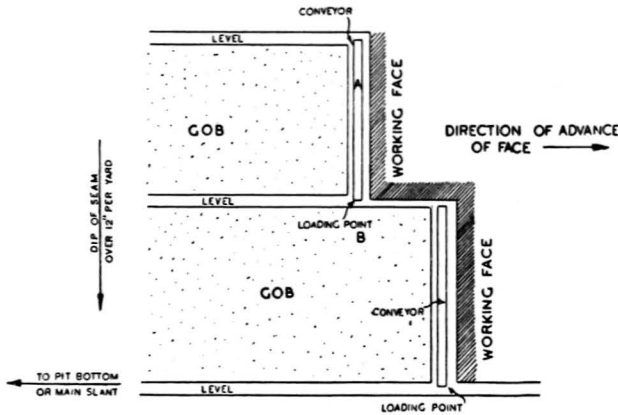
Fig. 7 shows the layout of single unit conveyor faces, and Fig. 8 the layout of double unit conveyors. The length of these faces varies considerably in different collieries. The length of face might be as little as 40-80 yards or as much as 200 yards. With a double unit conveyor this latter would result in a total width of panel of 400 yards. This is probably longer than the average for South Wales.

In the single unit conveyor system the coal is often discharged from the conveyors direct into trams standing in the main roadway. When double units are operating, the coal is discharged from both face conveyors into a main

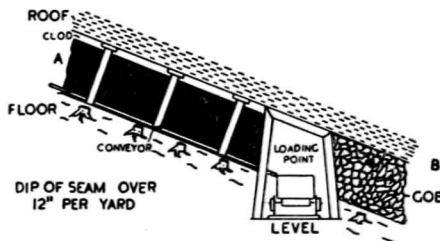
loading conveyor, which conveys the coal outbye along a central road to a point where it is discharged into trams.

The collier at the face, in most instances, mines the full section of the seam, although if the seam is too thick only part of it will be mined. The collier fills the coal on to the conveyors, which consist either of metal trays reciprocated by mechanical means or of endless moving rubber belts, both usually operated by compressed air.

In the single unit system two main roadways have to be developed and



(a) LAYOUT OF LONGWALL GRAVITY OR SINGLE UNIT CONVEYOR SYSTEM



(b) SECTION ALONG LINE A-B

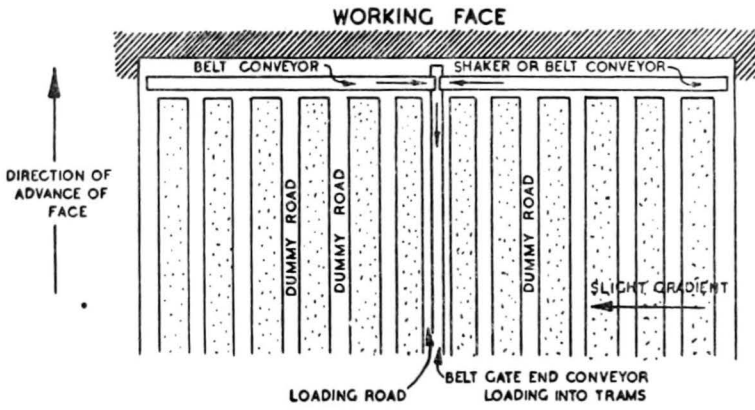
Fig. 7.—The longwall gravity or single unit conveyor system.

maintained, and in the double unit system there are three main roadways (Figs. 7 and 8).

In addition to mining the coal at the face and loading it on to the conveyors, the collier throws his dirty small coal and clod, etc., into the gobs. Rarely does he do any ripping of the roof in the roadways, this being done by special men (rippers or repairers), usually on a back shift.

To provide material for packing the gobs and to facilitate this work, "dummy" roads are driven in the roof and floor at intervals along the face. The packing of the gobs is usually done on the back shift by men specially employed for this work (packers).

Generally speaking, conveyor systems are less common in the anthracite field than in the steam coal area. In the anthracite collieries where these systems operate, the coal has usually been hand-got (e.g. in collieries A.1 and A.6), but in part of the Yard seam at colliery A.8 the coal during the past five years or so has been machine-cut, as well as being machine-conveyed. The combined system of machine-cutting and machine-conveying has been extensively developed in recent years in the steam coal area, though purposely it has not been illustrated in the present series of collieries that mine this class of coal. In this intensive form of conveyor mining there is a rapid advance of the coalface. The collier's functions are, of course, restricted, as compared with other systems, being confined mainly to the filling of the coal.



— LAYOUT OF DOUBLE UNIT CONVEYOR SYSTEM —

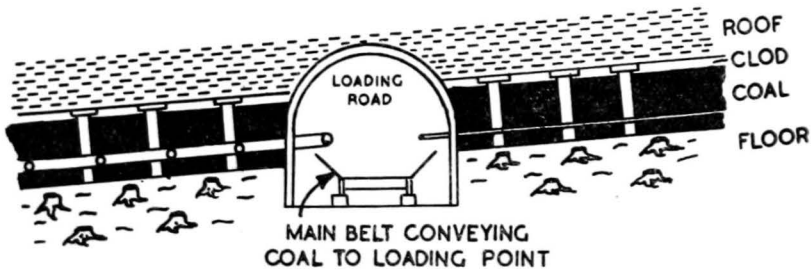
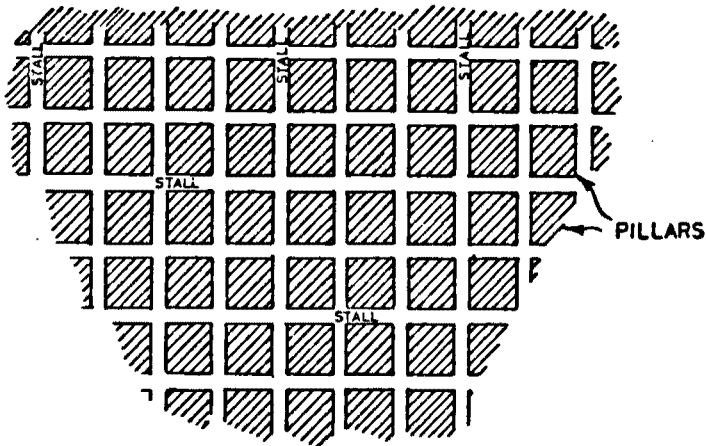


Fig. 8.—The longwall double unit conveyor system.

When the ground is very steep a single unit gravity conveyor system is sometimes used, as in part of colliery A.4. This is an alternative to the longwall top-hole system. The layout and development of the face are similar to the single unit conveyor system (Fig. 7), the only difference being that the conveyor trays are fixed and the coal slides down of its own accord and discharges directly into trams standing under the conveyor chute.

(f) *The pillar and stall system.* Pillar and stall work is not now very common in the South Wales coalfield. It has, however, been the chief system worked in the Eighteen Feet and Nine Feet seams of colliery A.7 and in the Nine Feet seam at A.8; and it was for a short period the chief system at colliery A.3. The method is confined to very thick seams or to thick seams where sufficient rubbish for

packing is not available. This system is very different from those described above, particularly in that there is no continuously advancing unbroken line of face. A panel of coal to be developed is selected, and it is then split up into a series of pillars by narrow drivages (stalls) with narrow cross-cuts at intervals. By this means, only a small part of the coal is extracted. After the panel has been traversed by the stalls and cross-cuts, a variety of methods is adopted for winning the coal from the pillars. It is rarely in South Wales that the whole of these pillars can be extracted safely, because of the nature of the roof and the difficulty of controlling it. The pillar and stall system is sometimes referred to as narrow work (see Fig. 9, which is very diagrammatic).



LAYOUT OF PILLAR & STALL SYSTEM  
(AS MUCH AS POSSIBLE OF THE COAL IN THE  
PILLARS IS RECOVERED 'ON RETREAT')

FIG. 9.—The pillar and stall system of mining.

When driving the stalls and cross-cuts the full thickness of the seam is mined. Roof-ripping at the face is rarely required. When the waste is packed, shale has to be brought into the working places from elsewhere.

(g) *The double stall system.* This system is really a combination of advancing longwall and pillar extraction on retreat. Pairs of stalls each take forward a face some 12 yards in width to a pre-determined line, and then each stall brings back half the pillar left on its rib side. There are a few places in the South Wales coalfield where this method is adopted. An example is colliery A.5, where the system was used up to about eight years before the investigation, when it was replaced by the longwall stall system.

#### (ii) *The use of blasting in coal and rippings*

To assist in the winning of the coal and in the operation of ripping, explosives may be used. Systematic blasting of the coal is practised in many anthracite mines. In blasting, the collier bores the shot holes and the fireman or shotsman does the actual firing, the latter being carried out as occasion arises, and therefore chiefly upon the coal-getting shift (in this respect collieries A.1 and A.6 are exceptional, all blasting having been recently transferred to the back shift). The amount of blasting in the coal is much reduced on machine-cut faces. Blasting in the coal has not been the practice in collieries mining steam or bituminous coal, whether the system of work has been hand-got or mechanical.

In the seams at the anthracite mines it is, moreover, usually the practice, as an aid to ripping, systematically to drill the cliff roof strata and blast them with explosives. On the other hand, in collieries where steam or bituminous coal is mined, ripping may be carried out with a smaller amount of blasting (e.g. colliery S.5) or without any at all (e.g. some seams at B.1, B.2 and B.3).

It has been stated earlier in this section that on the longwall stall system face-ripping is generally done by the collier. Where blasting is used he carries out all the operations except the actual shot-firing, the latter being done, as for the coal, by the fireman or shotsman. In the anthracite mines firing in rippings, as in the coal, usually takes place on the coal-getting shift (collieries A.1 and A.6 again being exceptional), but in steam and bituminous mines such firing as is necessary is confined to the back shift (afternoon or night shift, or between two shifts), when few men are working. In these latter mines, when blasting is required in rippings, the collier bores the shot holes on one coal-getting shift and clears and packs the debris on the next coal shift; alternatively, the drilling of the shot holes is done by special borers and the collier only clears and packs (e.g. in some places at colliery S.4); and sometimes even the entire operation of ripping at the face of the stall road is carried out on the back shift by rippers who are specially employed for this work, so that the collier's task is confined to actual cutting and filling of coal (e.g. in certain parts of S.2).

This separation of the collier's functions in the longwall stall system has become evident during the past few years in certain steam coal collieries using the intensive longwall stall system (see p. 22); in these collieries all ripping is done on the back shift by other workmen.

In the longwall tophole system, and in the pillar and stall system, little or no face-ripping is done and the question of shot-firing does not arise. In respect of conveyor systems also, blasting need not be discussed here, since the ripping of the widely-spaced conveyor roads is done usually by men other than colliers, and usually on the back shift.

Some of the contrasts in blasting between the anthracite and the non-anthracite mines of the South Wales coalfield may be summarised here. In the anthracite mines blasting has been extensively used in the coal and has also been systematically used as an aid to face-ripping; and, with certain exceptions already given, blasting has been carried out on the coal-getting shift. In steam and bituminous collieries blasting has not been the practice in the coal, and has been used to a less extent, and in some seams scarcely at all, for ripping purposes; moreover, in these collieries it has been confined to the back shift.

### (iii) *Occupational grades of miners*

The functions of some of the chief occupational grades engaged in mining have been indicated in the course of the above outline. Some further points need explanation. A coalminer or colliery worker is defined as a man employed in the coalmining industry either below ground or on the surface at a colliery. A collier is defined as a coalminer engaged in getting, hewing, cutting, winning or filling coal at the coalface; the term includes assistant collier. On conveyor faces the collier's functions are restricted as compared with those usual in stall work, both as to the handling of the coal and as to ripping. When the coal is cut, as well as conveyed, by machine his functions become still more restricted, being mainly confined to filling the coal on to the conveyors; in some such collieries, indeed, the collier is termed the filler. In this report the term collier is used also to cover a number of other limited classes of miner, in certain mines where these men are exposed to coalface dust on the coal-getting shifts. These classes include coal-cutter men (with assistants), conveyor attendants, timber-cutters, timber-drawers, dumpers and gate-end loaders.



The men in such classes worked mainly on conveyor faces, and the total number examined was small.

It may be mentioned that about half the underground employees in a colliery worked on a hand-got system are colliers. This is shown in Table V (p. 9), where the approximate proportions of the important occupational grades are shown for anthracite and non-anthracite mines in the Swansea Division of the South Wales coalfield. In this Division there is less mechanisation in either class of mine than in the Cardiff Division.

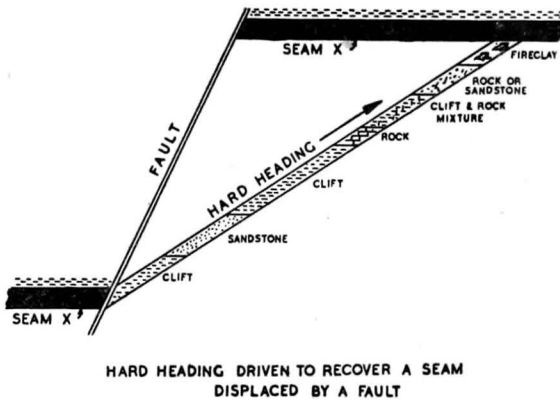
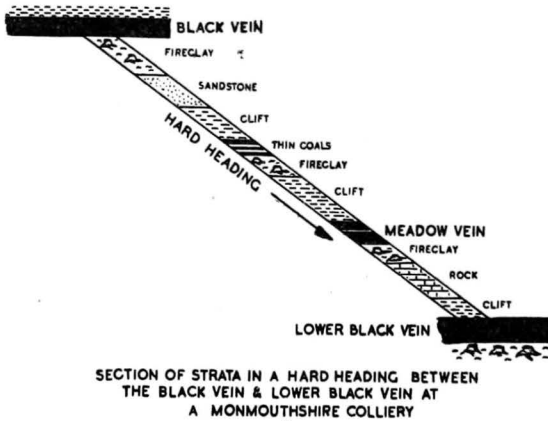


FIG. 10.—Diagram illustrating the term hard heading.

The occupations of repairer, borer and ripper are grouped together for the purposes of this report. Repairers are responsible for repairing and maintaining the roadways, mainly the larger or more permanent roads, although where the colliers do not do their own face-ripping in the roads (e.g. on conveyor faces), repairers may carry out this work also. Special men who give their time to ripping or to boring in rippings are sometimes termed rippers or borers (such men being less frequent in the anthracite part of the coalfield than in the steam coal area), though the term borer is sometimes used to refer to hard-heading men. The functions of the hard-heading man must now be explained.

Headings have been referred to frequently above. These headings in coal, with the roof or floor strata exposed in the upper or lower parts of their faces

in order to make room for traffic, must be distinguished from hard headings, in which the whole cross-section of the drivage consists of non-coal material, such as shales and sandstone. Cross-measure drivages, which connect one seam with another or form short-cuts to regain a seam in a faulted area, are hard headings (see Fig. 10). The sinking of a pit or the driving of a main slant involves similar work. Hard-heading work usually requires much drilling and blasting. In South Wales the special men who carry out this work are known as hard-heading men. There are not many of them (see Table V).

A number of men examined in this inquiry are classed as hauliers and riders. A haulier is a man in charge of a horse engaged in taking empty trams to the face and bringing the full trams out to the main assembling partings. A rider's duties are mainly confined to handling traffic underground; he works chiefly in the main roadways. These two occupations on the underground haulage roadways are here grouped together, as their functions are very similar.

A fireman's primary function is to carry out inspections for safety purposes, but he often also fires the shots for blasting. The functions of a shotsman are indicated by the name, but he may also occasionally perform the duties of a fireman.

#### (iv) *Details of methods of work at the 16 selected collieries*

Details of the methods of working at the 16 collieries selected for this inquiry are given in Table VI (p. 44), columns (14) and (15). In that table, only those methods are given that have been important over the period of the lives of the colliers examined, as judged from the men's industrial histories; where several methods are shown, they are placed in order of importance, as judged in this way. Mention of several methods must not be taken to mean necessarily that these have been in operation in different parts of the mine, unless that is indicated by their being named against different seams; the entries may refer to the whole mine, which has changed from one of the methods (possibly the most or the least important in the histories of the men) to another. In other words, the presentation of the methods is on the basis of historical importance in the lives of the men, and not on an areal basis at the present or any other time.

To give some examples: at A.6, system of work (a) had entirely replaced system (b) at the time of the inquiry, and was also the most important system over the period of the histories of the men examined; at A.1, system (b) had, at time of inquiry, replaced system (a) in respect of about 75 per cent. of the output of the mine, but (a) was the most important in the lives of the men examined; at A.3, in the Stanlyd seam, system (a) (i) was being used practically throughout this seam at the time of inquiry, system (a) (ii) having been the chief method of work for a short period in the past and having been gradually replaced; at A.2, systems (a) and (b) were both being used, depending upon the gradients, (a) being the more important in the lives of the men examined; at A.8, most of the output from the Yard seam (less important historically than the Nine Feet seam) was, at the time of inquiry, being obtained by system (ii) and most of the remainder by system (i), these two systems having almost replaced system (iii); in the histories of the men at A.8, however, system (i) was more important than system (ii) (see Table VI, columns (14) and (15)).

In conclusion, it should be emphasised that the 16 collieries were selected according to certain definite indications (see Chap. 4); they were not intended to form a representative cross-section of the various systems of work in the South Wales coalfield. For example, it may be seen from Table VI, column (14), that the longwall stall system was the most common in this series. This is partly because it was one of the criteria of choice, though it was not, in fact, the most important method at all the selected collieries and it was the most important system at many others outside the scope of this investigation.

## PART II. DETAILS OF PRESENT INQUIRY

## CHAPTER 4

## Procedure and Methods of Present Inquiry

The medical part of the South Wales field survey was begun in December, 1937, and, after interruptions due to the outbreak of war, it was completed in October, 1940. In all, some 2,000 miners from 16 collieries, and nearly 500 coal-trimmers from four coal-exporting ports, were examined.

The position of the 16 collieries, geographically and geologically, has been outlined in Chapter 2. In eight of them the coal mined was anthracite and in eight non-anthracite; in five of the latter the coal was steam and in three it was bituminous. The code letters A (anthracite), S (steam) and B (bituminous) were given to the individual collieries, to show to which of these main subdivisions of coal rank they belonged (from anthracite at the higher to bituminous at the lower end of the scale), while numbers attached to these letters show descending order of coal rank within each of the three main subdivisions.

Thus:—

8 Anthracite	..	..	{	4 high rank	..	..	A.1-A.4
				4 lower rank	..	..	A.5-A.8
5 Steam coal	..	..	{	3 carbonaceous	..	..	S.1-S.3
				2 semi-bituminous	...	...	S.4-S.5
3 Bituminous	..	..	..	..	..	..	B.1-B.3

At one of the four coal-exporting ports from which trimmers were examined, the coal handled was roughly two-thirds anthracite and one-third non-anthracite, and the port was therefore given the code designation PA (Port, Anthracite); at two others, PSa and PSb (near each other in situation and similar in most other respects), steam coal was mainly handled; and at the fourth port, PB (Port, Bituminous), the coal was mainly bituminous.

The salient features and methods of work of the collieries are presented in tabular form in Table VI (pp. 43-46); some particulars of the coal-trimmers are given in Table VII (p. 46). In these tables the chief reasons for selecting each colliery and port are also given.

Chronologically, there were three stages in the medical part of the field survey.

## FIRST STAGE OF SURVEY: EXAMINATION OF THE ENTIRE POPULATION OF ANTHRACITE COLLIERY A.3

## A. SELECTION OF COLLIERY

Colliery A.3 was chosen as an anthracite mine in which seams in the lower part of the Lower Coal Series were worked, and in which the incidence of certified silicosis was high according to the present arbitrary classification (see notes to Table VI, column (4)).

The average number of men employed underground for 1931-38 was 388. The total number of cases, from June, 1931, when the Medical Board for Silicosis first undertook the examination of all applicants for compensation, to the end of 1938, was 68; this gives an annual rate per 1,000 underground employees of 23.4, one of the highest rates in the coalfield. The workings were reputedly dry and deep, again according to arbitrary classification. The anthracite was of high rank and, taking the whole history of the colliery into consideration, the system of work that had been mainly in use—longwall stalls—was typical of the area. The collier cut the coal by hand, with the aid of blasting (carried out on the coal-getting shift), and filled it into the tubs. The collier was also responsible for obtaining adequate height for haulage in the roadway of his stall, by getting down the necessary thickness of rippings from the shale roof at the coalface in the advancing stall

roadhead, and by clearing and packing the resulting rubbish into the gob behind the face, for support of the roof and for ventilation. In the operations both of coal-getting and of ripping the collier was aided by blasting, which was carried out on the coal shift, and for which he bored the holes. (See Chapter 3 for explanation of mining terms.)

B. POPULATION EXAMINED

At colliery A.3, 560 men were examined, being all but four of those on the colliery register who were available for examination. The entire group is referred to as the "colliery registered population". It was made up as follows :—

Colliery working population* .. .. .	502
Men receiving compensation for partial or total disability on account of silicosis..	37
Ditto on account of accidents .. .. .	6
Other men idle on account of illness or accident for 3 months or more immediately preceding date of examination, but still on colliery register as acceptable for work. .. .. .	15
Colliery registered population† .. .. .	<u>560</u>

The "colliery working population" was made up as follows :—

Underground workers at time of examination .. .. .	396
Surface workers at time of examination but at some time underground..	46
Surface workers at time of examination and never underground..	60
Colliery working population .. .. .	<u>502</u>

About half the underground workers were colliers or assistant colliers.

C. METHODS OF EXAMINATION

For colliery A.3 these may be divided into: (i) radiological, (ii) clinical, (iii) lung volume determinations, (iv) tuberculin test, and (v) working history. Data under headings (i), (ii) and (v) were obtained for all the men, while tests (iii) and (iv) were carried out upon a sample of the men. It should be emphasised that code numbers, and not names, were used to identify records.

(i) Radiological examination

The X-ray unit was a transportable single valve set, with Coolidge fine focus 10-kw. tube, supplied and worked by Messrs. Portable X-Rays, Ltd. The unit was installed in the local Welfare Hall, and power was obtained by a special cable from the main supply. For film exposure the conditions were: focal film distance 54 in., time 0.1 sec., milliamperage 100, kvp varied according to thickness of chest, exposure made in standing position and on full inspiration. Before the film was taken, a fluoroscopic examination‡ was made of each man.

The X-ray films (radiographs) were reported on jointly by the two medical investigators, to whom the individual industrial histories (see p. 35) were unknown at the time. For purposes of confirmation, 25 men were selected whose films, taken on the transportable set, were typical of the various X-ray appearances found.

\* Colliery working population is defined as men in regular work at the colliery (including men idle on account of illness or accident for less than the whole of the 3 months immediately preceding the date of examination).

† Colliery registered population is defined as comprising the colliery working population plus silicosis and accident compensation cases plus other men idle on account of illness or accident for 3 months or more immediately preceding the date of examination but still on the colliery register as acceptable for work.

‡ i.e. X-ray examination by viewing the positive image on a fluorescent screen.

This group was invited to the Brompton Chest Hospital, where, under the direction of Dr. R. Rawlinson and Dr. J. V. Sparks, films were taken at 1/30 of a second, at a distance of 60 in., on a condenser-discharge set. At the same time a series of films was taken of each of these cases on the tomograph.\*

(ii) *Clinical examination*

This comprised (a) medical history, (b) physical examination, (c) exercise tolerance test, and (d) sputum examination. Of these, (a) and (b) were obtained for all the men, (c) for all except those in whom deformity of the lower limbs contra-indicated it, and (d) for most of those with cough. The history-taking, physical examination and exercise test were carried out without prior knowledge of the result of the X-ray examination, and at the same session.

(a) *Medical history.* Questions were asked by one or other of the investigators as to past illnesses, present symptoms and family history, all with special reference to cardiac and respiratory diseases.

(b) *Physical examination.* This was made by one or other of the investigators, and was also directed mainly to the cardiac and respiratory systems. It included assessment of colour of skin and mucous membranes, inspection of tongue, teeth, nose and throat, and examination of fingers for clubbing; measurement of blood pressure; measurement of standing height, sitting height, weight, chest circumference and circumferential expansion, and antero-posterior and lateral chest diameters; assessment of general condition, muscular development and amount of subcutaneous adipose tissue; examination of shape and movements of the chest, and for physical signs of abnormality of the heart or lungs. Other systems were examined only if the medical history indicated the need to do so. The blood pressure was taken in the sitting position, after the history, but before the exercise test. The systolic and diastolic pressures† were recorded, and the results were divided arbitrarily into three classes: class *a*, systolic under 160 mm. with diastolic under 95 mm.; class *b*, systolic 160 to 179 mm. with diastolic under 100 mm., or systolic under 160 mm. with diastolic 95 to 99 mm.; class *c*, systolic 180 mm. or over, or diastolic 100 mm. or over, or both.

(c) *Exercise tolerance test.* This test was directed jointly by the two investigators. A step 18 in. in height was used. The subject placed and kept one foot on the step and raised his body to the erect position on the step 20 times in 60 secs. He then placed both feet on the ground, and the degree of respiratory embarrassment was estimated. On the basis of this estimate the exercise tolerance of each individual was placed in one of four categories—category 1, no, or only slight, respiratory embarrassment; 2, definitely breathless; 3, respiratory distress; 4, breathless at rest—or in the intermediate half-categories, 1½ or 2½.‡

Since it seemed possible that these distinctions might be too fine to be useful, a comparison was made of the results of exercise tolerance tests carried out on two different occasions on a sample group of 91 men. This comparison is shown in Table VIII (p. 46), and an analysis of the consistency of the results is given in Table IX (p. 47). From Table VIII and Table IX (a) it seems clear that the half-category divisions are of little value. In Table IX (b), therefore, the exercise tolerance categories have been combined in various ways to form different classes (see note below table), and the consistency has been judged by the change in class observed on the two occasions.

\* For definition of tomography, see p. 50, footnote.

† i.e., the blood pressures during the contraction and expansion phases, respectively, of the heart.

‡ In addition to estimations of respiratory embarrassment, the pulse and respiratory rates were taken, with the subject standing, before, immediately after the test, and two minutes after the test. These results, however, were not used as a basis for deciding the exercise tolerance category.

Finally, the following classification of exercise tolerance was chosen for use throughout this report :

Class A (normal)	=	Categories 1 and 1½.
Class B (abnormal)	=	Category 2.
Class C (abnormal)	=	Categories 2½, 3 and 4.

Since the exercise tolerance, judged by the test, and the presence or absence of chronic breathlessness on exertion, judged by the medical history, will be used separately as the principal estimates of respiratory disability, it is desirable to know how far these are related. This relationship is given in Table X (p. 47), which shows that nearly 90 per cent. of those who were classed as A (normal) on the exercise test gave a negative history as regards breathlessness, while about half of those classed as B (abnormal) and nearly 80 per cent. of those in exercise tolerance class C (abnormal) stated in their history that they suffered from this symptom. Such results show satisfactory concordance between these two, separately obtained, criteria of respiratory disability.

(d) *Sputum examination.* Outfits for collecting sputum were given to all those who had expectoration and to a number of others. The examinations were carried out by Dr. A. F. S. Sladden at the Beck Laboratory, Swansea General Hospital. The appearance of the sputum was noted, and a smear from a concentrate was stained for tubercle bacilli. If the smear was negative, cultures and guinea-pig inoculations for tubercle were made.

#### (iii) *Lung volume determinations*

The lung volume and its subdivisions were determined by Dr. J. McMichael upon a sample group of 180 of the men examined at this colliery. In this connection certain radiological measurements of the chest (radiological chest volume, etc.) were made in each case. The methods used in this investigation have been described elsewhere (Herrald and McMichael, 1939; Aslett, Hart and McMichael, 1939).

#### (iv) *Tuberculin test*

To discover whether there was a relation between tuberculin sensitivity and the various X-ray appearances found in anthracite miners, tuberculin tests were made upon 151 men, representing all but six of the age-group 30-39 of colliery A.3 registered population. A tuberculin prepared by growing the tubercle bacillus on a synthetic medium and subsequently concentrating the filtrate therefrom by heat (Douglas and Hartley, 1934) was supplied by Dr. P. Hartley, National Institute for Medical Research; this had a strength equivalent to the International Standard. The Mantoux intracutaneous method of testing was used. The test was made by injecting 0.1 cc. of a 1:10,000 dilution, followed, if the result was negative, by a similar quantity of a 1:100 dilution.

#### (v) *Working history*

Detailed industrial histories were obtained from all the men examined at this colliery, initially by Mr. T. Waldin, H.M. Inspector of Mines, and subsequently by Mr. J. I. T. Jones, from the clerical staff of the Mines Department. The age last birthday, age at first occupation, and period of working life, were first ascertained. Next, the occupations since leaving school were set out, in chronological order, together with information as to the nature and duration of experience in each of them.

The following list indicates a number of the points covered (item (4) has special reference to colliers) :—

- (1) Names of all collieries at which the man had worked.
- (2) Occupations (collier, repairer, etc.) followed at each colliery, and duration in each.
- (3) Seams and districts in which the man had worked at each colliery.
- (4) Particulars of coal work and ripping work, e.g., system of work (longwall stalls, pillar and stall, longwall topholes, longwall conveyors, etc.), type of working place (stall, coal heading, etc.), nature of strata, implements used, and details of any blasting (number of shots and amount of explosive used, whether collier or special borer bored holes, type of drill used, shift on which firing was done, etc.).
- (5) Occupations other than at collieries (including war service).
- (6) Periods of idleness on account of accidents, illnesses, stoppages of work or unemployment.

**SECOND STAGE OF SURVEY : EXAMINATION OF SELECTED COLLIERIES  
("HOME-COLLIERIES") AT A FURTHER 15 SOUTH WALES COLLIERIES  
(A.1, A.2, A.4, A.5-A.8, S.1-S.5, B.1-B.3)**

**A. SELECTION OF COLLIERIES**

It was stated in Chapter 2 that the greater part of the output of the South Wales coalfield is obtained from the lower part of the Lower Coal Series. Mainly for this reason, one criterion in choosing collieries for the present survey was that the coal seams of most importance in the industrial histories of the men examined should lie in this horizon. The other reasons for adopting this criterion were to avoid the complication of a massive sandstone roof as is found in seams at the base of the Pennant Coal Series, and to reduce the variable due to the slight changes in rank of the seams in vertical sequence at a given point in the coalfield (see p. 17, footnote). With the possible exception of two of the anthracite mines (A.5 and A.6, see below), this general criterion was adhered to, and, indeed, many of the mines selected include the Nine Feet seam or one of its correlatives (see Fig. 2, pp. 14-15). The other main indications used in the selection of these collieries are given below (see also Table VI).

*(i) The further seven anthracite collieries*

Colliery A.1 was chosen because it had an incidence of certified silicosis of the same high order as that at colliery A.3, and collieries A.4, A.7 and A.8 because, on the arbitrary classification adopted, their incidences of certified silicosis were low, and because their workings, like those of A.3 and A.1, were reputed to be dry rather than damp. Colliery A.2 (working the same seam as the high incidence colliery A.1 and less than ten miles away) was chosen as a mine which also had a low incidence of certified silicosis, but in which the face conditions were reputedly damp, and A.5 was selected as a second mine with these properties. Colliery A.5, however, worked the Red Vein, which is somewhat higher up in the Lower Coal Series than the important seams of the other selected anthracite collieries. Colliery A.6 was therefore chosen as another Red Vein mine (in close vicinity), but as one in which the incidence of certified silicosis was high; the face conditions here were reputedly dry, like those at the other high incidence mines, A.1 and A.3. It may be noted that the two collieries with reputedly damp workings were shallow or medium in working depth (headcover), on the classification used, and that all but one of the other selected anthracite mines, including the high incidence mines, are classed as deep (see Table VI, column (9)).

*(ii) The eight non-anthracite collieries*

A criterion used for choosing all the non-anthracite collieries was that the workings should be dry and deep, on the present classification, so as to be

comparable with the high incidence anthracite mines. Satisfying this general condition, collieries S.1, S.2 and S.3 were selected because they mined carbonaceous steam coal; S.4 and S.5 because semi-bituminous steam coal was mined; and B.1, B.2 and B.3 because their coal was bituminous, the lowest ranked coal of all being mined at B.3. All these non-anthracite collieries had low incidences of certified silicosis.

In addition to the above main indications used in selecting the 15 collieries, further standards of suitability were aimed at, in order to obtain as good comparability as possible, both one with another and with colliery A.3, viz. :—

- (1) Mine at least 25 years old.
- (2) At least 100 men employed underground.
- (3) No frequent or long work stoppages; fair constancy in numbers employed, and amount of migration small.
- (4) Estimated sufficiency, for examination, of suitable colliers of ten or more years employment on coal (for criteria of suitability of colliers, see below).
- (5) Seams not too complicated for environmental study in relation to industrial histories of men to be examined.
- (6) More important methods of coal work over past 10–20 years to have been hand-cutting and hand-filling, preferably on the longwall stall system (as at A.3); conveyors, if present, to be recent and, if possible, sufficient working-places to be left for environmental sampling of the older conditions; intensive mining by machine-cutting to be avoided. Any face-ripping work to have been chiefly done by the collier, and roof-ripping preferred to floor-ripping (i.e. similar methods to A.3).

On these criteria alternatives could have been found in the anthracite area, both for the three high incidence mines\* and for the two low incidence damp mines actually selected; but the three low incidence dry mines were the only anthracite collieries of that type to meet the requirements. Even so, intensive mining by machine-cutting has been extensively practised during the past decade in an important seam in one of the latter group of selected mines (incidentally the only anthracite colliery with intensive mining at the time of the investigation).

Among non-anthracite mines, suitable alternatives could have been chosen for the bituminous coals and for the semi-bituminous steam coals; but for the carbonaceous steam coals, stoppages, migration and extensive mechanisation made it difficult to find any suitable collieries, and criterion (6) could not be completely satisfied. For example, at colliery S.3, the longwall "Barry" system had been mainly employed in all the relevant seams.

Even could the above standards of suitability have been completely achieved by all the collieries selected, comparability between coalface conditions in anthracite and non-anthracite mines must have remained deficient. For example, blasting in the coal is extensively practised in anthracite mines, but is not used in steam or bituminous coal mines; and blasting as an aid to face-ripping is also extensively used in the anthracite area, less in the steam, and only rarely in the bituminous coal collieries. Another important factor causing lack of comparability is the application of stone dust to the underground haulage roadways up to the coalface, so as to minimise explosions, which has been compulsory since 1920 in all non-anthracite mines, but is not employed in anthracite collieries.

Before concluding this subsection it is pertinent to consider once more how far these 16 collieries are representative of certain aspects of the South Wales coalfield.

The selection of the eight anthracite collieries was based mainly upon incidence of certified silicosis, three high and five low incidence mines being chosen, and also upon the reputed moisture conditions at the coalface, each of the three high incidence and three of the five low incidence mines being dry and the other two low incidence mines being damp. Geographical position and order of coal rank within the anthracite field were not primary considerations in choosing these collieries. Since the ratio of all anthracite mines with high, medium and low incidences of certified silicosis is 1 : 1 : 2 (Table IV, p. 8), the proportion of three high and five low incidence collieries in the selected group is reasonable. Again, since the great majority of the 23 anthracite mines classed as having high or medium incidences of certified silicosis (Table IV)

\* At the high incidence mine A.6, conveyors had been present sufficiently long to be more important than stall work in the men's histories, and, furthermore, no stalls remained for sampling the older conditions.



have workings that are reputed to be dry rather than damp, while half of the 22 mines classed as of low incidence are reputedly damp, the proportion of dry and damp mines among those selected seems also to be satisfactory. Finally, although geographical position and order of coal rank were not primary considerations, it so happens that the eight selected mines cover satisfactorily both the anthracite part of the South Wales coalfield and the anthracite portion of the South Wales coal rank band (see Figs. 1 and 3, pp. 11 and 16).

Unlike that of the anthracite group, the selection of the eight non-anthracite collieries was based primarily upon coal rank, incidence of certified silicosis being here made a secondary consideration, and the general condition being laid down that all these mines should be dry and deep. From such methods of choice it would be expected that the collieries would cover satisfactorily the steam and bituminous portions of the South Wales coal rank band, and this is the case (Fig. 3). They are also spaced fairly well over the eastern half of the coalfield (Fig. 1). The inclusion only of non-anthracite mines with low incidences of certified silicosis is reasonable, since such incidences are found in over 90 per cent. of all non-anthracite collieries (Table IV).

It may be concluded, therefore, that, despite their rather small total number (eight out of about 50 anthracite mines employing more than 100 men underground, and eight of about 150 non-anthracite mines of similar size), the collieries under consideration are fairly representative of the permutations and combinations of various aspects of the South Wales coalfield.

#### B. POPULATION EXAMINED

From the results of the first stage of the survey, the second stage was directed mainly to workers at the coalface, and 1,392 selected colliers were examined from the "working populations" of the 15 collieries.\* The number examined at each colliery is shown in Table VI, column (12), bracketed figures. Together with a comparable group of 104 colliers included in the population examined at colliery A.3 during the first stage, the total makes 1,496 men.

The selection of colliers for examination at these 15 collieries was made by means of a preliminary questionnaire, which in the earlier mines examined was issued to the entire working population, but in the later ones only to those who were, or had until recently been, colliers or assistant colliers. This questionnaire provided a rough summary of the industrial history of each man, and from these rough histories the selection was made. Briefly, the basis of selection was that a man's employment as collier should have been predominantly at the colliery under examination, that he should be in this occupation at the time of examination or have been so until recently, and that any part of his colliery working life not spent as collier should have entailed a presumed low dust hazard. These selected colliers may conveniently be termed "home-colliers."

The full basis of selection was as follows: collier (or assistant collier) for some period, and in this occupation at time of examination (the great majority) or until recently (within previous 3 years); 90 per cent. or more of total employment as collier spent at colliery under examination; never a fireman or shotsman; hard-heading worker not more than 1 year altogether; other underground occupations together less than 5 years; set work on surface screens less than 5 years.

The short period in hard headings was permitted in order to increase the numbers, a procedure that seemed justified because (1) the colliers thus included formed a small proportion (6.6 per cent.) of the total, and (2) the incidence of X-ray abnormality among them differed only slightly from that expected on the incidence among colliers with no hard-heading experience at all.

Three further points may be noted: (1) for colliery B.1 there was a further criterion of suitability, namely, that 80 per cent. or more of the period spent as collier at that mine should have been in the Rhas Las seam; and for colliery B.2 there was the further

\* Colliery working population is defined on p. 33, footnote; it excludes silicosis compensation cases.

criterion that 70 per cent. or more of the period spent as collier at that mine should have been under the cliff roof in the Black Vein, i.e. mainly Black Vein West Side; (2) a number of the colliers at A.5 had previously worked comparatively short periods in this occupation in the same seam, and under very similar conditions, at a neighbouring colliery; a similar position held for two seams at colliery S.1, though in this case it applied to most of the colliers examined and the periods at the neighbouring colliery had frequently been substantial; in both these cases work as collier at the neighbouring mine was counted as work at the mine under examination; (3) in certain mines where mechanical methods were used for getting coal, men in a number of additional occupations involving exposure to coal dust at the face on the coal shift were treated as colliers, e.g. coal-cutter men, gate-end loaders, timber-cutters and dumpers.

In selecting home-colliers of 20 or more years standing, all the suitable men at each mine were used, with the exception of mines S.3 and B.3, where sampling was carried out, owing to the excessive numbers of home-colliers available. At S.3 an evenly distributed half of the suitable men was taken, while at B.3 the procedure was to match the individual periods of employment on coal as far as possible against those of the similar group of home-colliers at A.3. In selecting home-colliers of 10-20 years standing, all the suitable men were used at the majority of the collieries. However, at A.5, S.3, B.1 and B.3 sampling was required, owing to excessive numbers, and the matching method (1 to 1) was employed; at A.6, by contrast, the number of suitable men available in the 10-20 years period-group was so small that none was examined. Finally, home-colliers of under 10 years standing were examined only at certain collieries (for the sake of economy), and at all these the same method of sampling by matching (1 to 1 (A.1, A.2, S.5 and B.3) or 2 to 1 (A.4 and A.8)) against the corresponding period-group of A.3 was employed.

### C. METHODS OF EXAMINATION

The examination of the selected colliers from the 15 collieries (i.e. all the collieries in the series except A.3) was limited to (i) radiological examination, and (ii) working history.

#### (i) *Radiological examination*

This was carried out with the same unit and under the same conditions as in the first stage of the field survey at A.3, except that fluoroscopy was omitted. The plant was installed either inside the pit-head baths of the colliery under examination, or in a local Welfare Hall or other suitable premises.

#### (ii) *Working history*

Full industrial histories were obtained as in the first stage of the survey. At ten of the collieries they were taken by Mr. J. I. T. Jones, and at the remainder by Mr. G. Jenkins, H.M. Inspector of Mines. At the same time a brief history of any respiratory illness or symptoms was obtained. (It may be mentioned that a small number of men—about 5 per cent. of those selected—had to be rejected owing to the subsequent detection of errors in their histories given on the preliminary questionnaire. The numbers examined, given in Table VI, column (12), are the *net* numbers after exclusion of these discards.)

### SUBSIDIARY PART OF SECOND STAGE OF SURVEY: EXAMINATION OF

#### (a) SCREENS WORKERS AT THE 15 COLLIERIES, AND

#### (b) HAULIERS AT TWO OF THEM.

(a) *Screens workers.* To study the possible effects of colliery dust away from the underground environment, enquiries were made at the majority of the 15 collieries as to whether there were any long-term workers on the surface screens who had spent little or none of their lives in underground occupations.

The original basis of selection was "20 or more years on the screens and never underground," but actually about one-third of those selected turned out to have been only 10-20 years on the screens, and a few had in fact worked short periods in underground occupations. To the 33 men so selected (A.1, 2; A.2, 3; A.4, 4; A.5, 2; A.7, 4; A.8, 3; S.2, 1; S.3, 4; B.1, 4; B.3, 6) were added 16 men from A.3 with 10 or more years experience on the screens and less than five years underground, giving a total of 49 from the 16 mines, of whom 34 were from the anthracite collieries.

These men were submitted to radiological examination and their working histories were taken, exactly as in the case of the colliers in the second stage of the survey.

(b) *Hauliers*. To obtain information upon the possible effect upon the lungs of the application of stone dusts (p. 99) to underground roadways (since the regulations of 1920 a measure that has been general in *non-anthracite* mines in order to minimise explosions), a limited investigation was made of men occupied as hauliers or riders on the underground roadways in collieries B.1 and B.2, two bituminous mines in which the stone dusts used have been mainly crushed local shales (see Table VI, column (16)).

The two mines were considered in combination for the present purpose, and the basis of selection was that a man should be a haulier or rider in one or other of them at the time of examination; that he should have been similarly employed for 10 or more years at either of these mines or at any other non-anthracite mine employing shale for stone-dusting; that he should never have been a fireman, shotsman nor hard-heading worker; that he should have been occupied as collier for less than 10 years, as repairer or underground labourer together less than 5 years, and as a screens worker less than 10 years. The generous allowance of period as collier was made because of the low incidence of X-ray abnormalities found amongst home-colliers at B.1 and B.2.

By these means were found 60 hauliers (31 from B.1 and 29 from B.2) who had been exposed to shale dust for 10 or more years in non-anthracite (mainly bituminous) mines. They were examined in the same way as the screens workers and home-colliers.

By extracting from this group men who satisfied more stringent criteria than those given above (never a fireman, shotsman nor hard-heading worker, and other underground occupations—including that of collier—together less than 5 years), and by altering somewhat the method of grouping, a sub-group of 37 non-anthracite hauliers of 10 or more years service was obtained, which could be directly compared with a corresponding group of 29 anthracite hauliers of similar length of service extracted from the population examined at colliery A.3.

### THIRD STAGE OF SURVEY: EXAMINATION OF SELECTED COALTRIMMERS AT FOUR SOUTH WALES COAL PORTS (PA, PSa, PSb and PB)

#### A. SELECTION OF PORTS

There are five important coal-exporting ports in South Wales and four of them were used for the present survey. Taking the past 30 years or so, it can be assumed that at port PA at least two-thirds of the coal shipped has been anthracite; that at PSa and PSb—ports near to each other and very similar in most other respects—mainly steam coal has been shipped; and that at port PB the coal shipped has been mainly bituminous, the remainder being chiefly steam coal. At these four ports, therefore, the three major divisions of rank of South Wales coal are fairly well and differentially represented (see also Table VII, p. 46).

#### B. POPULATION EXAMINED

At each of these ports there is a special body of coaltrimmers whose occupation is to handle the coal—for export or bunkers—when it enters the holds of the ships, levelling and trimming to secure an even distribution and the most

efficient use of space. From the "coaltrimmer working populations\*" of the four ports, 470 men were examined, the number examined at each port being shown in Table VII, column (4).

Their selection was made by a preliminary questionnaire, given to the whole working population, and, as with the colliers, the choice was based upon the rough industrial histories thus obtained. The basis of selection was much simpler than for colliers, since (1) except for minor and usually temporary adjuvant jobs such as tipper, waterman, call-boy, lamp-boy or screensman, coaltrimming is practically a single occupation, and (2) almost no migration from coaltrimming in one port to coaltrimming in another port was found, so that the necessity for differentiation into "home-trimmers" did not arise. The actual basis was that all the trimmers were accepted as suitable, except for the following categories; men with coalmining experience, men who were supervisors, men who had been on short-time for a long period, and men who were too fat for a satisfactory X-ray examination.

No coaltrimmers of under 10 years standing were examined. Examination of trimmers of 10-20 years standing was limited to port PSa, where an evenly distributed half of the suitable men was taken. Examination of trimmers of 20 or more years standing was carried out at each port. At PA all the suitable men of this period-group were used, while at the other three ports sampling was again necessary, owing to the excessive numbers available. The sampling procedure was to match, 1 to 1 (PSa and PSb) or 1½ to 1 (PB), the individual periods of employment as trimmer as far as possible against those of the 20+ years group of the PA trimmers.

### C. METHODS OF EXAMINATION

The examination was limited to (i) radiological examination, (ii) sputum test, and (iii) working history.

#### (i) *Radiological examination*

This was made in the same way as for the first and second stages of the survey, the unit being installed in local halls.

#### (ii) *Sputum test*

The distribution of sputum outfits was rather different from that in the first stage of the survey: instead of being mainly to those with the symptom of expectoration, it was mainly to those who showed X-ray appearances in any degree suspicious of focal changes. The examination of the sputum was carried out by Dr. Sladden, as in the first stage of the survey. It was limited to staining of a simple smear for tubercle bacilli; culture and guinea-pig inoculation were omitted.

#### (iii) *Working history*

Industrial histories were taken, by Mr. J. I. T. Jones, in the same way as for the first and second stages of the survey, and a brief respiratory history was also obtained at the same time.

In concluding this chapter, it should be stated that, in the ensuing descriptions of results, the three stages of the survey are drawn upon as occasion arises and are not kept in their chronological order.

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\* Coaltrimmer working population is defined as men in regular work at trimming (including men temporarily idle on account of illness or accident). The question of exclusion of silicosis compensation cases does not arise here, since the Workmen's Compensation (Silicosis) Acts do not apply to coaltrimmers.

## SUMMARY OF CHAPTER 4

(1) The medical part of the South Wales field survey was carried out from December, 1937, to October, 1940. It involved the examination of some 2,000 miners from 16 collieries, and of nearly 500 coaltrimmers from 4 coal-exporting ports. Chronologically the inquiry was in three stages.

(2) The first stage was the radiological and clinical examination of the entire population (including both surface and underground workers, and also 37 silicosis compensation cases) from anthracite colliery A.3 (560 persons), together with the taking of full individual industrial histories. Lung volume determinations and tuberculin tests were carried out on a selection of this population.

(3) The second stage was the radiological examination of selected colliers ("home-colliers") from a further 15 representative South Wales collieries, again with full industrial histories. The 16 mines (including colliery A.3) comprised 8 anthracite, 5 steam and 3 bituminous coal, all working seams in the Lower Coal Series; and the numbers of the selected colliers were: anthracite, 793; steam coal, 465; bituminous coal, 238; all 16 collieries, 1,496.

(4) As a subsidiary part of the second stage, examinations were made: (a) of long-term workers from the surface screens at the various collieries investigated, the total number examined (including a comparable group from A.3) being 49; and (b) of men occupied as hauliers or riders on the underground roadways at two of the bituminous coal collieries, who had been exposed for considerable periods to the shale dust used for stone-dusting, the total number examined being 60.

(5) The third stage was the radiological examination of coaltrimmers from 4 of the 5 main South Wales coal-exporting ports, together with the taking of industrial histories for all the men. Sputum examinations were carried out on a selection. Of the 4 ports, 1 exported mainly anthracite, 2 steam coal, and 1 bituminous coal. The total number of men examined was 470.

(6) A description is given of the methods of selection, and of the representativeness, of the collieries investigated, with a summary of their chief relevant characteristics and methods of work; the procedure and methods of examination of the men are also described. Similar information is given for the coal ports and for the coaltrimmers examined.

TABLE VI—(I) Characteristics of the 16 collieries included in the field survey

Coal rank. (1)	Colliery. (2)	Chief seams, with thickness and position. (3)	Incidence of certified silicosis. (4)	Reputed moisture conditions of workings. (5)	Estimated depth of workings. (Ft.)				Age of colliery. (Years) (10)	Average number employed underground, 1931-38. (11)	Number of men examined. (12)	Chief reasons for selection of mine for inquiry. (13)
					Min. (6)	Max. (7)	Average. (8)	Class. (9)				
Anthracite: high rank.	A.1 ..	Lower Pumpquart (3-3½ ft.) (L) ..	High	Dry	750	2,550	1,650	Deep	45	415	70 (68)	Anthracite in lower part of Lower Coal Series, with high incidence of certified silicosis.
	A.2 ..	Lower Pumpquart (3-3½ ft.) (L) ..	Low	Damp	20	750	400	Shallow	32	416	106 (103)	Anthracite in lower part of Lower Coal Series, with low incidence of certified silicosis and with damp workings.
	A.3 ..	Stanlyd (8-8½ ft.) (L) .. Little (3 ft.) (L)	High	Dry	1,000	1,900	1,350	Deep	45	388	560 (104)	As A.1.
	A.4 ..	Little (2½-3 ft.) (L) .. Upper Pumpquart (3 ft.) (L) Rock (3 ft.) (L) Gras-isaf (2-2½ ft.) (L) Stanlyd (6-6½ ft.) (LN)	Low	Dry	150	800	550	Medium	30+	354	136 (132)	Anthracite in lower part of Lower Coal Series, with low incidence of certified silicosis and with dry workings.
Anthracite: lower rank.	A.5 ..	Red Vein (4-5 ft.) (U) ..	Low	Damp	150	1,140	700	Medium	60	295	81 (79)	Red Vein (upper part of Lower Coal Series) anthracite, with low incidence of certified silicosis and with damp workings.
	A.6 ..	Red ein (2½-3 ft.) (U) ..	High	Dry	1,750	2,160	1,950	Deep	35	372	41 (41)	Red Vein anthracite, with high incidence of certified silicosis.
	A.7 ..	Nine Feet (10-11 ft.) (I N) Yard (3 ft.) (L) 18 Feet (8-11 ft.) (L)	Low	Dry	300	1,500	900	Deep	40+	1,144	119 (115)	As A.4.
	A.8 ..	Nine Feet (8-8½ ft.) (LN) Yard (3 ft.) (L)	Low	Dry	500	2,265	1,500	Deep	30	875	154 (151)	As A.4.
Steam: carb- onaceous	S.1 ..	Seven Feet (4-5 ft.) (L) .. Yard (3 ft.) (L)	Low	Dry	1,050	1,860	1,450	Deep	90	908	54 (54)	Lower part of Lower Coal Series, dry and deep workings, carbonaceous coal.
	S.2 ..	Six Feet (7-8 ft.) (L) Nine Feet (8-8½ ft.) (LN) Four Feet (8-7½ ft.) (L)	Low	Dry	1,465	2,160	1,850	Deep	45	810	47 (46)	Do. do.
	S.3 ..	Upper Four Feet (6½-6¾ ft.) (L) Six Feet (5½-6½ ft.) (L) Nine Feet (8-10 ft.) (LN) Seven Feet (4½-5 ft.) (L)	Low	Dry	2,010	2,330	2,160	Deep	60	1,622	99 (95)	Do. do.
Steam: semi- bitu- minous.	S.4 ..	Two Feet Nine (4-5 ft.) (L) Three Feet Ten (4-5 ft.) (L) Six Feet (6-7 ft.) (L)	Low	Dry	1,050	1,550	1,260	Deep	60+	660	116 (116)	As S.1, but semi-bituminous coal.
	S.5 ..	Lower Five Feet (5½-6 ft.) (L) Two Feet Nine (5-5½ ft.) (L) Lower New (4 ft.) (L)	Low	Dry	650	1,350	925	Deep	28	1,172	154 (154)	Do. do.
Bitu- minous.	B.1 ..	Upper Rhas Las. (7-8 ft.) (LN) ..	Low	Dry	1,610	2,400	2,000	Deep	28	1,368	102 (67)	As S.1, but bituminous coal.
	B.2 ..	Black Vein West (6-9 ft.) (LN) ..	Low	Dry	1,630	2,030	1,900	Deep	25	1,630	66 (37)	Do. do.
	B.3 ..	Black Vein (6½-9 ft.) (LN) .. Meadow Vein (6-8 ft.) (L) Big Vein (5½ ft.) (L)	Low	Dry	1,040	1,650	1,450	Deep	45	1,147	140 (134)	Do. do.

MEDICAL SURVEY

TABLE VI—(II) *Methods of work at the 16 collieries*

Colliery. (2)	Coal work. (14)	Face-ripping work. (15)	Period stone-dusting applied (years). (16)
A.1 ..	(a) Longwall stalls, hand-cut, hand-filled; blasting+, on coal shift, recently on back shift.	(a) By collier (roof); blasting+, on coal shift; later cleared and packed only (roof) by collier; blasting+, on coal shift, recently on back shift.	—
A.2 ..	(b) Longwall, hand-cut, machine-conveyed; blasting as (a)	(b) Not by collier and recently on back shift	—
A.2 ..	(a) Longwall top-hole, hand-cut, hand-filled; blasting+, on coal shift ..	(a) None .. .. .	—
A.3 ..	(b) Longwall stalls, hand-cut, hand-filled; blasting as (a)	(b) By collier (roof); blasting+, on coal shift	—
A.3 ..	(a) Stanlyd: (i) Longwall stalls, hand-cut, hand-filled; blasting+, on coal shift.	(a) (i) By collier (top coal and roof); blasting+, on coal shift .. .. .	—
	(ii) Pillar and stall, hand-cut, hand-filled; blasting as (a)	(ii) Roof or none	
A.4 ..	(b) Little: As (a) (i)	(b) As (a) (i)	
A.4 ..	(a) Longwall stalls, hand-cut, hand-filled; blasting±, on coal shift ..	(a) By collier (roof); blasting+, on coal shift .. .. .	—
A.5 ..	(b) Longwall, hand-cut, gravity-conveyed; blasting as (a)	(b) By collier (floor); blasting as (a)	—
A.5 ..	(a) Double stalls, hand-cut, hand-filled; blasting+, on coal shift ..	(a) By collier (roof or floor); blasting+, on coal shift .. .. .	—
A.6 ..	(b) Longwall stalls, hand-cut, hand-filled; blasting as (a)	(b) By collier (roof); blasting as (a)	—
A.6 ..	(a) Longwall, hand-cut, machine-conveyed; blasting rare, on back shift ..	(a) Not by collier and on back shift .. .. .	—
A.6 ..	(b) Longwall stalls, hand-cut, hand-filled; blasting+, on coal shift, recently on back shift.	(b) By collier (floor); blasting+, on coal shift, recently on back shift	—
A.7 ..	(a) Nine Feet: Pillar and stall, hand-cut, hand-filled; no blasting ..	(a) None .. .. .	—
A.8 ..	(b) Yard: Longwall stalls, hand-cut, hand-filled; blasting+, on coal shift	(b) By collier (roof); blasting+, on coal shift	—
A.8 ..	(c) 18 Feet: Pillar and stall, hand-cut, hand-filled; blasting+, on coal shift	(c) None .. .. .	—
A.8 ..	(a) Nine Feet: Pillar and stall, hand-cut, hand-filled; no blasting ..	(a) None .. .. .	—
	(b) Yard: (i) Longwall stalls, machine-cut, hand-filled; blasting rare	(b) (i) By collier (roof); blasting+, on coal shift .. .. .	
	(ii) Longwall, machine-cut, machine-conveyed; no blasting	(ii) Not by collier and on back shift	
	(iii) Longwall stalls, hand-cut, hand-filled; blasting+, on coal shift.	(iii) As (i)	
S.1 ..	(a) Seven Feet: Longwall stalls, hand-cut, hand-filled; no blasting ..	(a) (i) By collier (roof); blasting+, on back shift .. .. .	Shale 19, then limestone 11.
	(b) Yard: Longwall stalls, machine-cut, hand-filled; no blasting .. .. .	(ii) As (i) but no blasting	
S.2 ..	Longwall stalls, hand-cut, hand-filled; no blasting .. .. .	(b) (i) By collier (roof); blasting+, on back shift	Shale 18, then limestone 12.
		(ii) Not by collier; blasting+, on back shift	
		Six Feet: (a) By collier (roof); no blasting .. .. .	
		(b) Not by collier; blasting±, on back shift	
		(c) By collier (top coal); no blasting	
		Nine Feet: (a) By collier (top coal); no blasting	
		(b) By collier (roof); blasting±, on back shift	
		(c) None	
		Four Feet: Not by collier; blasting+, on back shift	
S.3 ..	Longwall "Barry" system, hand-cut, hand-filled; no blasting .. .. .	Four Feet: By collier (roof); no blasting .. .. .	Shale 24, then limestone 1.
		Six Feet: (a) By collier (roof); no blasting	
		(b) Not by collier; no blasting	
		(c) Cleared and packed only (roof) by collier; blasting+, on back shift	
		Nine Feet: By collier (top-coal); no blasting	
		Seven Feet: (a) As Six Feet (a)	
		(b) As Six Feet (a)	
S.4 ..	Longwall stalls, hand-cut, hand-filled; no blasting .. .. .	(a) By collier (roof); blasting±, on back shift .. .. .	Shale 15, then limestone 5.
		(b) Cleared and packed only (roof) by collier; blasting+, on back shift (one district of 3 ft. 10 seam).	
S.5 ..	Do. do. do. do. .. .. .	By collier (roof); blasting±, on back shift	Limestone 17.
B.1 ..	Do. do. do. do. .. .. .	By collier (roof); no blasting .. .. .	Shale 30.
B.2 ..	Do. do. do. do. .. .. .	Do. do. .. .. .	Fuller's earth 3, then shale 17.
B.3 ..	Do. do. do. do. .. .. .	By collier (bottom-coal or roof); no blasting .. .. .	Fuller's earth 10, then limestone 10.

*Notes to Table VI*

- Column (1). Anthracite is subdivided into high rank and lower rank; steam coal is subdivided into carbonaceous (i.e. higher rank) and semi-bituminous (lower rank); bituminous coal is not subdivided.
- (2). Colliery code letters A, S and B = anthracite, steam and bituminous, respectively. Within each of these major divisions of rank the code numbers also indicate order of rank. Hence the order of collieries in this table is by coal rank.
- (3). For each colliery the seams are placed in order of importance, as judged from the occupational histories of the men examined (bracketing means equality); unimportant seams are omitted. (Colliery S.1 and an adjoining and very similar colliery, with the same seams, are treated as one; while at collieries B.1 and B.2, only men who had worked mainly in one particular seam were examined and the other seams are therefore omitted from consideration.) The thicknesses given for the seams are approximate. The symbol (L) = lower part of the Lower Coal Series, and (U) = upper part, whilst (LN) indicates that the seam is the Nine Feet or one of its correlatives.
- (4). Arbitrarily classed as "high", "medium" and "low" incidences as follows:—High, annual incidence-rate of cases for 1931–38 = 8.0 or more per 1,000 employed underground; medium, rate = 3.5–7.9; low, rate = less than 3.5.
- (5). Two classes, namely, dry rather than damp and damp rather than dry, (Mainly based on unpublished reports of Swansea Divisional Inspector of Mines.)
- (6)–(9). The term "depth of workings" is used to indicate the amount of head-cover immediately overlying the workings, and it is on account of the undulating character of the surface in the South Wales coalfield that minimum and maximum working depths are given, as well as an average figure. The average figure is not necessarily the half-way between maximum and minimum, but it is a figure arrived at by consulting the plans of the colliery and it has regard to the numbers of men working and having worked (in the relevant seams) over the past 15 years or so. The classification into "deep", "medium" and "shallow" is arbitrary; some of the mines classed here as deep would scarcely be called deep if in other coalfields. (Mainly based on unpublished reports of Swansea Divisional Inspector of Mines.)
- (10). Refers to seams in Lower Coal Series.
- (11). Average number of men employed underground from 1931–1938.
- (12). The unbracketed figures are the totals examined at each mine, while those in brackets are the numbers of "home-colliers" (see p. 38). The difference between the two figures is accounted for at colliery A.3 by the remainder of the colliery registered population, at B.2 by selected hauliers examined, at B.1 also by hauliers together with some selected workers examined from the surface screens, and at the other collieries also by small numbers of screens workers examined.
- It should be mentioned that a small number of the men selected at these collieries (about 5 per cent.) had to be excluded from the analysis, owing to subsequent detection of errors in their rough histories given on the preliminary questionnaire (see text). The numbers tabulated here are the *net* numbers after exclusion of these discards. (The foregoing, of course, does not apply to colliery A.3, where no such questionnaire was used.)
- (13). Note that the terms "dry" and "damp" are by reputation and not by measurement.
- (14) & (15). The methods (a), (b) and (c) and their subdivisions (i), (ii) and (iii) are placed in order of importance, as judged from the occupational histories of the men examined; unimportant methods are omitted. The methods (a), (b) and (c) refer to different seams only when specifically stated. The operation of ripping consists in (1) getting down, with or without boring followed by blasting, and (2) clearing and packing. "By collier" means that, except for the actual shot-firing (done by the fireman or shotman), both (1) and (2) are performed by the collier. "Cleared and packed only by collier" means that (1) is carried out by another class of workman (with boring and blasting) and (2) by the collier. "Not by collier" means that both (1) and (2) are done by another class of workman. "None" means that no face-ripping is done.
- The amount of blasting in the coal and in rippings is indicated by the signs ++, +, ±, rare, and no blasting.
- (For explanation of mining terms see Chapter 3.)



## PULMONARY DISEASE IN WELSH COALMINERS

- (16). Stone-dusting has been general on the roadways of non-anthracite mines since 1920, though some collieries began to use it before this date. The different types of stone-dust in use at each mine, with the periods during which they have been used, are placed in chronological order. The sources of the shale dusts used were as follows:—S.1, from its Yard seam; S.2, from the Yard seam at a nearby colliery; S.3, from its Six Feet seam; S.4, from its Two Feet Nine seam; B.1, from its Rhas Las seam; B.2, from a similar neighbouring colliery.

TABLE VII

*Particulars of the coaltrimmers at the four coal ports included in the field survey*

<i>Rank of coal mainly handled.</i> (1)	<i>Port.</i> (2)	<i>Coaltrimmer employment roll, 1940.</i> (3)	<i>Number of coaltrimmers examined.</i> (4)	<i>Chief reasons for selection of port for inquiry.</i> (5)
Anthracite ..	PA	210	101	Mainly anthracite handled.
Steam coal ..	PSa	463	142	Mainly steam coal handled.
Steam coal ..	PSb	467	103	Mainly steam coal handled.
Bituminous ..	PB	315	124	Mainly bituminous coal handled.

*Notes to Table VII*

- Column (2). Port code letters A, S and B = anthracite, steam and bituminous, respectively. Ports PSa and PSb are near each other and similar in most other respects.
- (4). The figures given are the *net* numbers examined after exclusion of a small number of selected men that had to be rejected from the analysis, owing to errors in their rough histories given on the preliminary questionnaire.

TABLE VIII

*Comparison of results of exercise tolerance tests carried out on two occasions on 91 men at colliery A.3*

<i>First test.</i>		<i>Second test.</i>					
<i>Exercise tolerance category.</i>	<i>Number in each category.</i>	<i>Number in each exercise tolerance category.</i>					
		1	1½	2	2½	3	4
1	43	28	15	—	—	—	—
1½	29	6	19	4	—	—	—
2	9	—	2	4	—	3	—
2½	5	—	1	—	2	2	—
3	5	—	—	—	2	3	—
4	—	—	—	—	—	—	—
All categories..	91	34	37	8	4	8	—

TABLE IX

Consistency of results of exercise tolerance tests carried out on two occasions on 91 men at colliery A.3 (derived from Table VIII)

(a) Shown by the number and percentage of men placed in the same category on both occasions

Exercise tolerance tests.	Number.	Percentage.
Same category* both occasions .. ..	56	61.5
Change by a half-category .. ..	31	34.1
Change by a whole category .. ..	4	4.4
Total .. ..	91	100.0

(b) With the exercise tolerance categories combined in various ways to form different classes

Exercise tolerance tests.	Method of classification.†					
	(i)		(ii)		(iii)	
	Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
Same class both occasions.	77	84.6	81	89.0	84	92.3
Change of class ..	14	15.4	10	11.0	7	7.7
Total ..	91	100.0	91	100.0	91	100.0

\* Exercise tolerance categories are 1, 1½, 2, 2½, 3 and 4 :—

1 = no, or only slight, respiratory embarrassment.

1½ = intermediate.

2 = definitely breathless.

2½ = intermediate.

3 = respiratory distress.

4 = breathless at rest.

† Exercise tolerance classifications :—

(i) Three classes—composed respectively of categories 1 and 1½; 2 and 2½; 3 and 4.

(ii) Three classes—composed respectively of categories 1 and 1½; 2; 2½, 3 and 4.

(iii) Two classes—composed respectively of categories 1 and 1½; 2, 2½, 3 and 4.

TABLE X

Relationship between (i) presence or absence of symptom of chronic breathlessness on exertion (as judged from medical history) and (ii) result of exercise tolerance test\*, among men at colliery A.3 (colliery registered population)

Exercise tolerance class.	Breathlessness.					
	Absent.	Present.	Total.	Absent.	Present.	Total.
	Number.			Percentage.		
A	312	48	360	86.7	13.3	100.0
B	65	52	117	55.6	44.4	100.0
C	12	44	56	21.4	78.6	100.0
All classes ..	389	144	533	73.0	27.0	100.0
Not tested ..	16	11	27	59.3	40.7	100.0
Total ..	405	155	560	72.3	27.7	100.0

\* When tests were carried out on two occasions the result used for classification was that of the first test.

## CHAPTER 5

## Classification of X-ray Appearances

Among the best-known classifications of the X-ray appearances found in the pneumokonioses\* are that used by the South African authorities for silicosis among gold miners on the Rand (Simson, Strachan and Irvine, 1930; Miners' Phthisis Medical Bureau, 1939), and that put forward in 1935 for silicosis by an authoritative American committee (Pancoast *et al.*, 1935). As the first stage of the present survey at anthracite colliery A.3 was proceeding, it became apparent that certain differences from the X-ray changes found in these descriptions of classical silicosis were being encountered. Among these differences were: (1) the less opaque and less well-defined appearance of the discrete "nodular" shadows; (2) the difficulty of recognising tuberculous changes of the type often termed infective silicosis, tuberculo-silicosis, or silicosis with tuberculosis; and (3) the frequent occurrence of a widespread fine reticular pattern in the lung fields. Even the classification used in the Pennsylvania field-investigation among anthracite miners, made by the United States Public Health Service (Bloomfield *et al.*, 1935), did not seem entirely applicable.

While, therefore, previous classifications have been of great assistance, it was decided to adopt a rather different one, based upon the examination of the 560 films of the colliery A.3 "registered population" (see p. 33). The different categories of the present classification are listed below; and in order to illustrate their relative frequency, the number of films from colliery A.3 which were placed in each category is given in brackets:—

*X-ray Categories*

- |  |                                  |                             |  |  |
|--|----------------------------------|-----------------------------|--|--|
| (a) Normal (307†)                                |                                  |                             |  |  |
| (b) Reticulation (121‡)                          |                                  |                             |  |  |
| (c) Nodulation (52)                              |                                  |                             |  |  |
| (d) Coalescent nodulation (42)                   | } (d-f) Major consolidation (61) | } (c-f) Consolidation (113) |  |  |
| (e) Massive shadows (12)                         |                                  |                             |  |  |
| (f) Multiple fluffy shadows (7)                  |                                  |                             |  |  |
| (g) Local gross fibrosis of uncertain cause (12) |                                  | } (g-h) Indefinite (19)     |  |  |
| (h) Lung fields equivocal (7)                    |                                  |                             |  |  |

A description of the appearance of each of these X-ray categories will now be given:—

*Description of Appearances of the Different X-ray Categories*  
(See X-ray Plates at end of this Chapter.)

*Category:*

(a) *Normal.* Lung fields normal. (Films with homogeneous or patchy shadows at one or both apices—? tuberculous, ? pneumokoniotic in nature—but with the rest of the fields normal, are included in this category.) (Plate 1.)

(b) *Reticulation.* Lung fields show a fine network, sometimes sharp and lace-like in pattern, but much more often blurred in appearance.§ The network occupies from half of one lung field to (more frequently) the whole of both fields, though the apices are relatively free. It is as marked at the periphery of the fields as it is nearer the hila.|| Shadows to be described under

\* Pneumokoniosis (contracted from pneumonokoniosis) is a general term used to signify any dust-ridden state of the lungs severe enough to impair health. Silicosis is a pneumokoniosis due to the inhalation of silicon dioxide in uncombined form.

† Including films with homogeneous (3) or patchy (5) apical shadows.

‡ Including films with homogeneous (6) or patchy (16) apical shadows.

§ In a small proportion of cases, again, the mesh of the network is wider and the strands thicker, but it has not been thought desirable to subdivide the reticulation category. (The proportion of such atypical reticulation cases is somewhat greater among coaltrimmers than among coalminers—see p. 103.)

|| The hilum of the lung is the depression at its root where the large blood vessels and bronchial tubes enter and leave.

the heading of nodulation, if present in addition, are limited to one rib space. (Films with homogeneous or patchy shadows at one or both apices, but with reticulation elsewhere, are included in the reticulation category.) (Plates 2-8.)

Reticulation differs from "increased lung markings" in that the latter are linear in appearance rather than a fine network, and radiate from the hila, fading towards the periphery. (As an alternative to reticulation, the term "granularity" has been suggested to us by Dr. H. E. Watson.)

(c) *Nodulation*. Multiple, discrete shadows, 2-5 mm. in diameter, a considerable number to a rib space; they may occupy from two rib spaces to the whole of both lung fields, when they give a snowstorm effect to the picture. The shadows usually have a moth-eaten appearance and an irregular and ill-defined margin. Although discrete from one another, they tend to merge into the surrounding reticulation, which is nearly always present in addition. (From this it follows that films with reticulation, but with shadows of the above description also present to the extent of two or more rib spaces, are classified under the heading of nodulation.) (Plates 8-12.)

Nodulation corresponds most nearly to the "generalised mottling" or "nodulation" of classical silicosis, but the shadows of the classical condition differ in being somewhat more opaque, and sharper in outline.

Since reticulation is evident in practically all nodulation films, the nodulation category really refers to nodulation *plus* reticulation.

(d) *Coalescent nodulation*. As (c) but with one or more areas where the shadows appear to be coalescent or conglomerate. Reticulation is nearly always present as well. (Plate 13.)

(e) *Massive shadows*. One or more large, dense, homogeneous shadows, with part or all of the outline smooth, rounded and well-defined. They are often symmetrically distributed and are usually associated with well-marked emphysema.\* In the majority of films, shadows of the type described above, under the heading of nodulation, are present in addition; so also is reticulation. (Plates 14-15 and 18-19.)

Massive shadows correspond to the "pseudo-tumoral" and "cricket-ball" shadows of the literature.

(f) *Multiple fluffy shadows*. Shadows, more than 1 cm. in diameter, rounded, irregular or stellate in shape, and fluffy in appearance and outline. Situated irregularly and asymmetrically. In most films reticulation is also present. (Plates 16-17.)

(d, e, f) *Major consolidation*.

(c-f) *Consolidation*.

The four categories—nodulation, coalescent nodulation, massive shadows and multiple fluffy shadows—are grouped under the general heading of "consolidation," and the last three of these categories are classed together as "major consolidation." Consolidation, like reticulation and nodulation, is used as a purely descriptive X-ray term and does not presuppose any special clinical or pathological change.

(g) *Local gross fibrosis of uncertain cause*. Possible causes included tuberculosis, bronchiectasis,† etc.

(h) *Lung fields equivocal*. Difficulty in classification, due mainly to enlarged cardiac shadow, sometimes to thick chest. (Note that films showing an enlarged cardiac shadow, but with the lung fields *unequivocal*, are classified according to the appropriate category of the lung fields.)

(g, h) *Indefinite*.

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\*"Pulmonary emphysema" is a condition of the lungs characterised by a persistent dilatation of the air sacs with atrophy of their walls, resulting in a loss of the normal elasticity of the lung substance.

†"Bronchiectasis" is a condition in which there is persistent dilatation of the walls of the bronchial tubes.

From the description given above it follows that, except for some in category (e), where the changes may have been obscured by gross emphysema, practically all the films classified as "consolidation" (categories c-f) at colliery A.3 showed reticulation as well. Consequently, the category of consolidation really refers to consolidation *plus* reticulation, while the reticulation category refers to reticulation without consolidation.

It should be noted that the great majority (95) of the 113 cases classed as consolidation had had 10 or more, and more than half had had 20 or more, years employment as colliers (whatever their other occupations if any); on the other hand, few of these consolidation cases had had any considerable experience as hard-heading workers (9 with three or more, 5 with six or more and 1 with ten or more years), while in only 3 cases had the predominant occupation been hard-heading or other rock work. Consequently, the appearances described for consolidation in this classification relate mainly to colliers and certainly cannot be taken as necessarily representative of the changes in hard-heading workers. Inspection of films from South Wales miners who have been predominantly engaged in hard ground work suggests that in such cases the discrete shadows of nodulation tend to be of the more opaque and sharply outlined type characteristic of classical silicosis.

As stated above, the present classification was arrived at mainly on the basis of examination of the films from one anthracite colliery. However, from examination of the additional films of anthracite and non-anthracite colliers obtained during the second stage of the survey, and of coaltrimmers obtained in the third stage, together with inspection of part of the large collection of films of the Cardiff Panel of the Medical Board for Silicosis, it was concluded that the classification was suitable for the whole of the present investigation.

As a check on X-ray technique, a sample of 25 of the men examined at colliery A.3 on the transportable set was also filmed with the condenser-discharge unit of the Brompton Hospital, and at the same time tomograms\* were taken (see p. 34). The condenser-discharge films were found in the main to confirm those of the transportable unit, while the chief findings from tomography were that: (1) among appearances classified as reticulation on the flat film small areas of nodulation were sometimes revealed on tomography (the network of reticulation itself was not visible on the tomogram); (2) nodulation when visible on the flat film was also shown by tomography; (3) nodulation which was doubtful on the flat film was sometimes definite on tomography; and (4) coalescence was sometimes evident on the tomogram where it had hardly been suggested on the flat film.

#### SUMMARY OF CHAPTER 5

(1) A convenient classification of X-rays has been devised for use in the present inquiry. The categories have been termed: (a) normal, (b) reticulation, (c) nodulation, (d) coalescent nodulation, (e) massive shadows, (f) multiple fluffy shadows, and (g-h) indefinite. The categories (c-f) have been grouped together under the heading consolidation, categories (d-f) being termed major consolidation. The two main divisions of X-ray abnormality are thus reticulation and the composite category, consolidation.

(2) It should be stressed that almost all the X-ray films from anthracite colliery A.3 which were classed as nodulation and coalescent nodulation—as well as most of those classed as multiple fluffy shadows and the majority of those classed as massive shadows—showed reticulation in addition. Hence, for practical purposes, the consolidation category refers really to consolidation *plus* reticulation, while the reticulation category refers to reticulation without any of the changes of consolidation.

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\* Tomography, or sectional radiography, is the method of X-ray examination whereby a radiograph is produced representing a selected section or layer of the lung or other structure at a known depth from the surface.

**REPRESENTATIVE  
X-RAY PLATES**

(SEE CHAPTER 5).

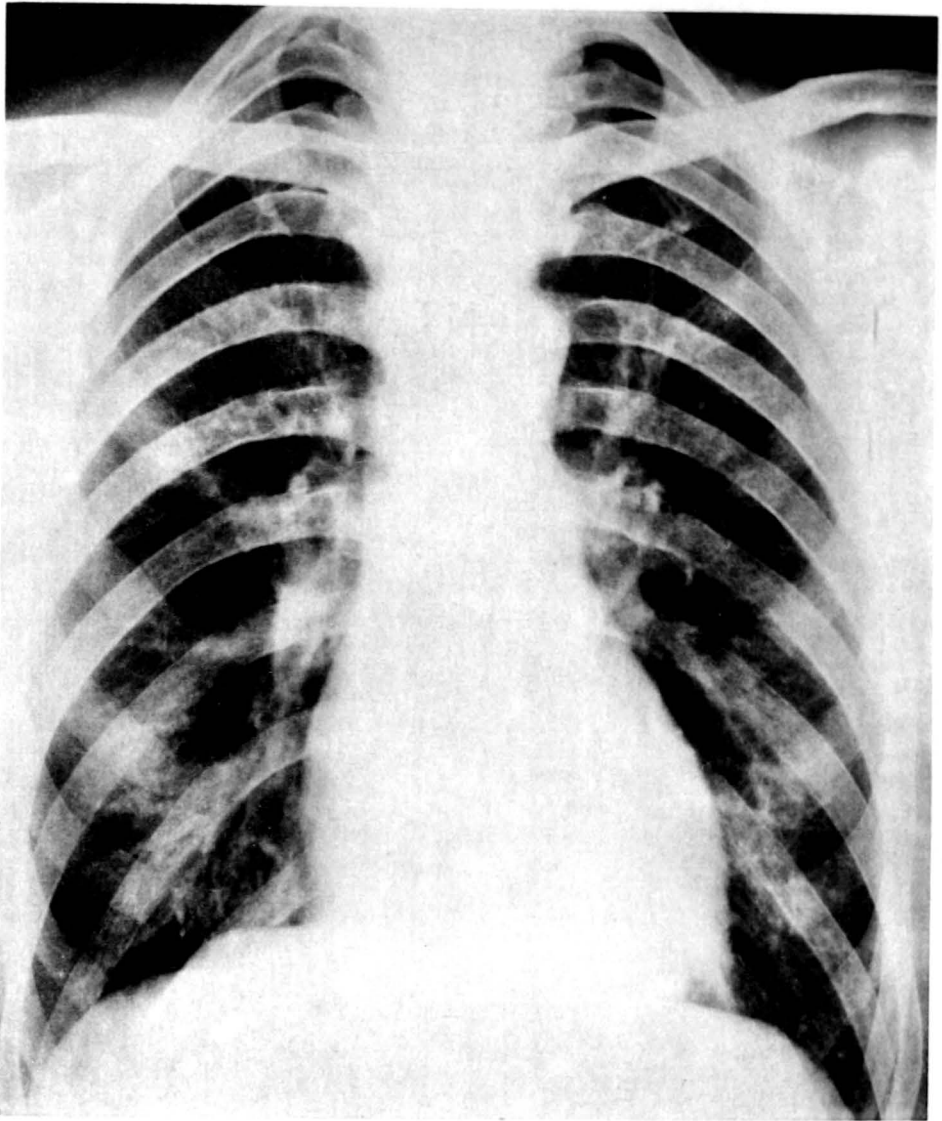


PLATE 1a.—**Category (a) Normal.** Non-miner, aged 42 yrs., attending Brompton Chest Hospital, London. Plate to be used as normal control when examining subsequent plates.

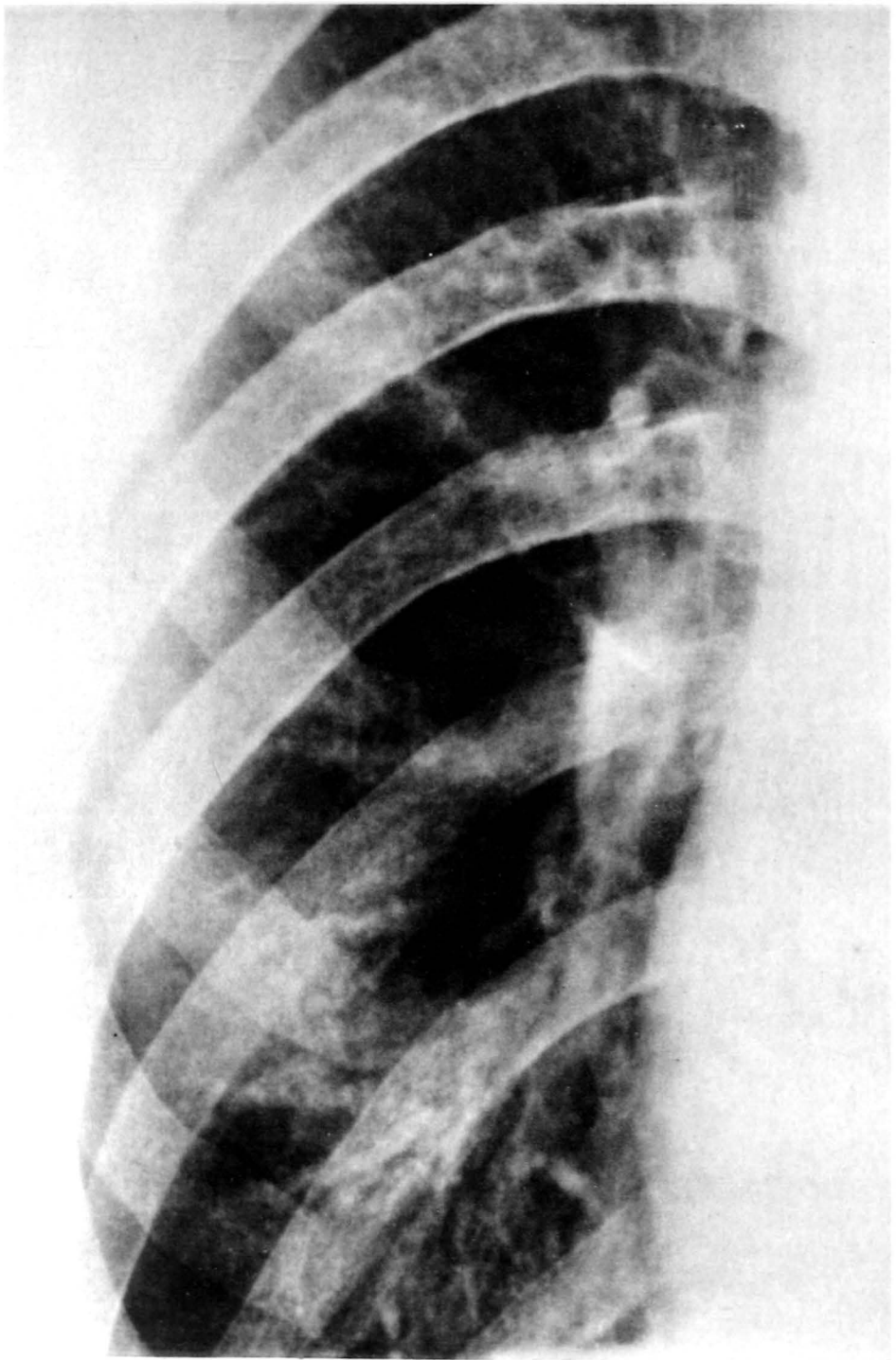
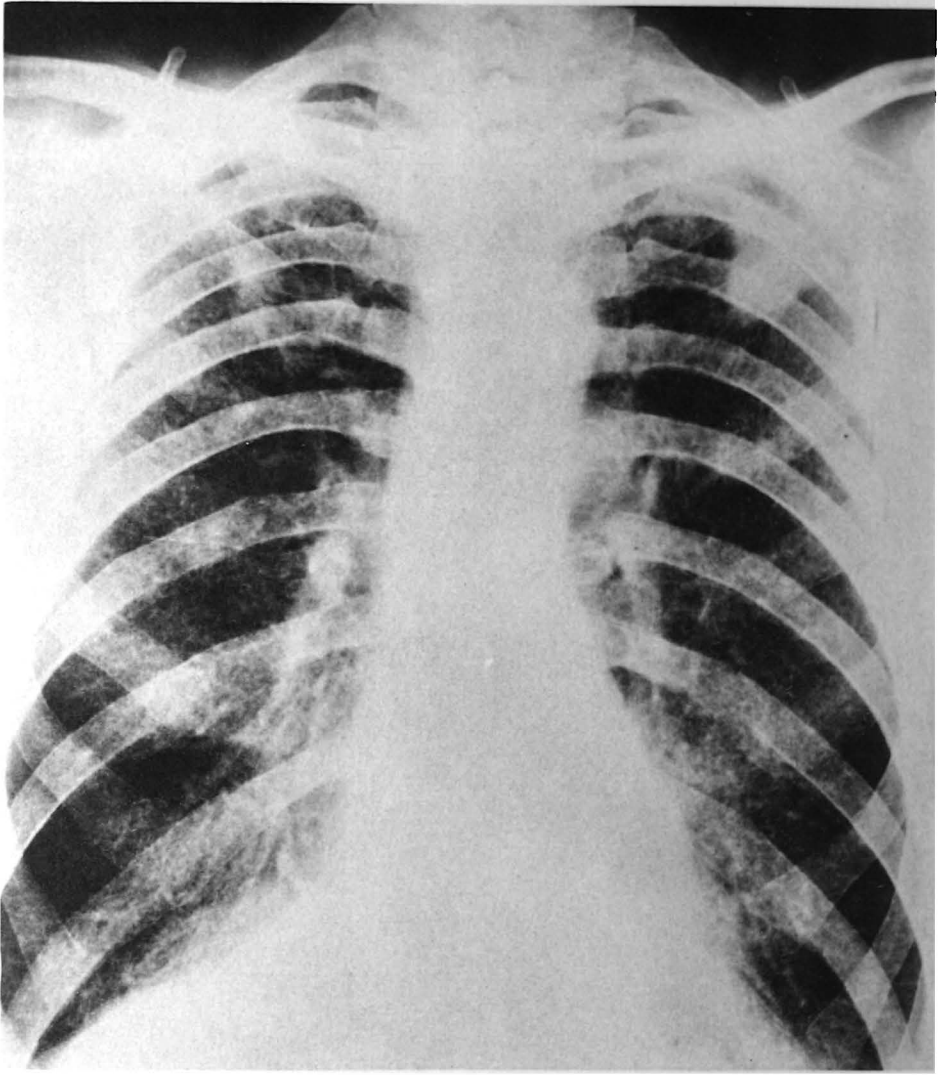
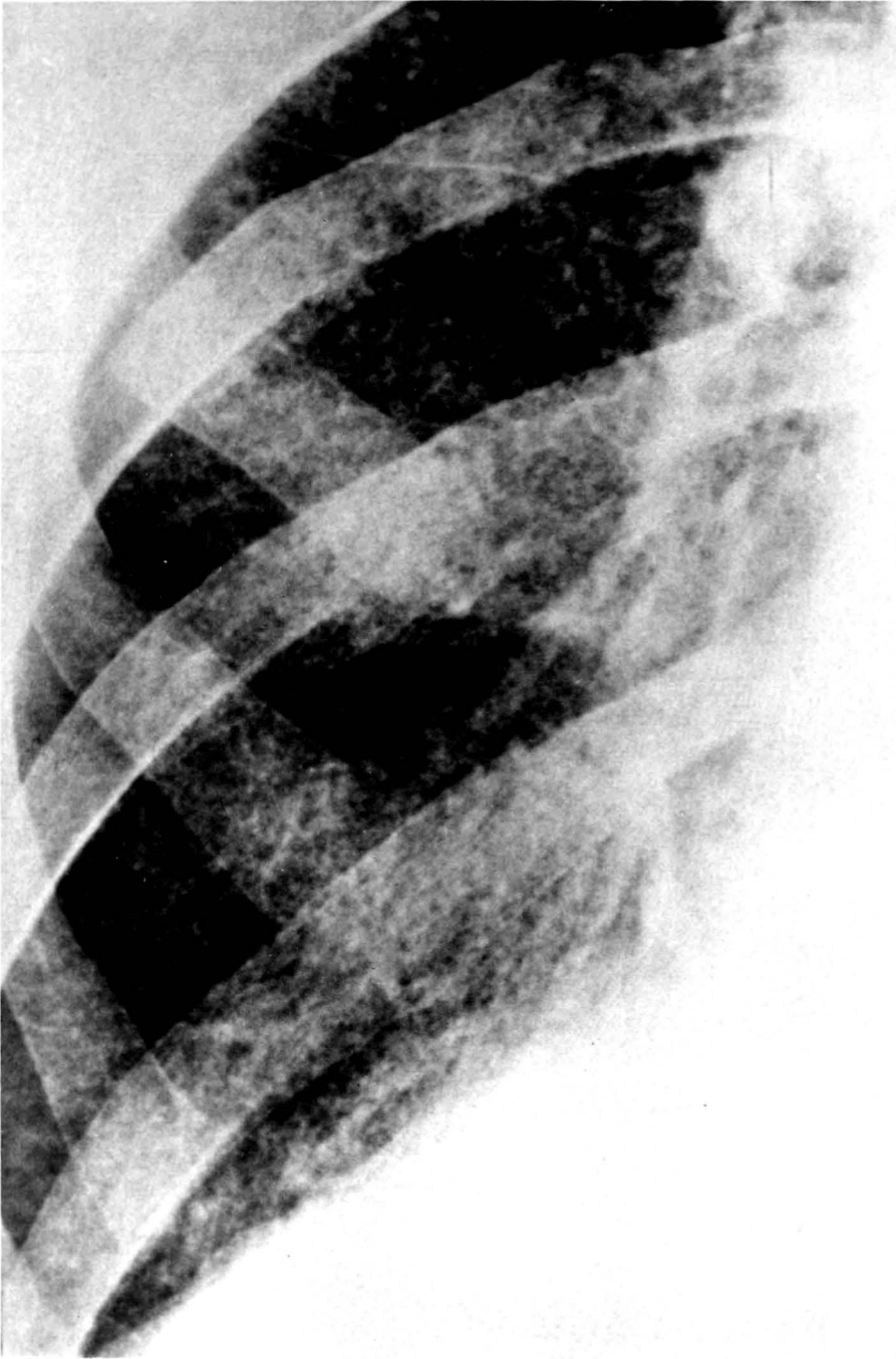


PLATE 1b.—Right middle zone of Plate 1a.





**PLATE 2a.—Category (b) Reticulation.** Miner, aged 55 years., from colliery A.3 (anthracites)  
Colliery occupations: collier (anthracite), 26 yrs.; haulier and rider, 5 yrs. The reticulation is of a  
relatively uncommon type, the fine network being sharp and lace-like in pattern. Left apex show  
also a homogeneous shadow.



**PLATE 2b.**—Right lower zone of Plate 2a.

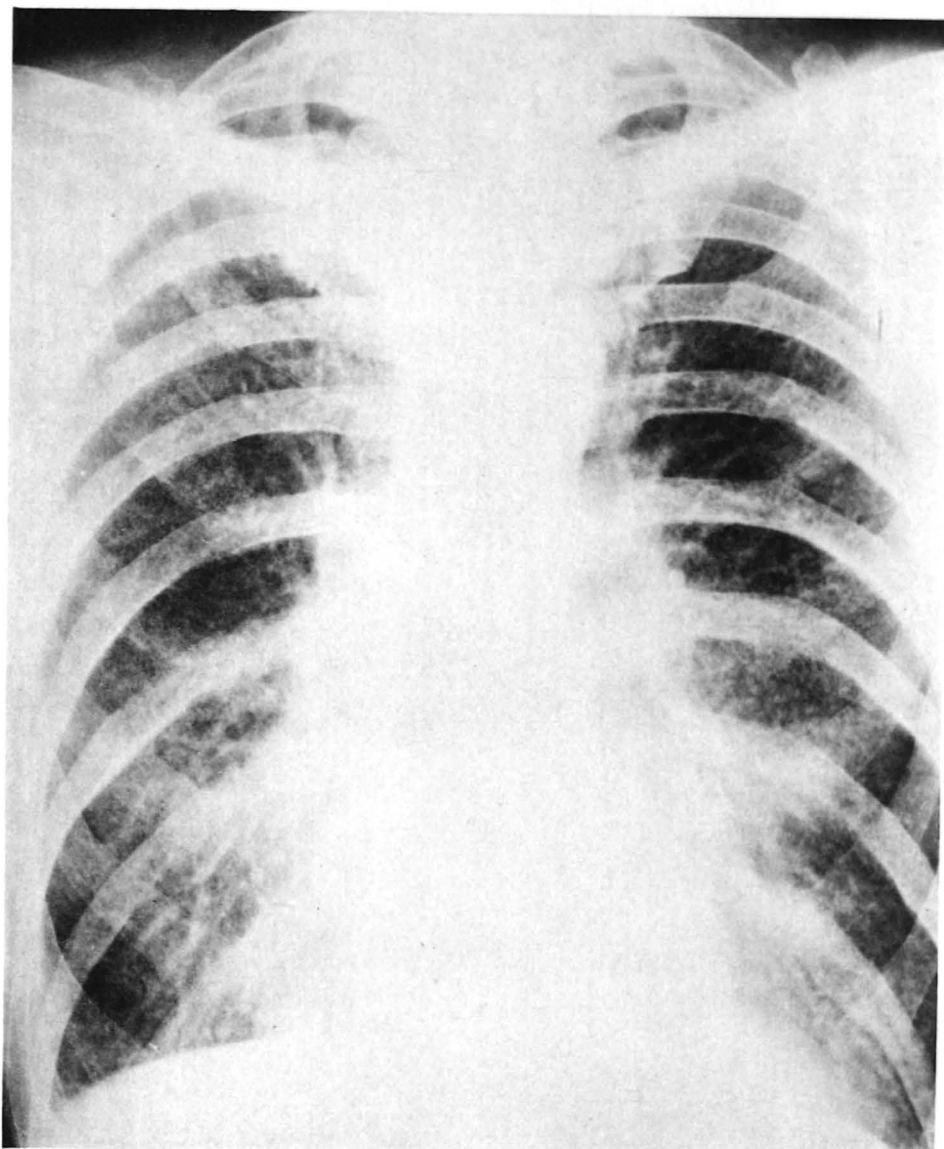


PLATE 3a—**Category (b) Reticulation.** Miner, aged 60 yrs., from colliery A.5 (anthracite). Colliery occupations: collier (anthracite), 43 yrs. The reticulation is of the same type as in Plate 2.

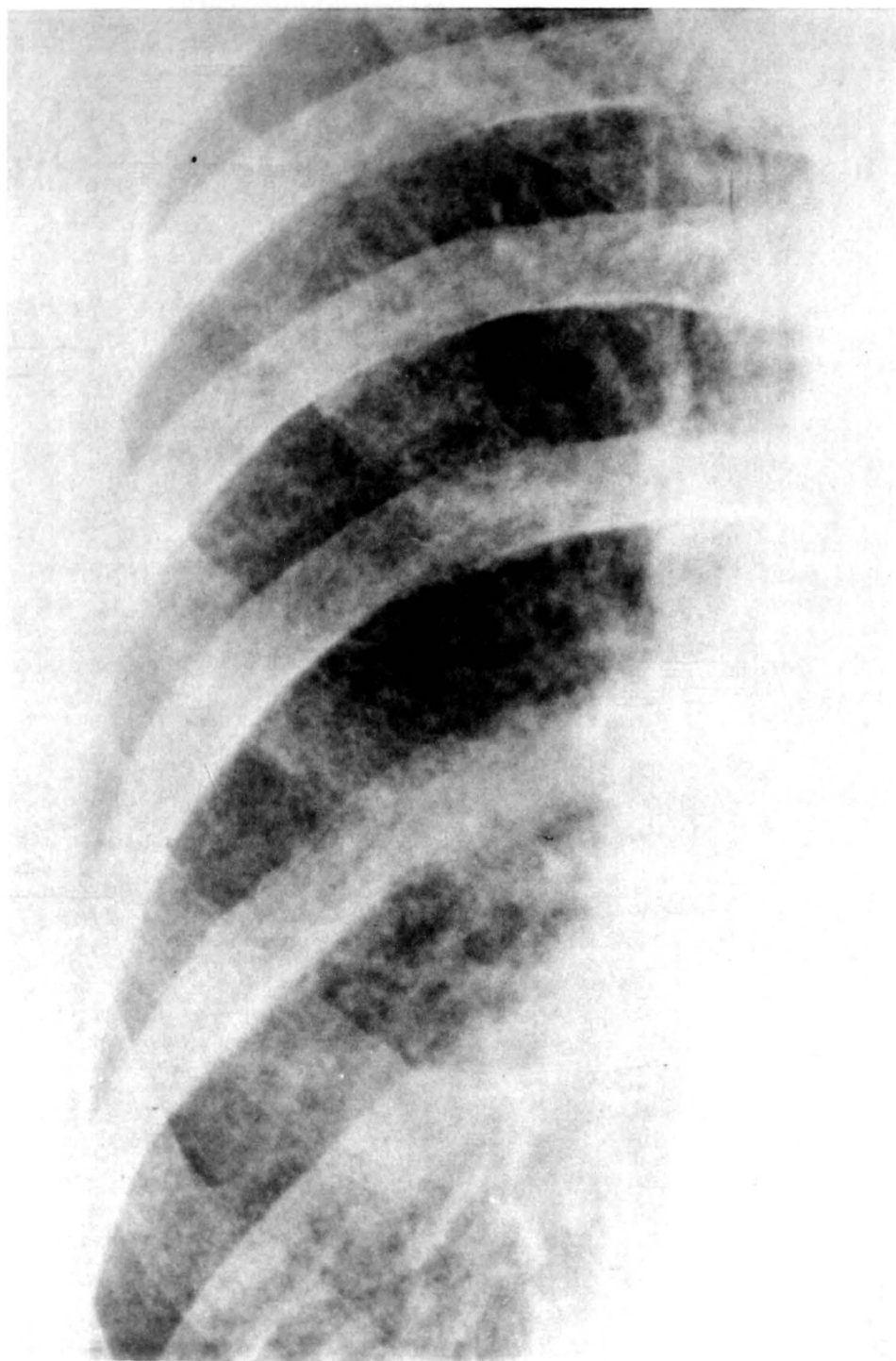


PLATE 3b.—Right middle zone of Plate 3a.

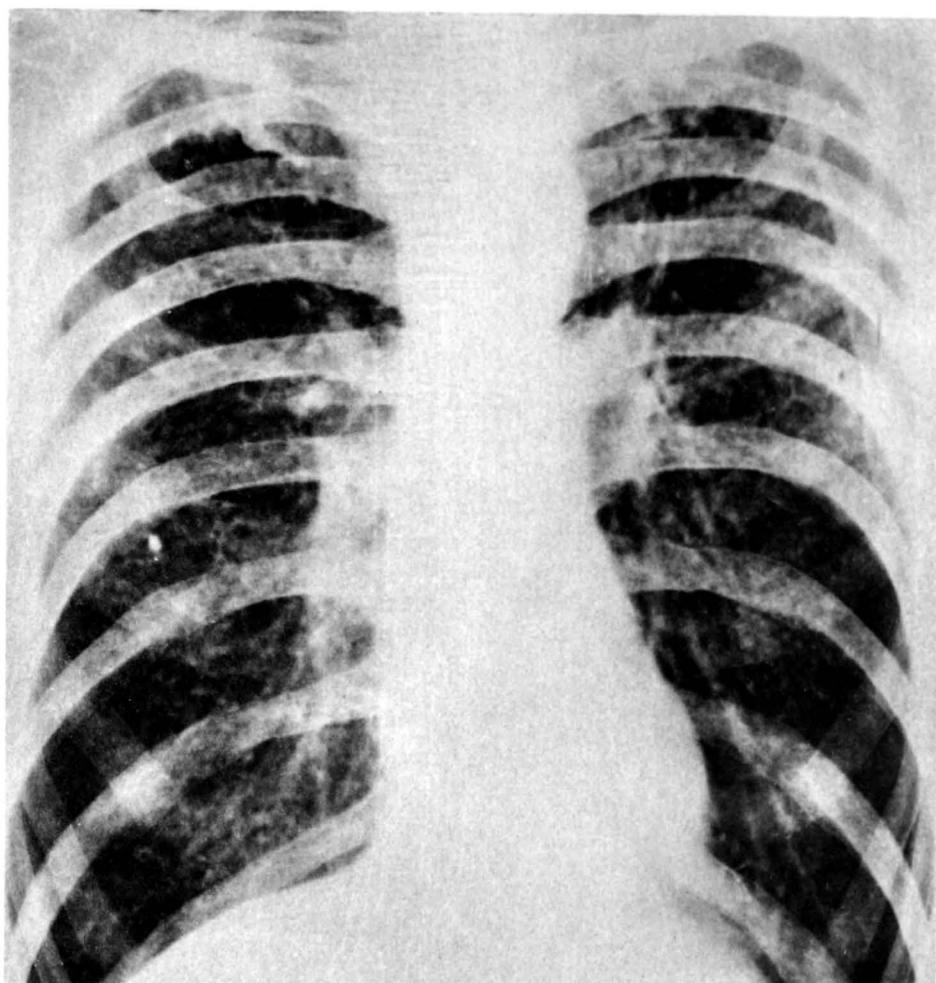


PLATE 4a.—**Category (b) Reticulation.** Miner, aged 60 yrs., from colliery A.3 (anthracite). Colliery occupations: collier, 43 yrs. (non-anthracite, 9 yrs., anthracite, 34 yrs.) The reticulation, best seen in right lung field, is of a relatively uncommon type, the network having a wider mesh and thicker strands than the average. Both apices show also patchy shadows and calcified spots.

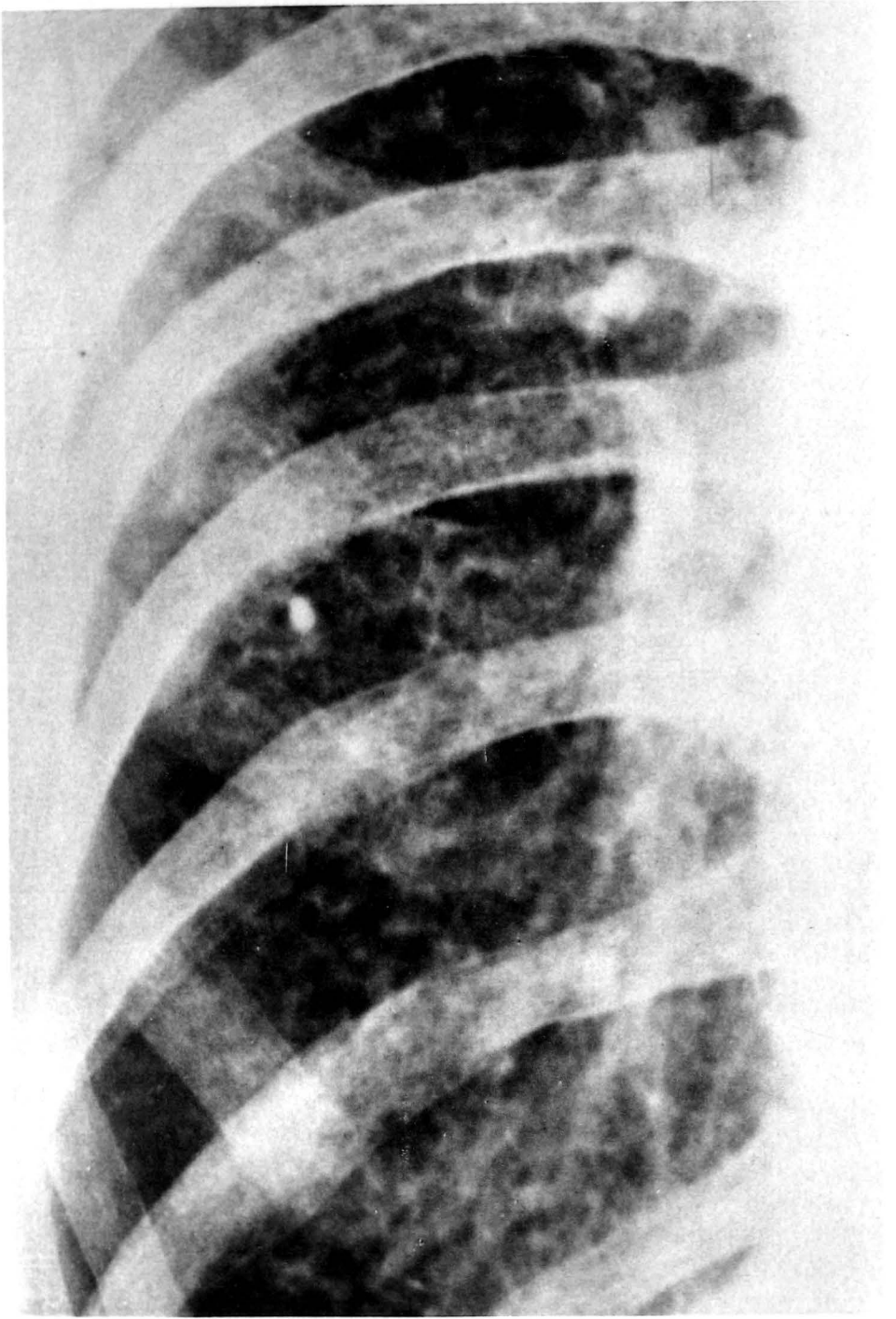


PLATE 4b.—Right middle zone of Plate 4a.

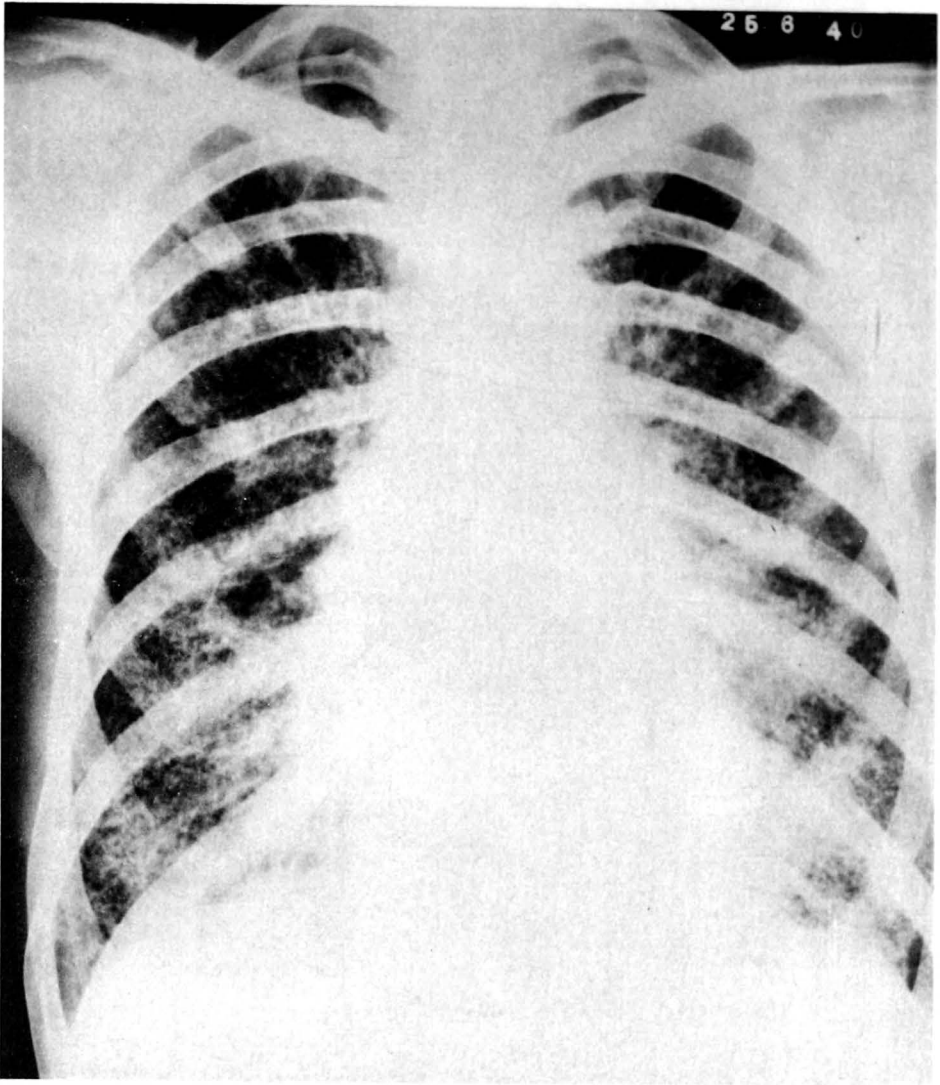


PLATE 5a.—**Category (b) Reticulation.** Miner, aged 55 yrs., from colliery S.3 (steam coal). Colliery occupations: collier (steam coal), 38 yrs.; engine boy 3 yrs. The reticulation is of a relatively uncommon type, the network being very dense, particularly in the lower zones.

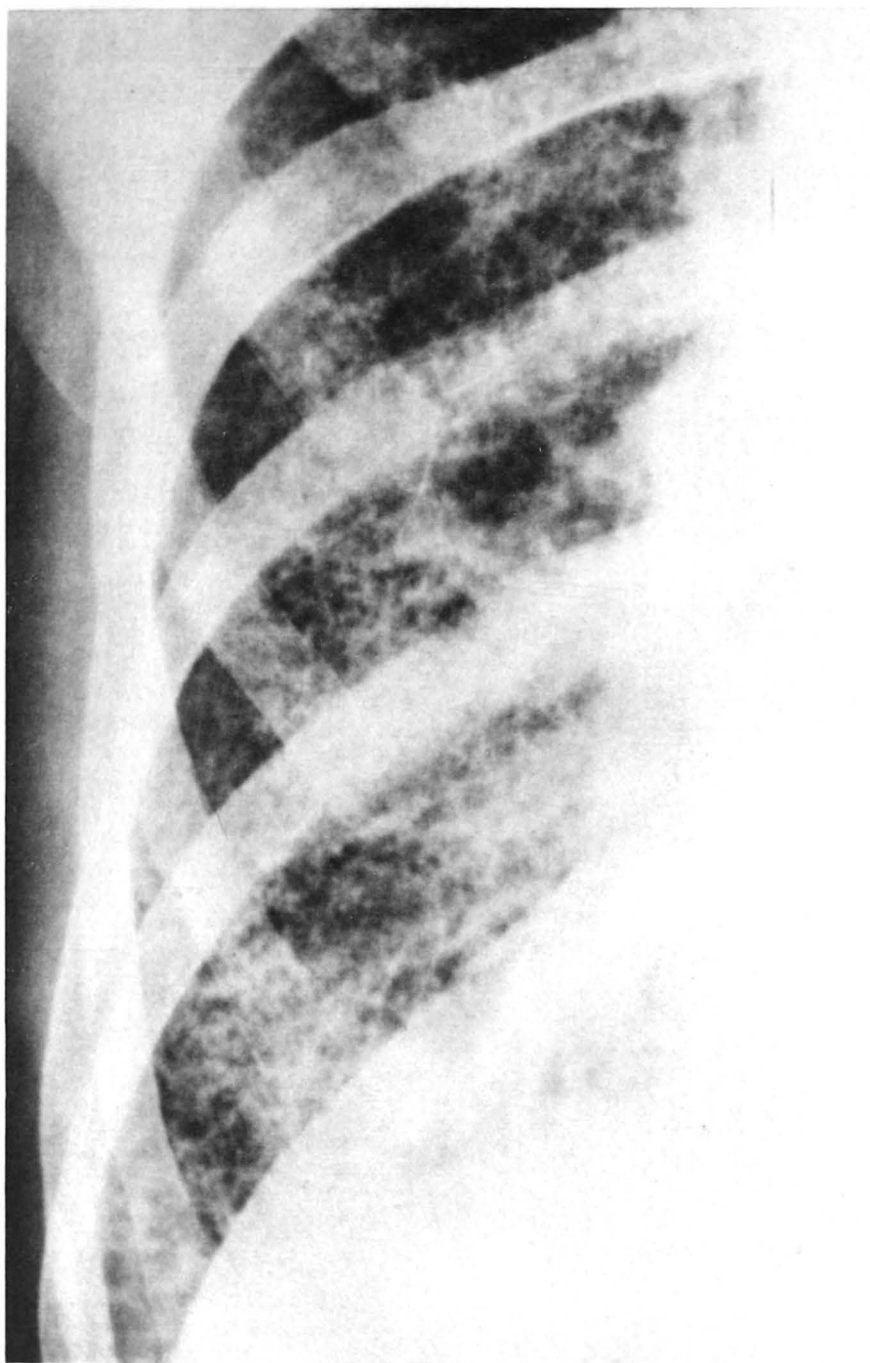


PLATE 5b.—Right lower zone of Plate 5a.



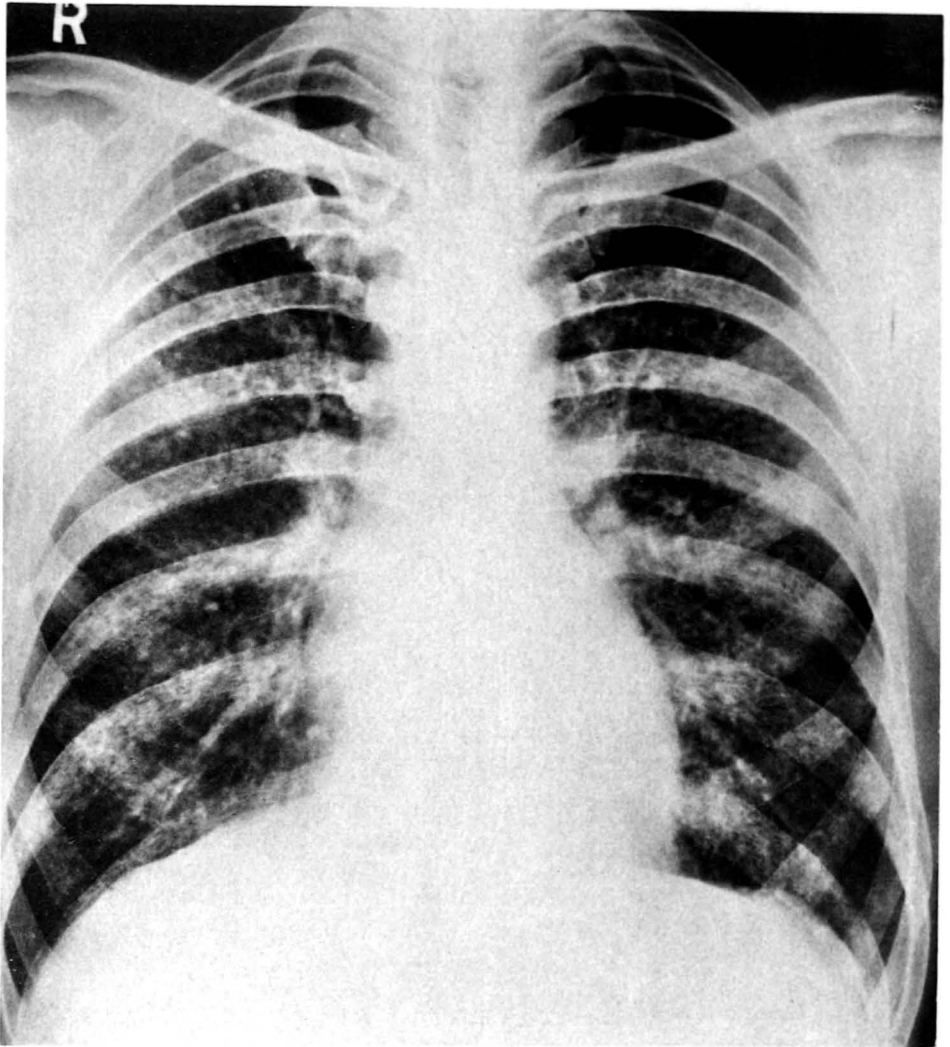


PLATE 6a.—**Category (b) Reticulation.** Miner, aged 37 yrs., from colliery A.3 (anthracite). Colliery occupations: collier (anthracite), 17 yrs.; fireman-shotsman, 2 yrs.; repairer, 2 yrs. The reticulation is of the common type, the fine network being blurred in appearance. The reticulation occupies the whole of both lung fields, excepting apices; it is as marked at the periphery of the fields as nearer the hila.

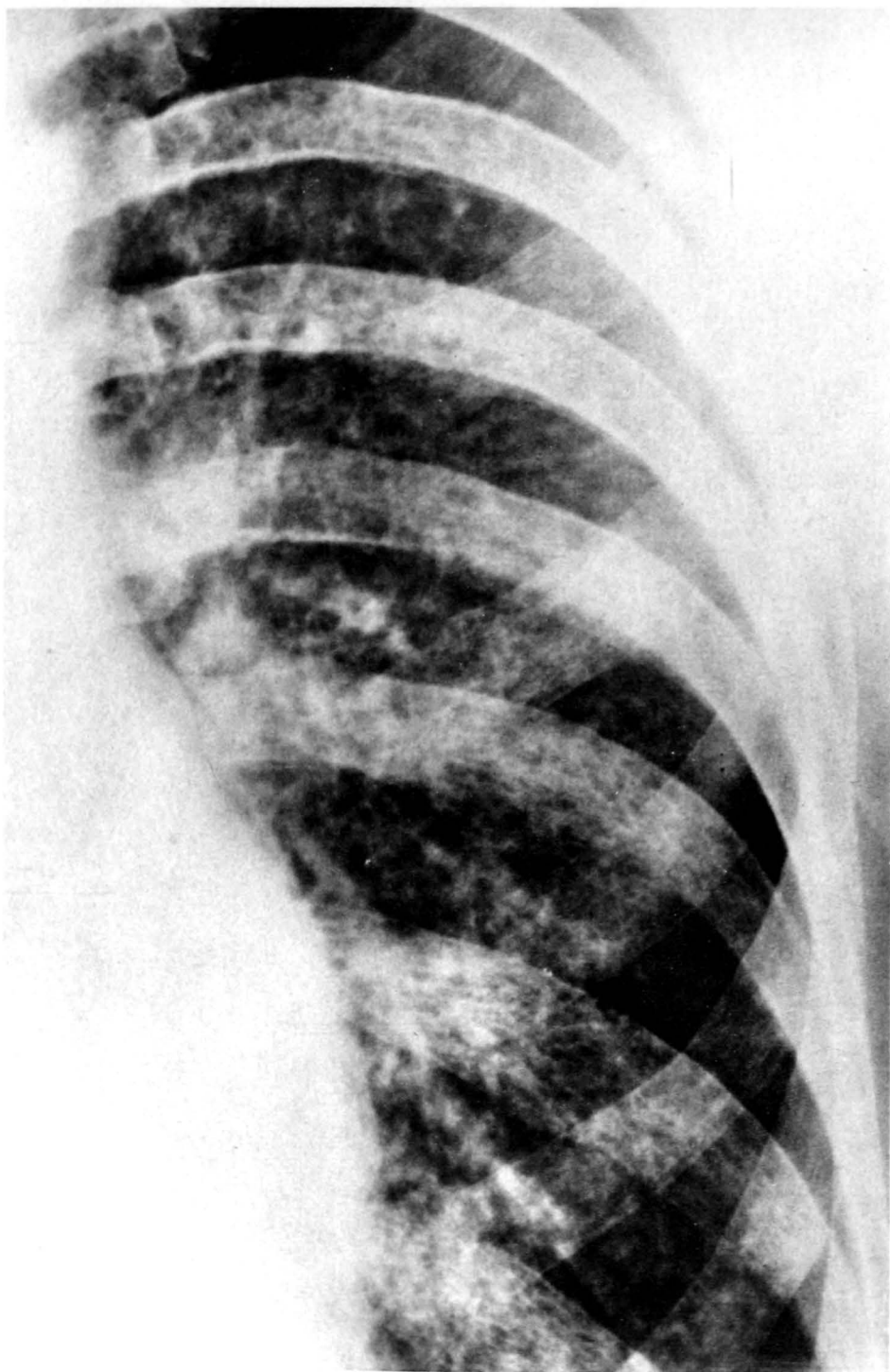


PLATE 6b. —Left middle zone of Plate 6a.

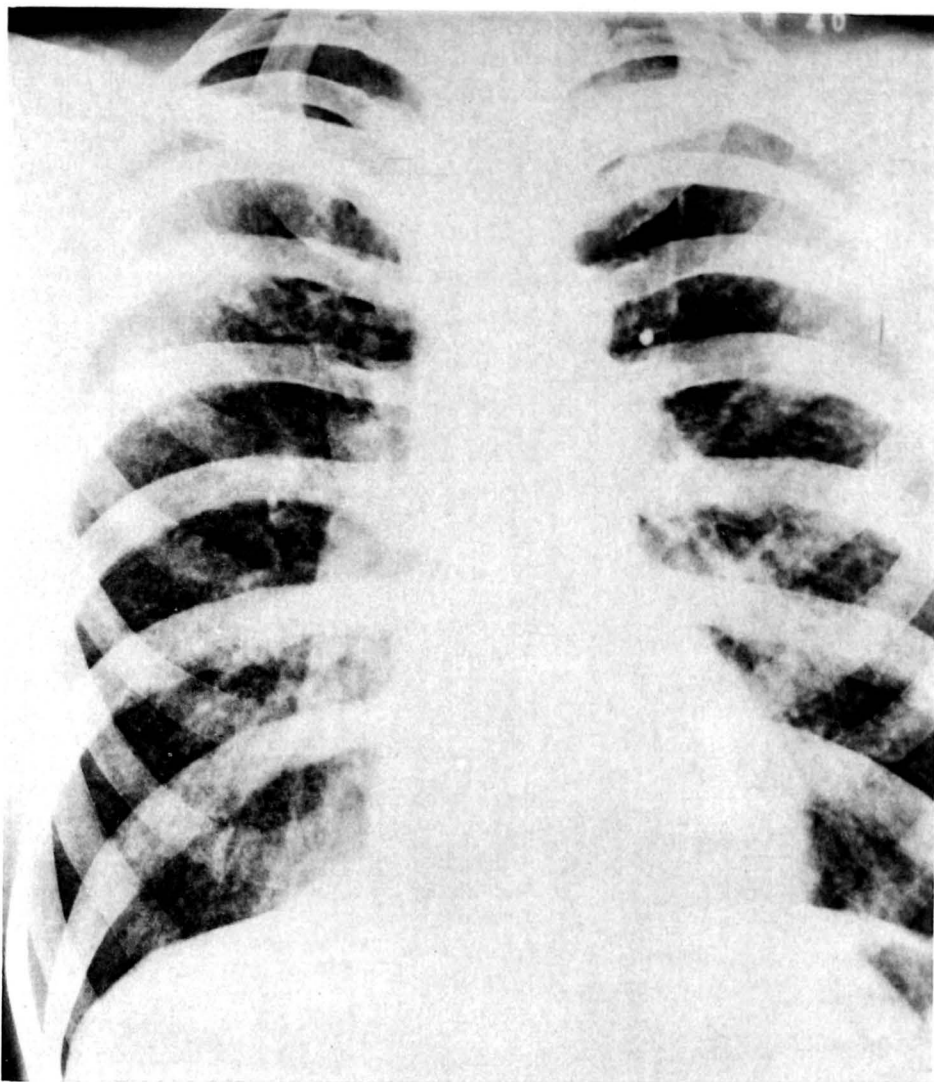


PLATE 7a.—**Category (b) Reticulation.** Miner, aged 37 yrs., from colliery S.3 (steam coal). Colliery occupations: collier (steam coal), 23 yrs. The reticulation is of the common type, as in Plate 6.

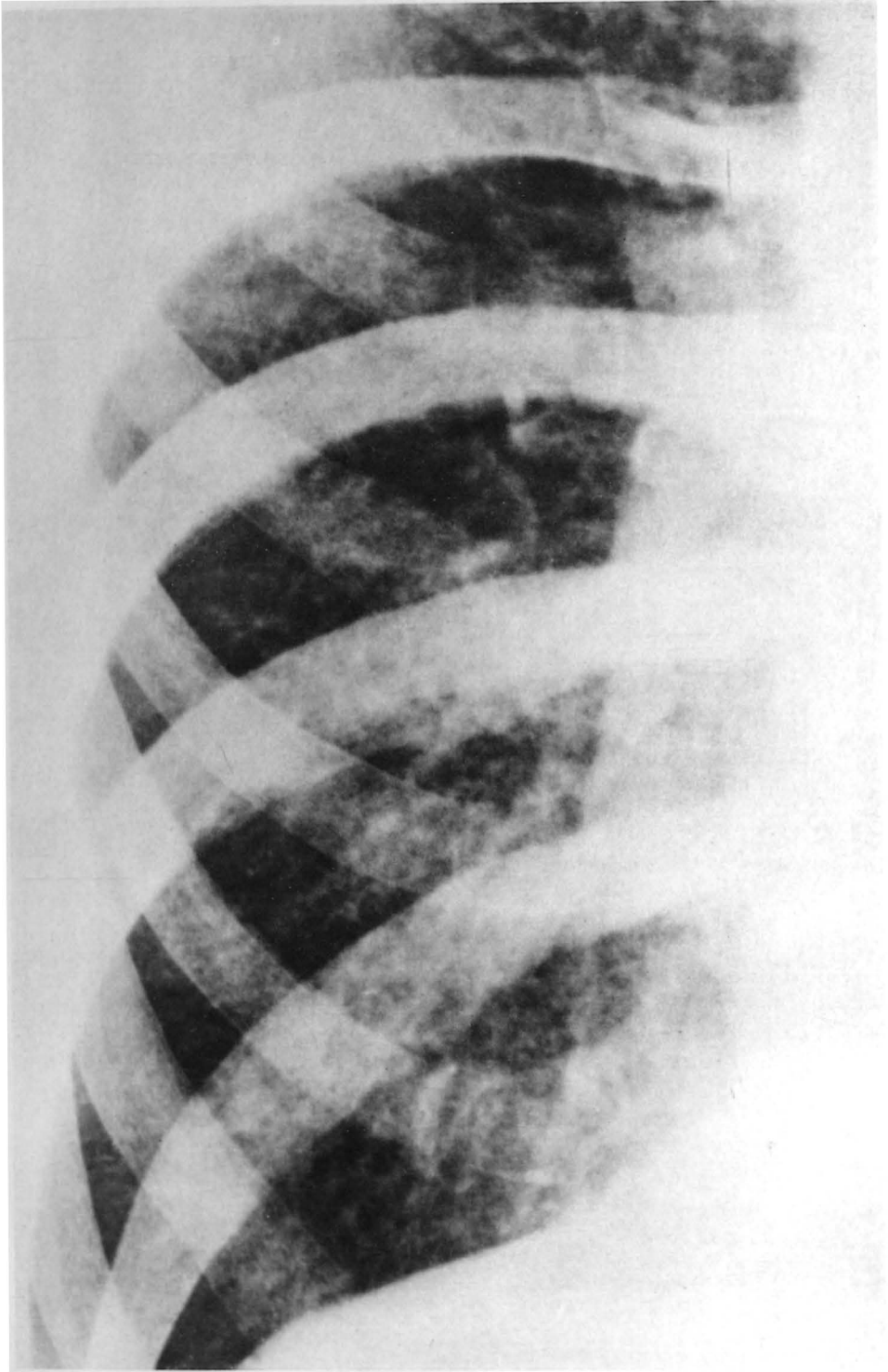


PLATE 7b.—Right middle and lower zones of Plate 7a.

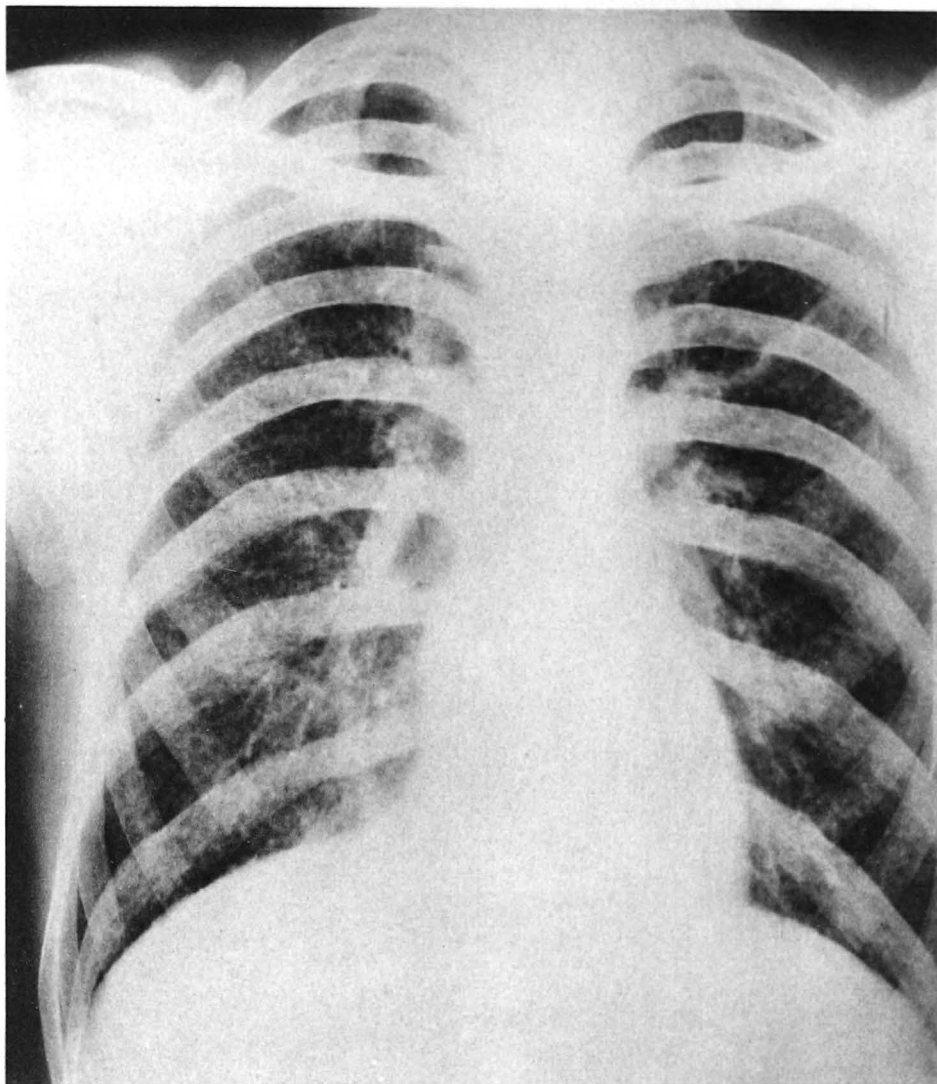


PLATE 8a—**Category (b) Reticulation**, and **Category (c) Nodulation**. Miner, aged 33 yrs., from colliery S.3 (steam coal). Colliery occupations: collier (steam coal), 18 yrs. The right lung field shows reticulation of the common type, the fine network being blurred in appearance; the left lung field, especially its upper and middle zones, shows shadows of early nodulation on a background of reticulation.

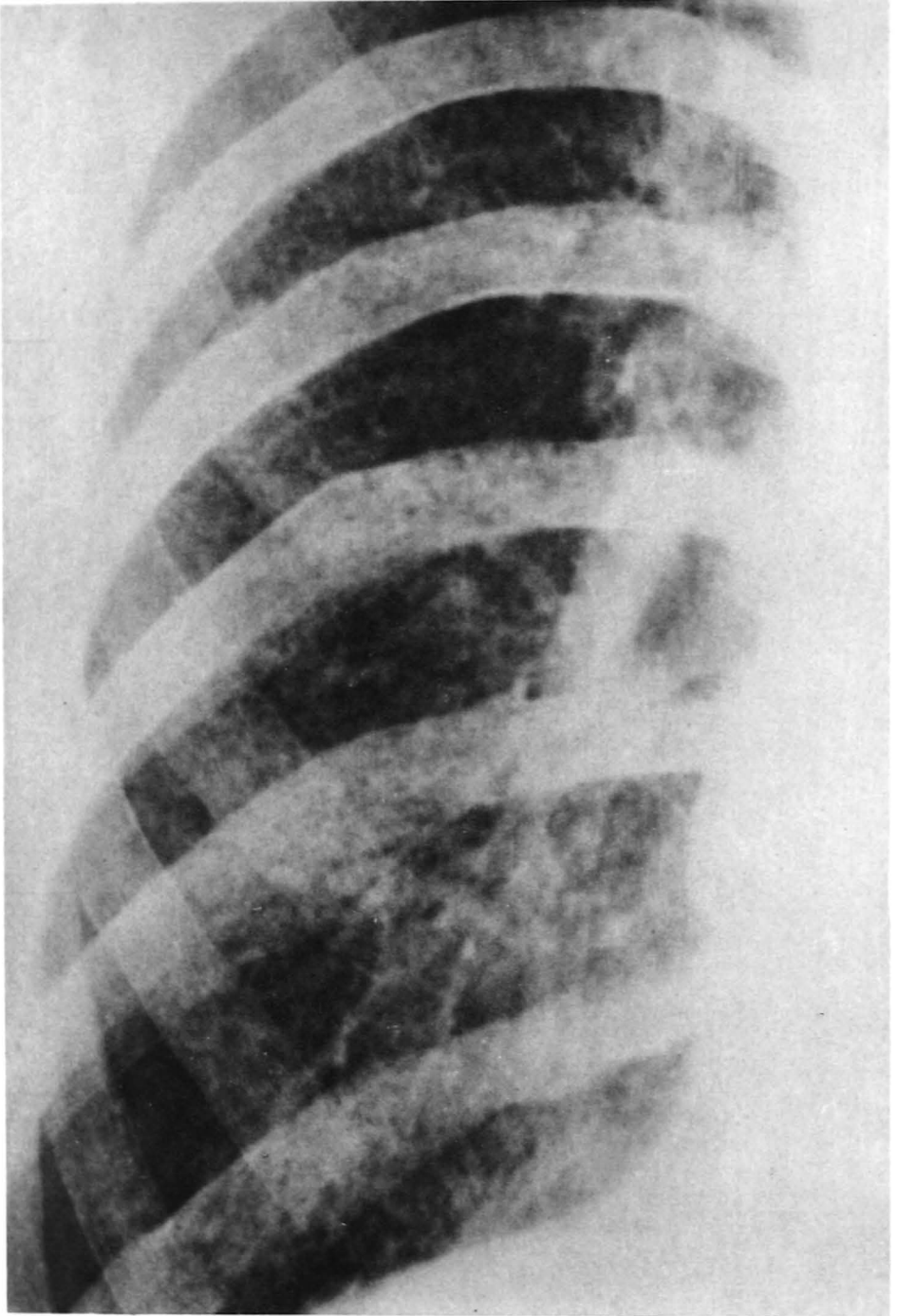


PLATE Sb.—Right middle zone of Plate Sa, showing reticulation.

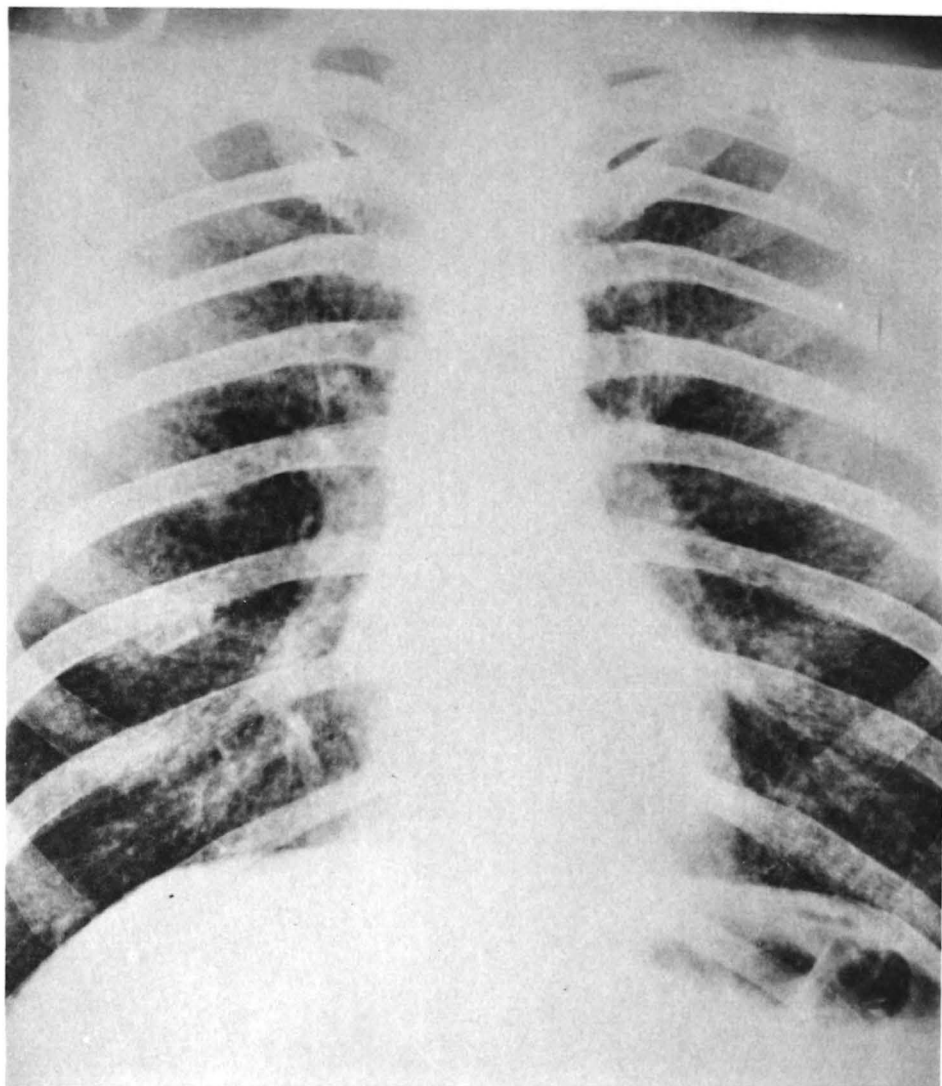


PLATE 9a.—**Category (c) Nodulation.** Miner, aged 36 yrs., from colliery A.3 (anthracite). Colliery occupations: collier (anthracite), 21 yrs. The shadows of nodulation are present in both lung fields, though not widespread; reticulation also is very evident.



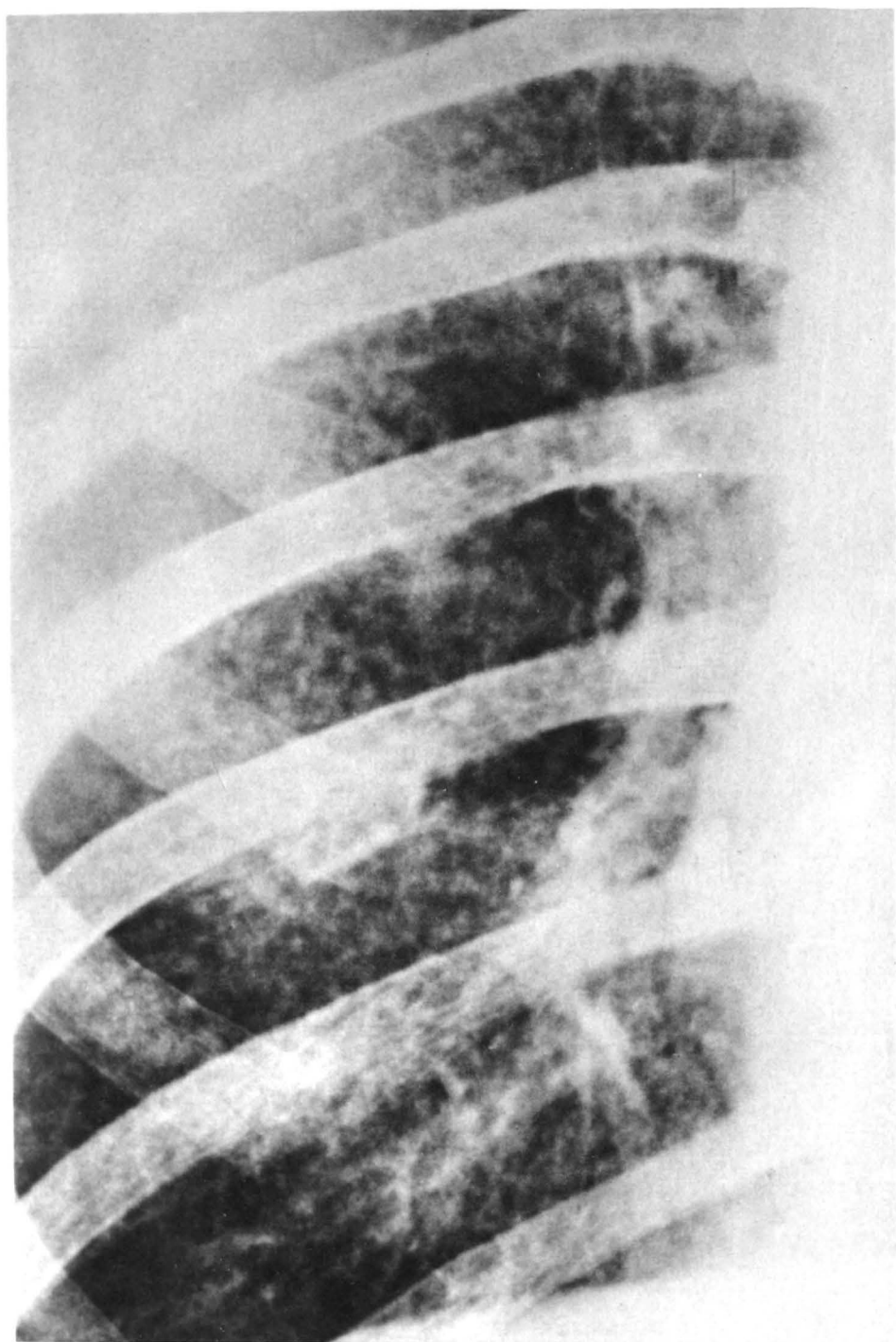


PLATE 9b.—Right middle and lower zones of Plate 9a.



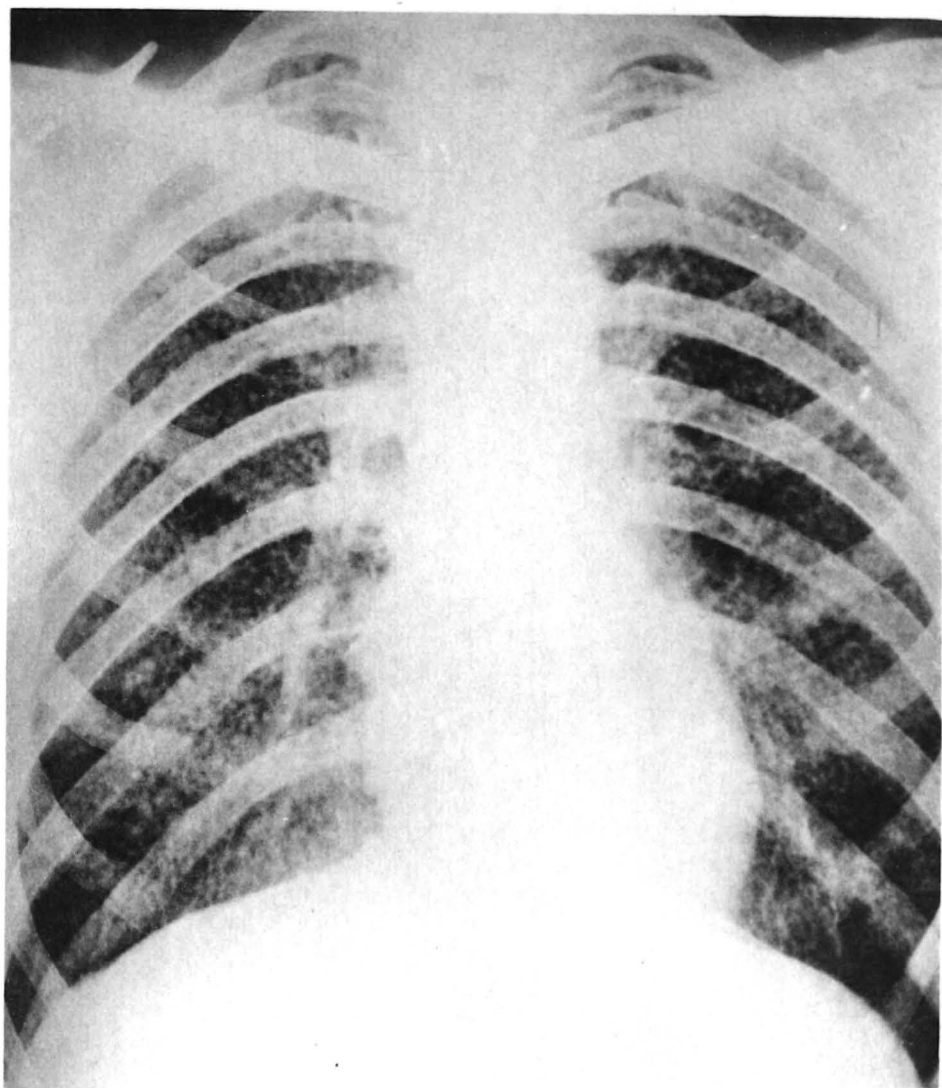


PLATE 10a.—**Category (c) Nodulation.** Miner, aged 37 yrs., from colliery A.3 (anthracite). Colliery occupations: collier, 22 yrs. (non-anthracite, 17 yrs., anthracite, 5 yrs.); hard-heading worker, 1½ yrs. The shadows of nodulation are more evident than in Plate 8; they are widespread in both lung fields against a background of reticulation.

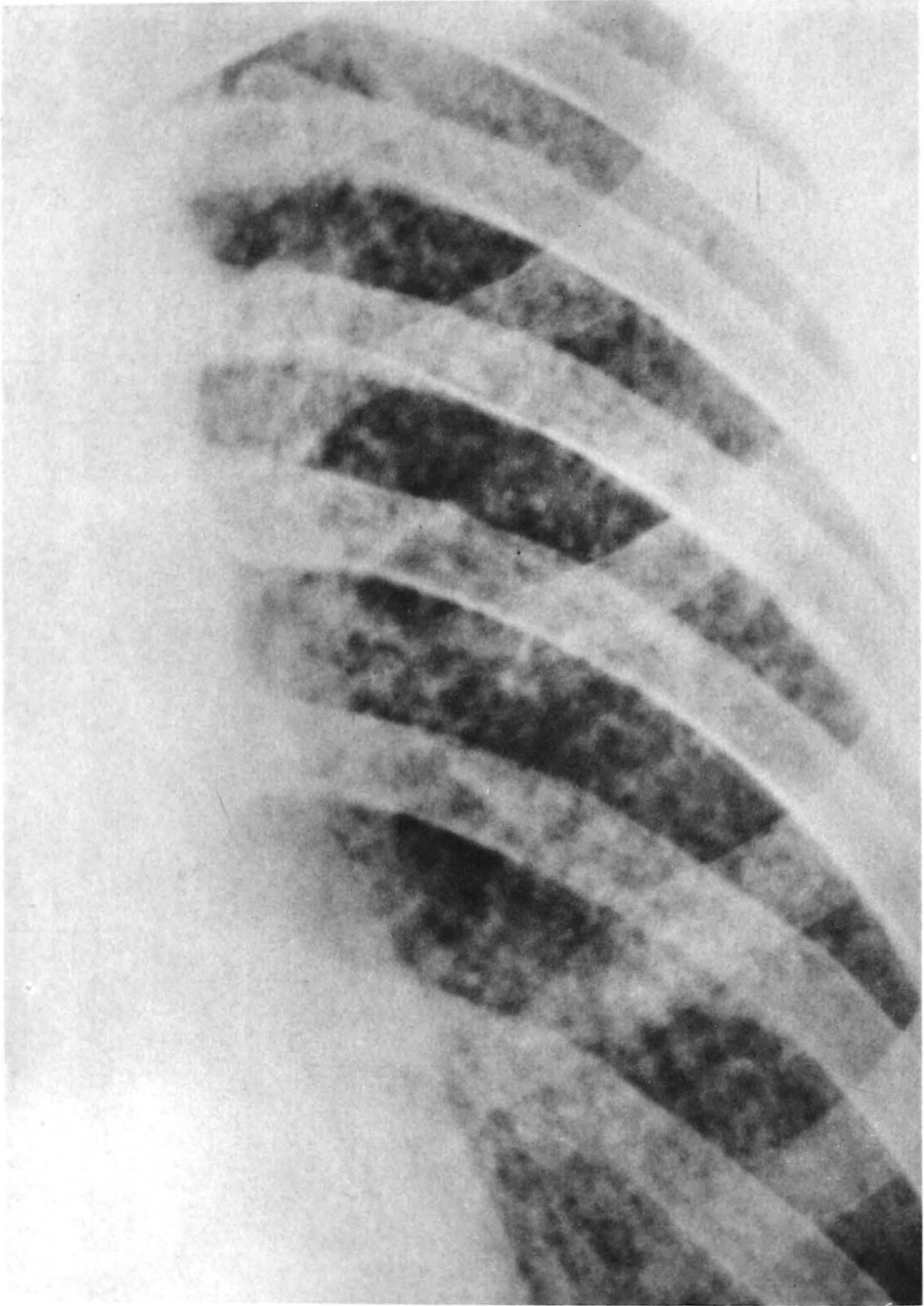


PLATE 10b.—Left middle zone of Plate 10a.

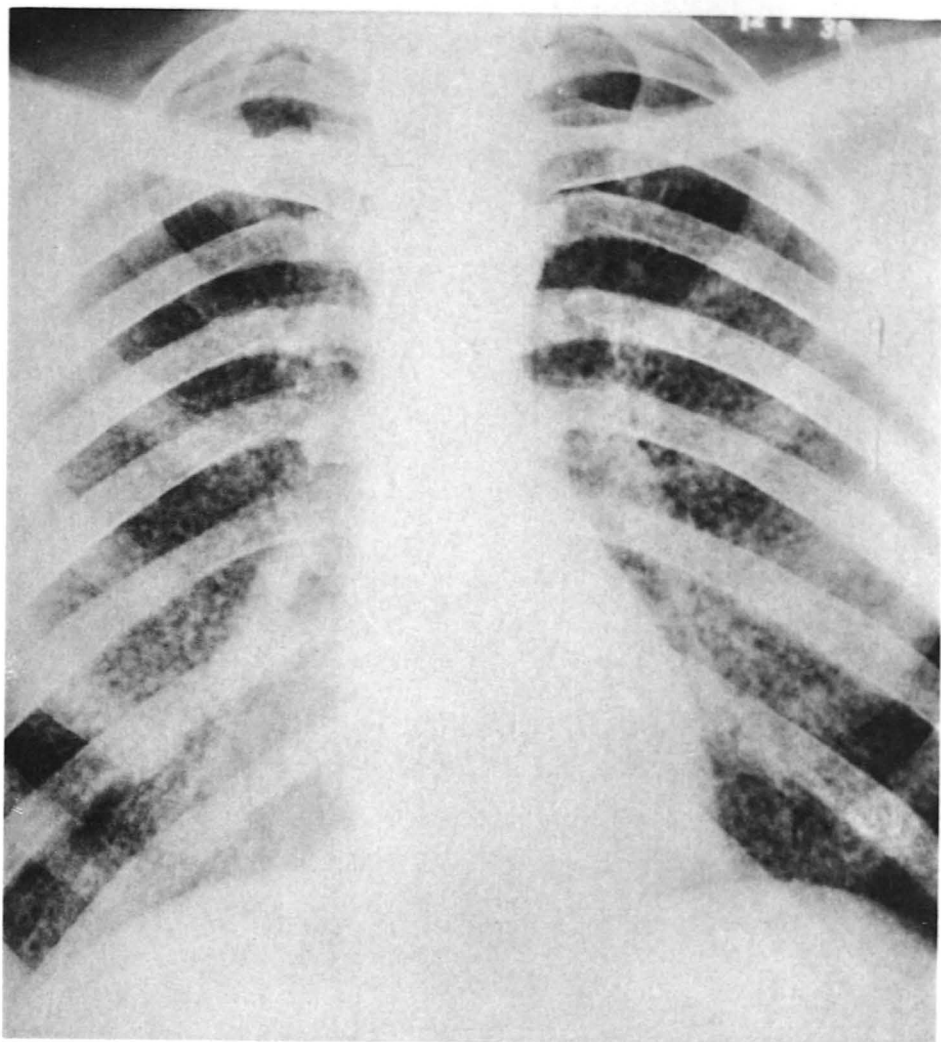


PLATE 11a.—**Category (c) Nodulation.** Miner, aged 32 yrs., from colliery A.1 (anthracite). Colliery occupations: collier (anthracite), 13 yrs. The multiple discrete shadows of nodulation are more evident than in Plates 9 and 10; they occupy the whole of both lung fields against a background of reticulation, giving a snowstorm effect.

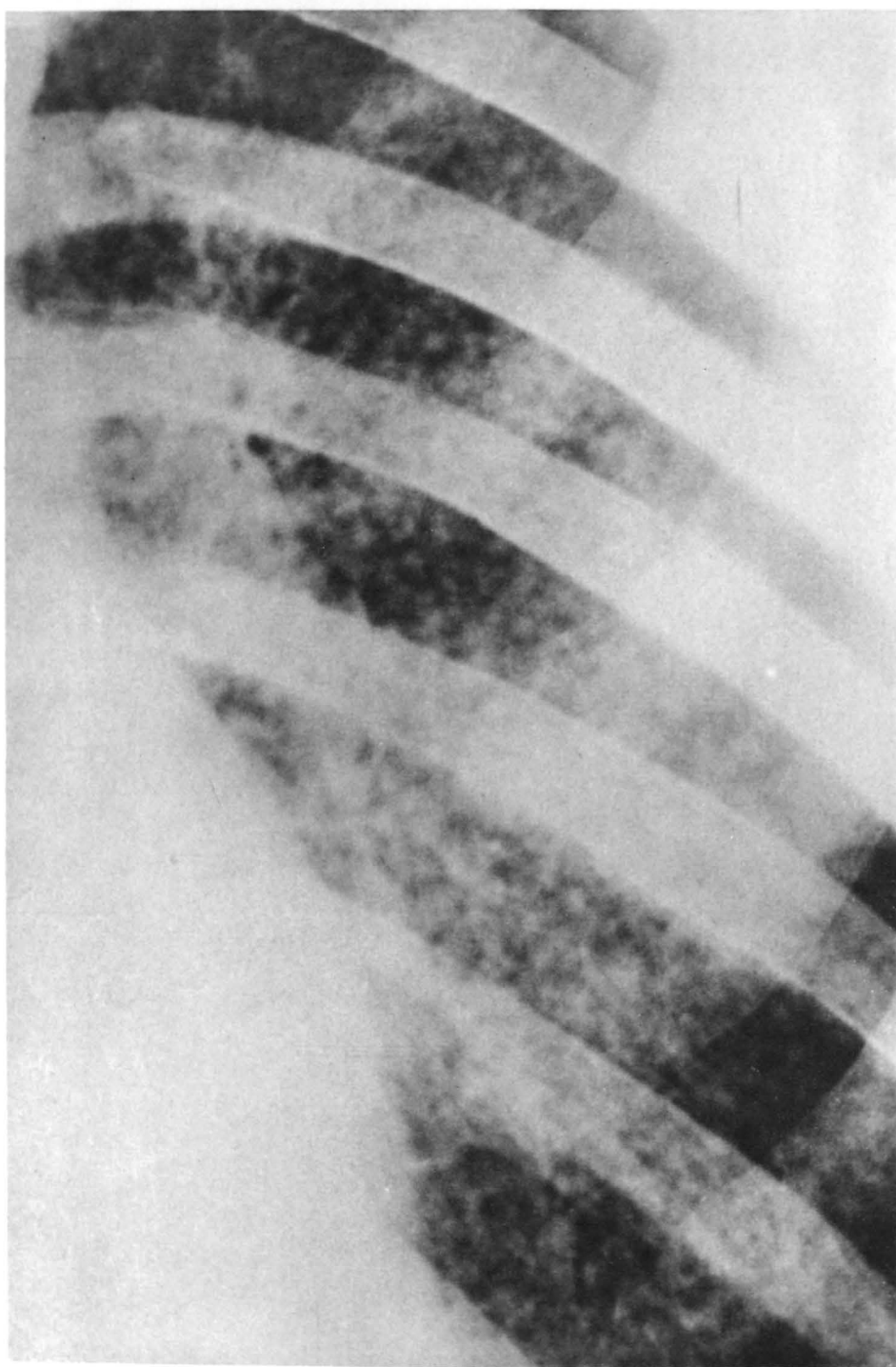


PLATE 11b.—Left middle and lower zones of Plate 11a.

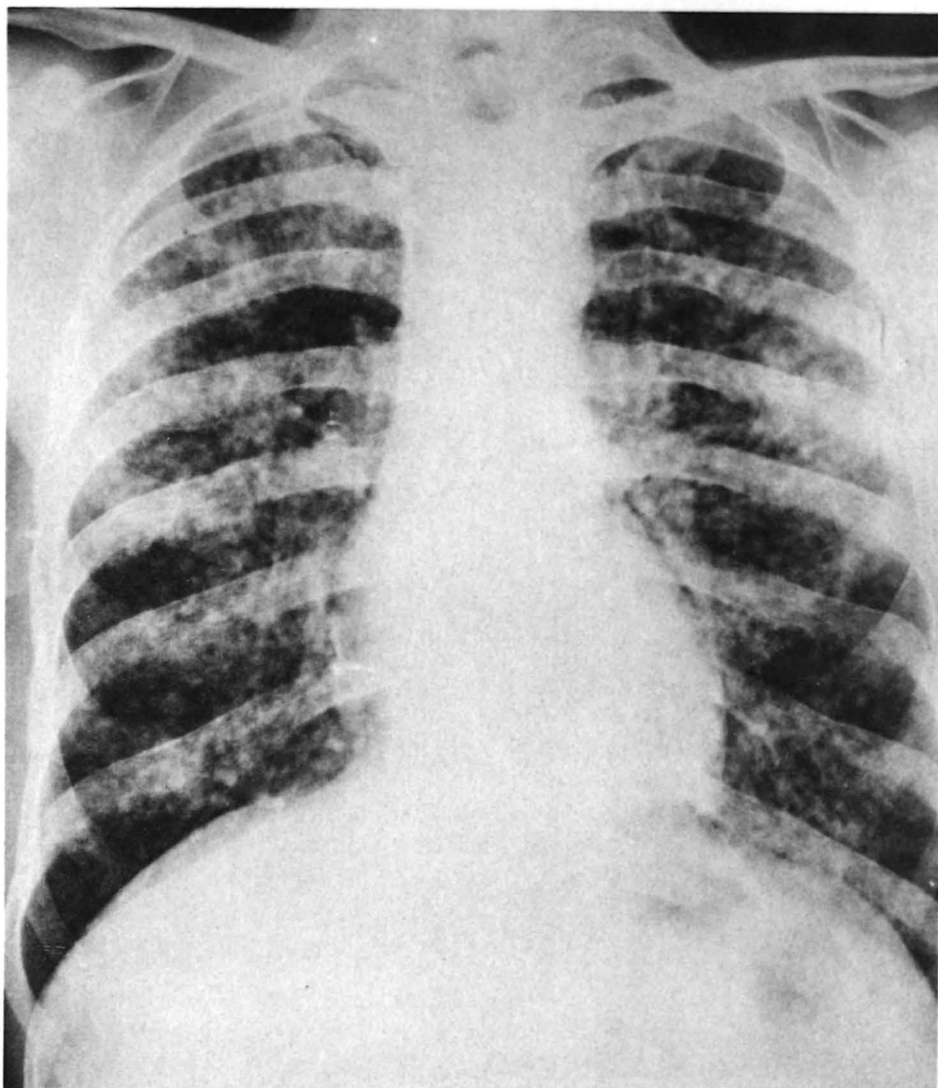
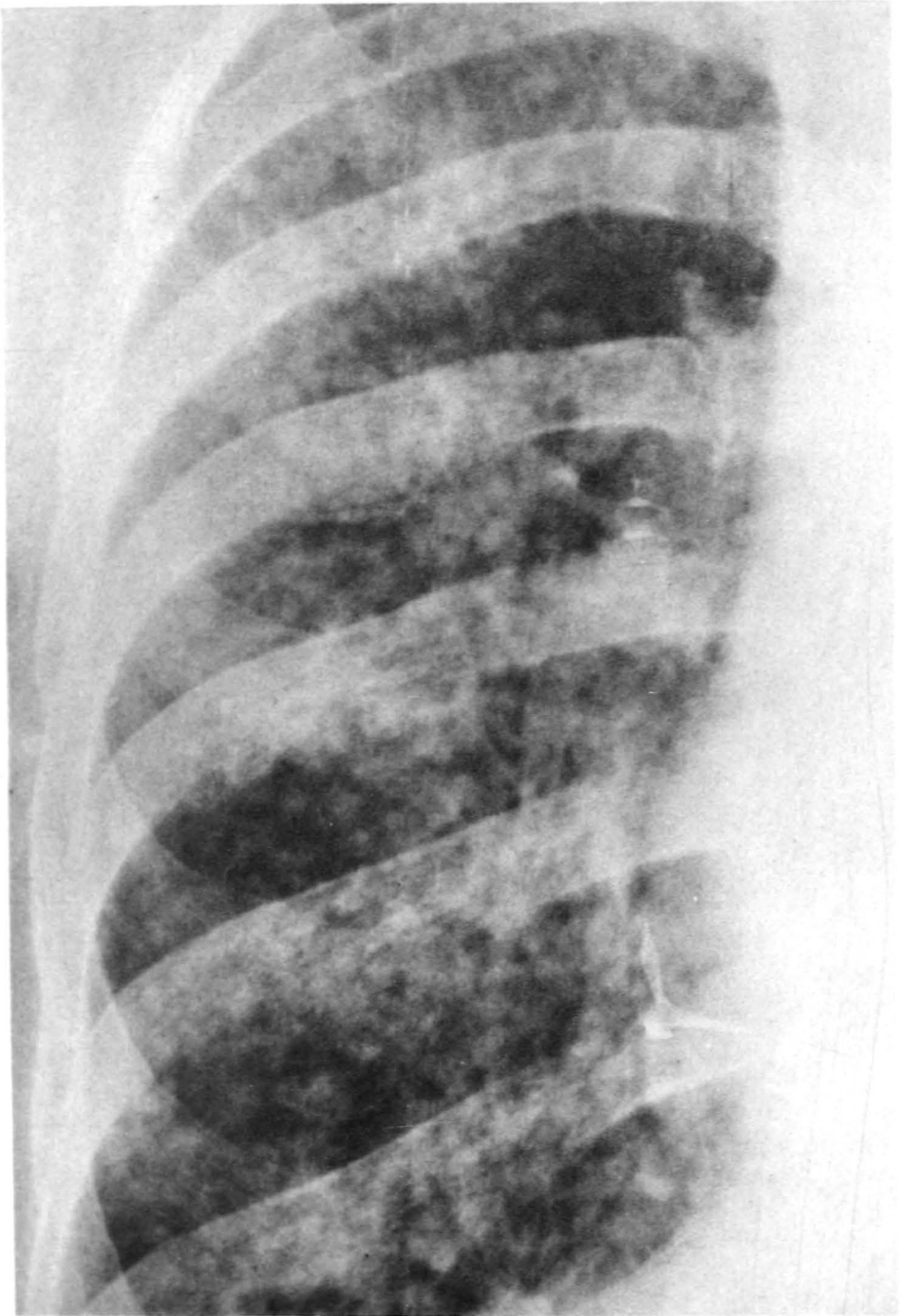


PLATE 12a.—**Category (c) Nodulation.** Miner, aged 48 yrs., from colliery A.3 (anthracite). Colliery occupations: collier (anthracite) 32 yrs. The shadows of nodulation are larger than in plates 9-11.



**PLATE 12b.**—Right middle zone of Plate 12a.

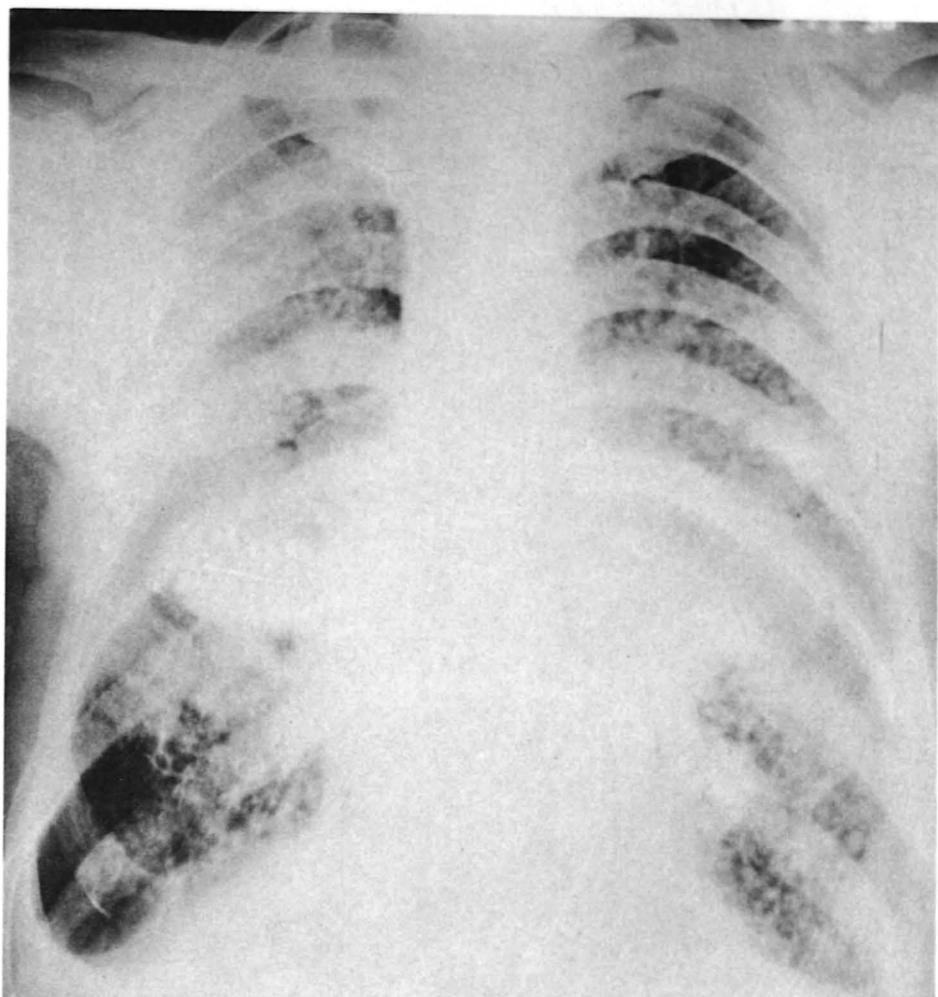


PLATE 13.—**Category (d) Coalescent Nodulation.** Miner, aged 49 yrs., from colliery A.3 (anthracite). Colliery occupations: collier (anthracite), 13 yrs.; fireman-shotsman (anthracite), 23 yrs. The shadows of nodulation appear to be coalescent or conglomerate in several areas, this appearance being shown best in the left middle zone; reticulation also is evident.

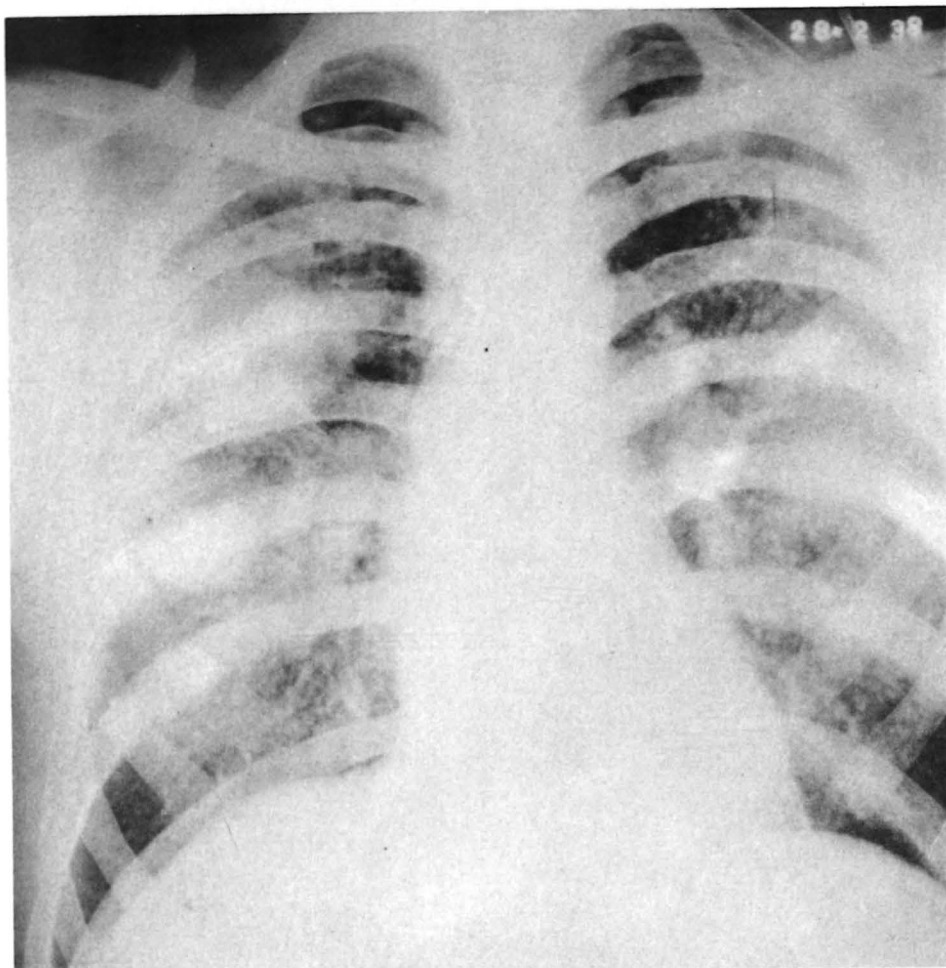


PLATE 14.—**Category (e) Massive Shadows.** Miner, aged 40 yrs., from colliery A.3 (anthracite). Colliery occupations: collier (anthracite), 24 yrs. Dense homogeneous shadows (“cricket-ball” shadows) in right lung field; left lung field shows coalescent nodulation and also reticulation.



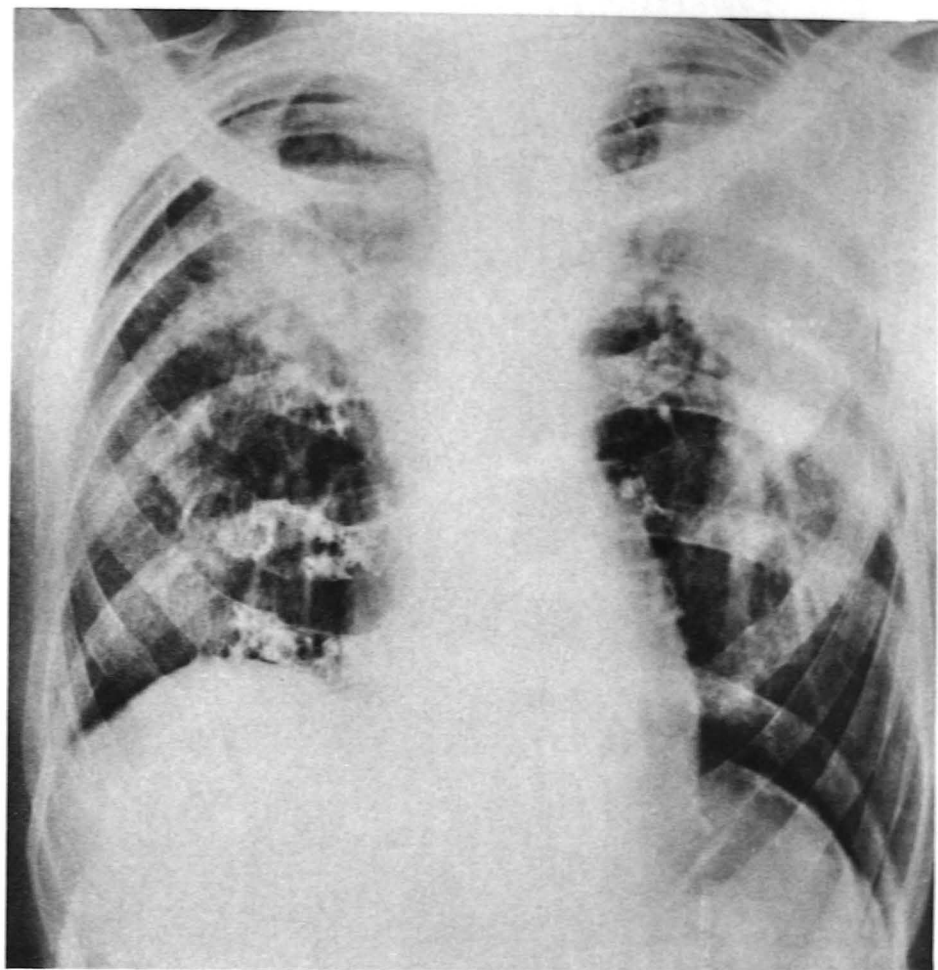
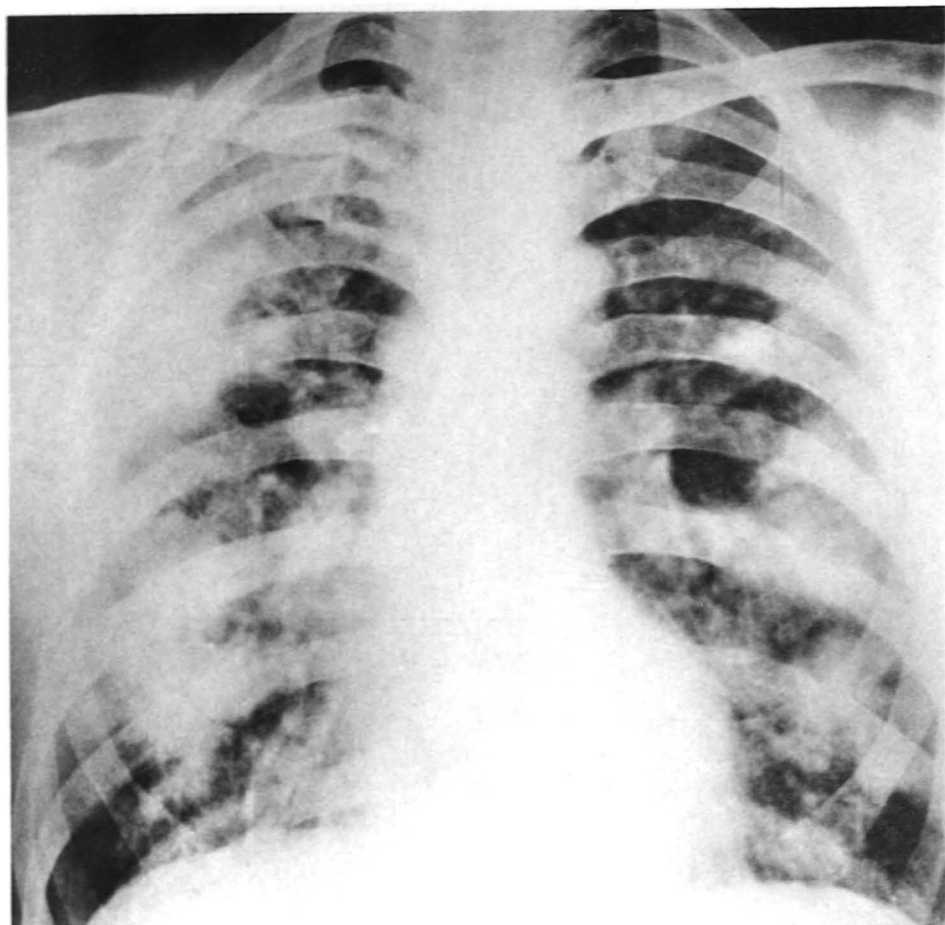


PLATE 15.—Category (e) Massive Shadows. Miner, aged 67 yrs., from colliery A.3 (anthracite). Colliery occupations: surface screens worker (anthracite), 42 yrs. Large dense homogeneous shadow in left upper zone, and commencing similar shadow in right upper zone. Emphysema at bases.



**PLATE 16.—Category (f) Multiple Fluffy Shadows.** Miner, aged 50 yrs.; from colliery A.3 (anthracite). Colliery occupations: collier, 31 yrs. (non-anthracite, 4 yrs., anthracite, 27 yrs); surface worker, 4 yrs. Shadows, rounded or irregular in shape and fluffy in appearance, irregularly situated in both lung fields.

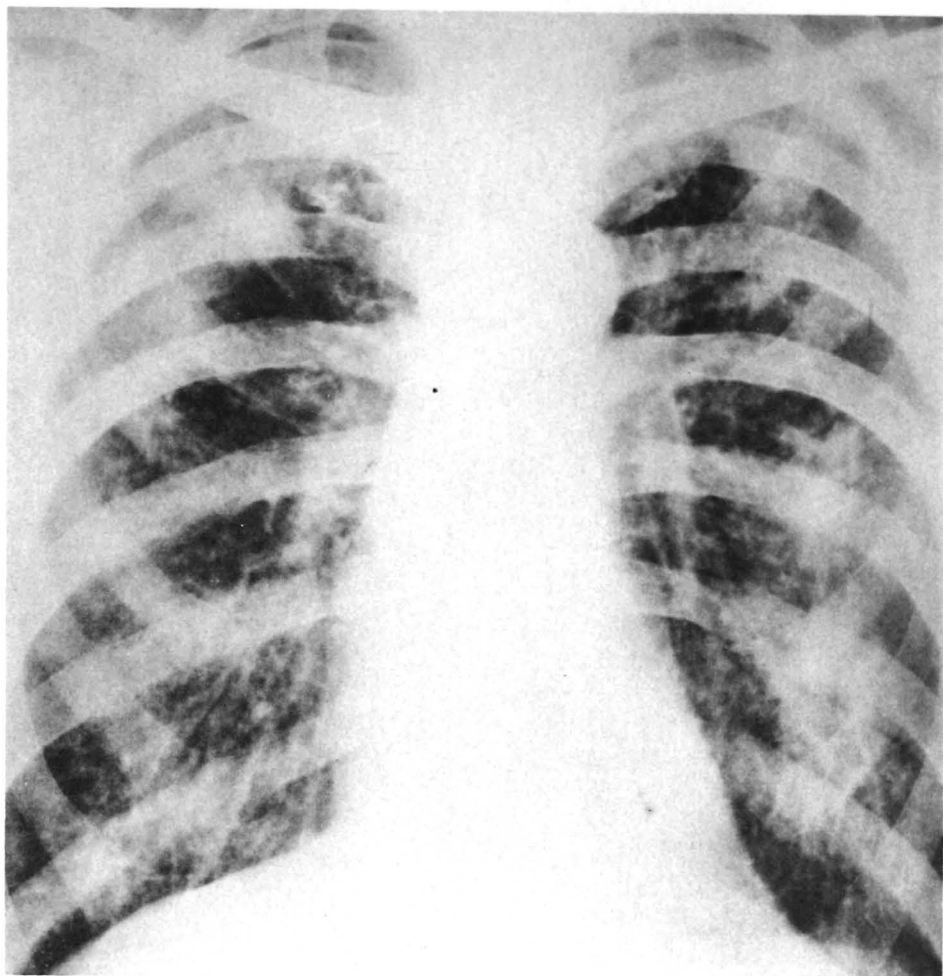
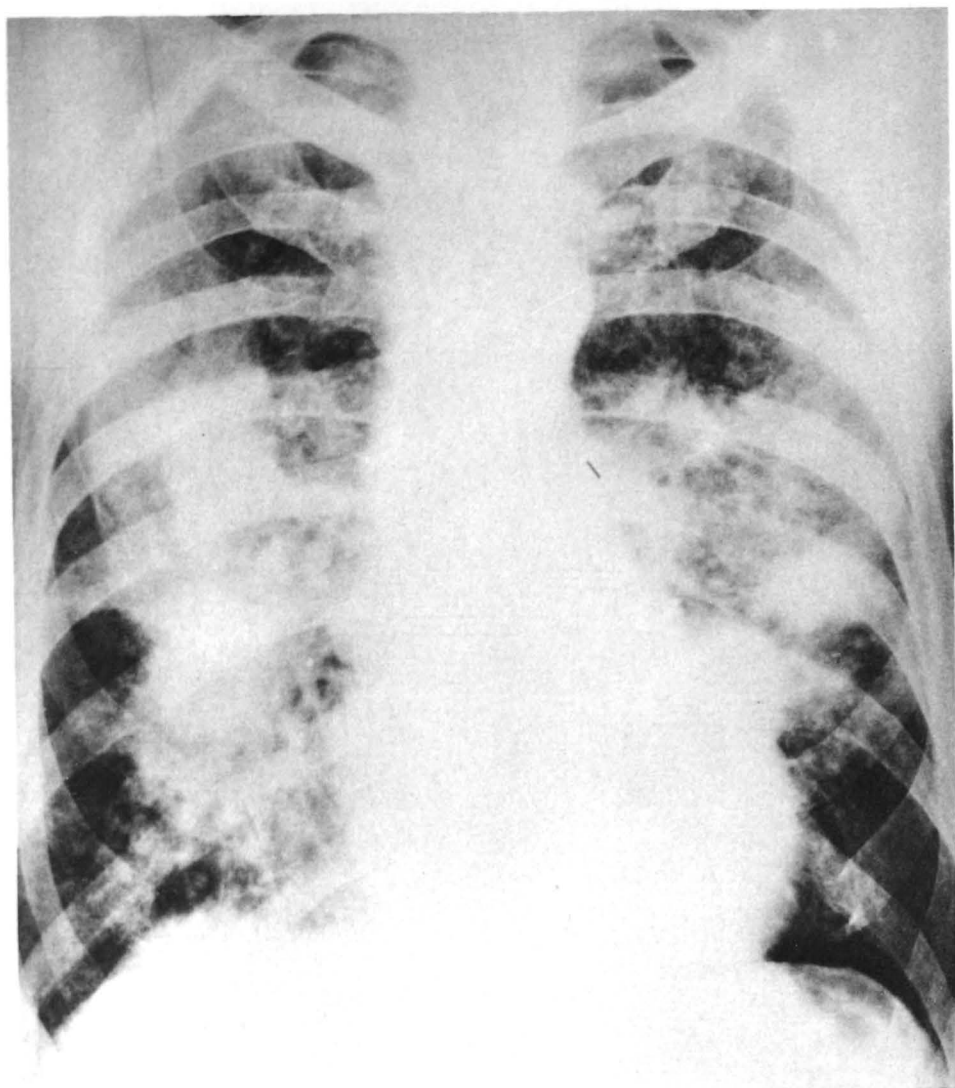


PLATE 17.—**Category (f) Multiple Fluffy shadows.** Miner, aged 56 yrs., from colliery A.3 (anthracite). Colliery occupations: collier (anthracite), 34 yrs.; haulier, 4 yrs. Shadows, stellate in shape and fluffy in appearance, situated irregularly in both lung fields; reticulation also is evident.



**PLATE 18.—Category (e) Massive Shadows.** Coaltrimmer, aged 64 yrs., from port PSa (steam coal). Occupations: domestic service, 17 yrs.; trimmer, 32 yrs. Large, dense, sharply-outlined shadows in right lung field, and commencing similar shadows in left middle zone. Emphysema at bases.

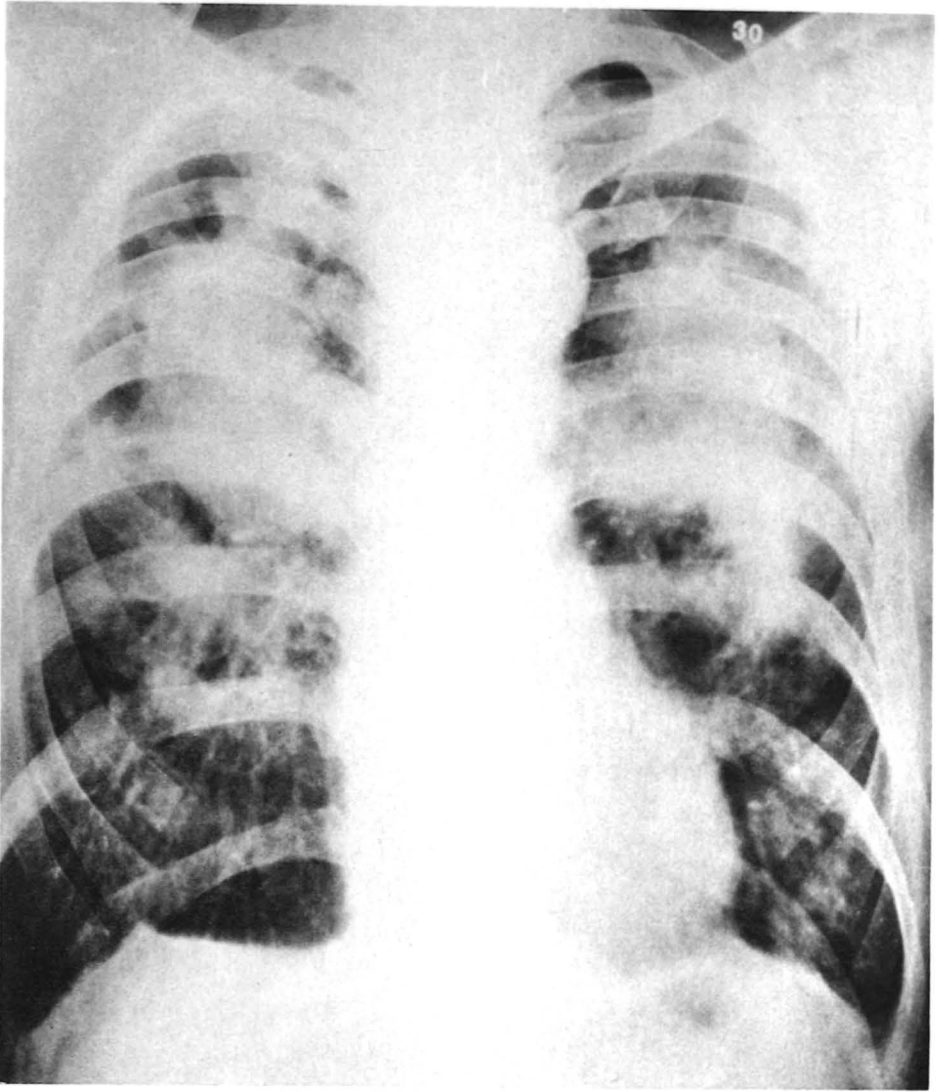


PLATE 19.—**Category (e) Massive Shadows.** Coaltrimmer, aged 59 yrs., from port PSb (steam coal). Occupations: previous employment, 9 yrs.; trimmer 37 yrs. Large, sausage-like shadow in each middle zone, symmetrically situated.

## CHAPTER 6

**Incidence of X-ray Abnormalities attributable to Dust in the chief Occupational Classes of Anthracite Miners (based upon Findings at Colliery A.3)**

The results of the X-ray examinations at anthracite colliery A.3, obtained during the first stage of the medical survey, have been analysed in three ways: (A) to show the general incidence of X-ray abnormalities in the colliery population; (B) to show which individual occupations are the main sources of these abnormalities; and (C) to show the risks of employment for various lengths of time in the different occupations. It must be pointed out that (B) and (C) are rather different. A certain occupation may be extremely risky but very few men may have been employed for long in it, whereas another occupation may be less dangerous but many men may have spent considerable periods in it. In such an instance, although the first occupation entails the greater risk of developing pulmonary X-ray abnormalities, the second provides most of the abnormal appearances actually found and therefore constitutes the greater problem.

## A. GENERAL INCIDENCE OF X-RAY ABNORMALITIES

Table XI (p. 60) shows the percentage-incidence of the different X-ray changes in the registered population, total working population and underground working population of colliery A.3. The *registered population*, it will be remembered (p. 33), includes the silicosis compensation cases; the *total working population* comprises the men in regular work and so excludes these cases; and the *underground working population* excludes all surface workers. For judging incidence, the percentages based upon the total and underground working populations are probably the most informative.

It will be seen that the two main X-ray deviations from normal at this colliery were reticulation and the changes termed consolidation. Of the films of the underground workers, 26·3 per cent. were classed as reticulation, and 18·7 per cent. as consolidation, i.e. nearly half were abnormal. The most frequent of the categories composing the consolidation group was nodulation, which was found in 10·3 per cent. of the underground workers. The high incidence-rate of certified silicosis at this colliery (annual rate, 1931-38, 23·4 per 1,000 underground workers) is borne out by the high percentage-incidence of X-ray consolidation shown by these figures.

In Table XII (p. 61) the total working population of Table XI (502 men) is divided into (i) underground workers at time of examination—396 men; (ii) workers on surface at time of examination, but previously at some time employed underground—46 men; and (iii) surface workers with no underground employment experience—60 men. The whole working population and each of these sub-groups are subdivided by age, and the number and percentage of X-ray abnormalities are shown.

This table brings out the following points:—

(1) The working population as a whole was evenly divided into men of over and under 40 years of age, but among the underground workers the younger men were in excess. It may be noted that 10 of the 396 underground workers were under 20 years of age and 17 were 65 or more years old.

(2) Of the 204 men whose radiographs were classed as abnormal in the whole working population, 188 were underground workers and 13 were surface workers with some underground experience; only three were surface workers with no previous underground employment, and each of these had worked 20 or more years on the surface screens exposed to colliery dust. The incidences of abnormal radiographs in the three groups were: underground, 47·5 per cent.; surface and

underground, 28·2 per cent. ; and surface only, 5·0 per cent. The distribution of the 114 cases classed as reticulation is similar to that of all the abnormalities together (figures shown in brackets in table). Clearly, therefore, the predominant source of the X-ray abnormalities is underground work.

(3) The correlation between underground work and the X-ray abnormalities—particularly the fact that only three of the 204 radiologically abnormal cases were derived from the 60 surface workers with no underground experience, and that even these three men had had long contact with dust—is of considerable importance as a control on the criteria of X-ray diagnosis adopted in the present investigation. Since the occupational histories of the men examined were unknown to the medical investigators when the X-ray diagnoses were made, and since the age-distribution of the surface workers covers the span of working life, it may be inferred that the films classed in abnormal categories under special nomenclature, e.g. reticulation, have not been confused with appearances to be found with any notable degree of frequency in the ordinary male population of this coal-mining area.

#### B. DISTRIBUTION OF THE X-RAY ABNORMALITIES OF THE COLLIERY WORKING POPULATION AMONG THE DIFFERENT OCCUPATIONS

It is difficult to elicit from any simple tabulation the occupations mainly responsible for the X-ray abnormalities found at a colliery, since many of the men have been engaged in several colliery occupations during their lives. In Tables XIII and XIV (pp. 62 and 63) allowance has, so far as possible, been made for this multiplicity of occupations. In Table XIII the men have been grouped in the main X-ray categories and the distribution of their duration of employment among different individual occupations is shown by the *average period* spent in each occupation. In Table XIV the *percentage-frequency of different periods* spent in each occupation is shown ; this tabulation is limited to the reticulation and consolidation categories.

Since Tables XIII and XIV provide similar information, the conclusions to be drawn from them will be considered together :—

(1) The outstanding occupation in the histories of the men in the two main categories of X-ray abnormality, reticulation and consolidation, is that of collier. Over 90 per cent. of the men with these changes had been colliers for some period, and over two-thirds had been colliers for 10 years or more (Table XIV). This occupation could therefore account for the greater part of the changes. The association is further supported by the progressive increase in the time spent in this occupation as one passes from normal to the changes termed consolidation. For the average number of years spent as collier by the normals was 5·6, by those with reticulation 15·1, by those with nodulation 17·3, and by those classified as major consolidation 20·0 (Table XIII). The most striking contrast is between normals, on the one hand, and all abnormalities on the other.

(2) No important individual occupation other than that of collier could alone have been responsible for the X-ray abnormalities to more than a minor extent. About two-thirds of the men showing reticulation or consolidation had never been hauliers or riders, and about two-thirds had never been repairers, borers or rippers—in contrast to the very few (less than 10 per cent.) who had never been colliers (Table XIV). Moreover, the progressive increase in length of employment among the men showing progressively more abnormal X-rays, which was well-marked for the occupation of collier, is not evident for that of haulier or rider, nor for that of repairer, borer or ripper. For example, the average number of years spent as haulier or rider by the normals was 3·2, by those with reticulation 2·7, by those with nodulation 3·0, and by those with major consolidation 1·8 ; the corresponding averages for time spent as repairer, borer or ripper were 1·7, 2·9, 1·2 and 1·9 years (Table XIII).

In contrast to this, the two other important underground occupational categories listed, i.e. hard-heading worker and fireman or shotsman, do show, like the occupation of collier, an increasing average length of service as one passes from normal to consolidation. The average number of years spent as hard-heading worker by men with normal radiographs was 0·20, by those with reticulation 0·18, with nodulation 0·45, and with major consolidation 1·48; and the corresponding averages for time spent as fireman or shotsman were 0·3, 0·7, 0·8 and 2·6 (Table XIII). Although these average periods are all small and must therefore be treated with caution, and although part of their increase with the degree of X-ray abnormality might be due to a correlated increase in the period spent as a collier\*, the data provide some evidence that the occupations of hard-heading worker and fireman or shotsman carry a special risk, as does the occupation of collier. However, the finding that over three-fourths of the men showing reticulation on X-ray and about two-thirds of those classed as "consolidation" had never been hard-heading workers, and that over 90 per cent. of men in these two X-ray categories had never been employed as firemen or shotsmen (Table XIV), showed that these occupations—dangerous though they might be—could have only a small share of responsibility for the number of X-ray abnormalities actually found at this colliery.

(3) The source of the X-ray abnormalities is unlikely to have been merely the general level of dustiness obtaining in underground work at this colliery, *apart from* any special occupational risk, as the total amount of underground work, excluding time spent as collier, shows no increase from normal to consolidation. The average numbers of years were: normals 8·1, reticulation 7·8, nodulation 5·8, major consolidation 8·5 (Table XIII). Nor do age and total duration of employment as such, i.e. the wear and tear of life, appear to have been important factors, since the average total working life and mean age of the normal, reticulation and nodulation X-ray categories were nearly the same (Table XIII).

(4) From the above (2) and (3), considered in conjunction with (1), it may be inferred that the greater part of the X-ray abnormalities attributable to dust found in such large numbers at this anthracite colliery not only could have been, but actually had been, contracted at the coalface during the occupation of collier, and that this applies to reticulation as well as to the changes termed consolidation.

The increasing prominence of the occupation of collier in the histories of these men as one passes from normal to consolidation is accounted for mainly by coal work at colliery, A.3 itself. The average number of years spent as collier at this mine by men with normal X-ray films was 2·8; by men with reticulation it was 8·7; by those with nodulation, 13·8; and by those with major consolidation, 16·4; the corresponding average periods spent as collier at other collieries were 2·8, 6·4, 3·5 and 3·6 years, i.e. a much smaller increase (Table XIII). The average periods spent as collier at colliery A.3, expressed as percentages of the total periods of employment as collier, also show an increase, being, respectively, 50, 58, 80 and 82. Finally, while over two-thirds of the men showing reticulation, and 90 per cent. of those with consolidation, had worked as colliers at this colliery itself for some period, only about half of the men in these two main categories had had any experience on the coal at any other colliery (figures not shown). From these results it may be concluded that the greater part of the X-ray changes, including both reticulation and those termed consolidation, developed during the occupation of collier, had been contracted at colliery A.3 itself and had not been imported from other collieries. The latter, taken together, appear to have contributed more towards the appearances of reticulation than to those of consolidation.

\*Length of work in hard headings and as fireman or shotsman both show some correlation with length of work as collier. The average period spent as collier by men (all X-ray categories) with no hard-heading experience was 9·3 years; by men with hard-heading experience of from 1 week to 1 year, it was 14·5 years; and by men with hard-heading experience of 1 year or more it was 12·3 years. Similarly, the average period spent as collier by men with no experience as fireman or shotsman was 9·7 years; by those with experience as fireman or shotsman of from 1 week to 10 years, it was 15·2 years; and by men with 10 or more years of this experience it was 13·4 years.



In a further analysis (not shown) on the lines of Table XIII, it was inferred that the greater part of the present X-ray abnormalities contracted during the occupation of collier at this mine had been contracted in one or both of two of the seams worked, i.e. Stanllyd and Little Vein. It was not possible to assess the relative contributions of these two seams, since the men's length of employment in one was closely correlated with that in the other; another analysis indicated, however, that the fact that, after similar total lengths of service, some colliers developed abnormalities, while others remained normal, was not due to difference in the relative periods worked in the two seams. The minor responsibility of the three other seams mined at one time or another at colliery A.3 follows from the small proportion of men that had worked in them for any considerable period; it does not necessarily imply any smaller inherent risk.

### C. INCIDENCE OF X-RAY ABNORMALITIES IN DIFFERENT COLLIERY OCCUPATIONS ACCORDING TO LENGTH OF EMPLOYMENT

In the preceding section the relative contributions of different occupations to the X-ray abnormalities found among colliery A.3 working population were assessed so far as possible, having regard to the complexity introduced by the frequency of mixed occupational histories. In the present section the analysis is of another type. Members of the colliery working population who had worked for different periods in a given occupation, and whose other colliery occupations had been such as could be presumed not to have contributed significantly to their dust risk, are here considered, and the incidences of the X-ray changes are then given for each length-of-employment group. By isolating the selected occupation in this way, its time-risk can be studied and compared with the risks of other occupations similarly treated.

#### (i) *Colliers*

In Table XV (p. 64) are set out the percentage-incidences of X-ray abnormalities among selected colliers from the colliery working population, grouped according to their total period on the coal. The basis of selection was that they should have been employed as collier (or assistant) for some period, and that any other colliery employment should have entailed a presumed low dust hazard.

In making the actual selection the procedure was to build up the numbers stage by stage. The first stage was on the stringent basis that the men should have had no occupation underground at a colliery other than as collier, and no set work on the surface screens; this produced only 48 men. The basis of selection was then broadened, in stages, so as to increase the total numbers, by allowing limited periods in certain other occupations; and the fourth stage of 177 men is given in Table XV. The extended basis seemed warranted since (1) at each stage up to this last the incidence of abnormalities of the newly-added men did not exceed that expected on the incidence shown in the previous stage, and (2) analyses, to be given later, of the time-risks of the added occupations suggested that, provided the periods were limited, the total risk was unlikely significantly to exceed that due to work as collier alone.

Analysis of the time-risk of the whole group of 177 selected colliers, as given in Table XV, Part (i), which includes men who had worked as colliers at other mines, shows a progressive increase of incidence and degree of X-ray changes with duration of employment at the coalface. In men with under five years experience, there were no abnormalities; at 5-10 years, there was reticulation only (in 24 per cent.); at 10-20 years, the incidence of reticulation increased (to 46 per cent.), and nodulation and coalescent nodulation appeared (in 15 and 5 per cent. respectively, making the group of major consolidation 5 per cent. and the whole consolidation group 20 per cent.); at 20-30 years, the incidence of reticulation decreased (to 30 per cent.), while that of nodulation and coalescent nodulation increased (to 35 and 11 per cent. respectively) and one case of massive shadows (3 per cent.) appeared (bringing major consolidation up to 14 per cent. and the whole consolidation group up to 49 per cent.); at 30-45 years, coalescent nodulation increased still further (to 23 per cent.), and

one case of multiple fluffy shadows (4 per cent.) appeared (bringing major consolidation up to 27 per cent.), but nodulation decreased (to 5 per cent.), so that the whole consolidation group showed a reduction (to 32 per cent. from 49 per cent.), though its incidence still was more than at 10-20 years (20 per cent.). The most notable points, therefore, appear to be: (1) no definite abnormalities under five years and no consolidation changes under 10 years; (2) reticulation, nodulation, coalescent nodulation, appearing in that order, with massive and multiple fluffy shadows developing late (though the absolute numbers in these latter categories were very small); (3) apparent transfer of part of reticulation to nodulation and of nodulation to coalescent nodulation; (4) decrease of the consolidation group as a whole in later years, presumably due to removal of affected men from the industry, with compensation.

Analysis of the time-risk of the sub-group of 91 "home-colliers," i.e. those of the main groups who had worked as colliers predominantly at this mine, is given in Table A.V, Part (ii), and shows very similar results to the above, allowing for the smaller number of employment period-groups used. The incidence of abnormalities, particularly of the more advanced changes, is here even higher. In the period-group 10-20 years, the total percentage with abnormal X-ray films was 72, composed of 41 per cent. reticulation and 31 per cent. consolidation; and in the period-group 20-45 years, as many as 77 per cent. had abnormal X-rays, composed of 26 per cent. reticulation, 49 per cent. consolidation, and 3 per cent. indefinite. The concentration of the X-ray abnormalities that occurred with the process of selection is shown by comparing their incidence among the entire underground working population of 396 men with that among the group of 91 home-colliers. The percentages for the underground workers were: reticulation, 26; consolidation, 19; indefinite, 3; total abnormal, 48 (Table XI). For the home-colliers the corresponding percentages (all periods of employment) were 31, 30, 1, and total abnormal, 62, i.e. higher figures.

The time-risk of the small sub-group of 31 "outside-colliers," i.e. those of the main group who had worked as colliers chiefly at other mines, is given in Table XV, Part (iii), and shows a contrast to that of the home-colliers of Part (ii). From a comparison between (1) the percentage-incidences (all periods) of X-ray abnormalities observed among the outside-colliers and (2) the calculated incidences expected for home-colliers having a similar distribution of numbers by period of service (Table XV, Part (iii), bottom two lines), it may be inferred that the incidence of abnormalities, particularly of consolidation, was probably lower among the outside-colliers than among the home-colliers.

A further comparison (tabulation not shown) was made between the percentage-incidences of X-ray abnormalities among two fresh groups selected for contrast from the colliery working population. The basis of selection was that the men should have been employed for some period as collier, and that this employment had been (A) 10 years or more at A.3 and less than 5 years altogether at other collieries, or (B) 10 years or more at other collieries and less than 5 years at A.3. In both cases the men were further grouped according to the total period spent as collier (10-20 years or 20-45 years). No account was taken of the nature of or time spent in any other occupations, so that the comparison was cruder than that in Table XIV, Parts (ii) and (iii); the numbers, however, were larger, group (A) comprising 113 and group (B) 60 men, all with 10 or more years service on the coal. This comparison confirmed the greater risk of the coal work at colliery A.3 as compared with the outside collieries *taken as a whole*, and again suggested that the latter had tended to produce reticulation without the same degree of transfer to the group of changes comprising consolidation.

The suggested lesser risk of coal work at the outside collieries, taken as a whole, in producing (among the present population of colliery A.3) the more advanced X-ray changes might well be related to the fact that, at least so far as the 31 men in Table XV, Part (iii), were concerned, these outside collieries happened to have been mainly either anthracite collieries with low or medium incidences of certified silicosis, or abandoned anthracite mines with unascertainable incidences—in contrast to the very high incidence of certified cases (1931-38) reported from colliery A.3. These "outside-colliers" of A.3, however, unlike its "home-colliers," tended either not to be on the coal at the time of examination, or to have had a gap in their employment as colliers after leaving their last outside-colliery. This introduces a possible fallacy into all the comparisons between the time-risks of collier's work at A.3 and at other collieries, based upon the present A.3 population, if it be true that changes due to dust can recede after cessation of contact with the exciting cause. In any case such a fallacy would not affect the conclusion on p. 53 (derived from Table XIII), namely, that the greater part of the X-ray changes actually found in the working population of colliery A.3, and contracted during the occupation of collier, had been initiated in this colliery itself and had not been imported. This latter conclusion is indeed supported by Table XV. For if, as may be presumed, the 92 abnormal

radiographs (categories *b-f*) attributable to dust of the 177 selected colliers (Part (i)) were due to work in this occupation, then the 55 abnormal X-rays of 91 of these men (Part (ii)) had almost certainly been produced at A.3 and not at outside collieries, whereas only the 8 abnormal X-rays of 31 of them (Part (iii)) had probably been produced at outside collieries rather than at A.3. The 29 abnormal films of the remaining 55 of the 177 selected colliers (employment as collier at A.3, 20-90 per cent. of total) could be accounted for by coal work either at A.3 or at other collieries.

### (ii) *Hauliers*

In Table XVI (p. 65) are set out the percentage-incidences of the X-ray abnormalities among 40 selected hauliers from the colliery working population, grouped according to their total periods as haulier or rider. The basis of selection was similar to that used for the selected colliers, namely, that some period of their employment should have been as haulier or rider and that any other colliery occupations should have entailed a presumed low dust hazard.

Analysis of the risks of this occupation is hampered by the small numbers in each length-of-employment group, which reduces the value of comparison with the corresponding period-groups of colliers of Table XV, Part (i). A comparison based upon the incidence of the whole group (all periods, unstandardised) is not entirely satisfactory, since the distribution of men in the different employment period-groups differs somewhat from that in Table XV, Part (i). To allow, so far as possible, for these differences in period-distribution, calculation was therefore made of the numbers and percentages of X-ray abnormalities that would have been expected amongst these hauliers if in each length-of-employment group they had had the same incidences as the corresponding employment group of the colliers. Comparison of these expected values with the corresponding observed values allows some assessment of the time-risk of the hauliers against the time-risk of the colliers.

It will be seen, in fact, from Table XVI that the observed incidences of total abnormalities, of reticulation, and of consolidation, in the hauliers were all considerably less than the expected incidences. The ratio of observed to expected was about one-half for reticulation and less than one-third for consolidation. So far as the scanty figures permit of inferences, these differences suggest that the occupation of haulier or rider entailed, for both types of X-ray change, an appreciably smaller risk than the occupation of collier. It should further be noted that the basis of selection permitted the hauliers to have spent a short period as collier, and this might account for some of the abnormalities observed among them. Indeed, all the 11 hauliers who had had no other dusty occupation showed normal X-rays, whereas the number of normals expected was only 3.8 (see footnote to Table XVI). Hence the estimate of the risks of the occupation of haulier provided by Table XVI errs, if anything, somewhat on the high side.

As already indicated, the above assessment of the relative time-risks of haulier and collier is based upon 40 of the former (Table XVI), of whom only 29 had been in this occupation for 10 years or more, and upon 177 of the latter (Table XV, Part (i)), of whom 120 had been on the coal for 10 years or more. In order to enlarge the populations at risk, a second comparison was made (Table XVII, p. 66). Two groups (including some individuals from the previous ones) were selected from the colliery working population on the following basis: (A) 10 years or more occupied as haulier or rider and less than 5 years as collier (44 men); or (B) 10 years or more as collier (at A.3 or elsewhere) and less than 5 years as haulier or rider (204 men). The men selected were further subdivided, group (A) according to total period as haulier or rider (10-20 or 20-45 years), and group (B) similarly according to total period as collier. No account was taken of the nature of or time spent in any other employment.

From Table XVII, comparison between the percentage-incidences of abnormalities in groups (A) and (B) for similar periods of service supports the evidence provided by Table XVI, that the time-risk of the occupation of haulier was considerably smaller than that of collier. It should be stressed that, while the incidences of abnormalities in these groups are capable of being used in this way for comparing the time-risks of the occupations of haulier and collier, neither group by itself indicates the absolute risk of one or other of

these occupations, since the occupational effect is too incompletely isolated. Better estimates of the absolute risks are provided by Tables XV and XVI, already discussed.

### (iii) *Repairers*

It is more difficult to isolate the effect of the occupation of repairer than that of haulier, owing to the more frequent adulteration of the industrial history of the former by other dusty employments. The only practicable means of assessing the risk was to compare a necessarily small group of repairers with colliers, in the following way. Men were selected from the colliery working population on the basis that their employment should have included 10 years or more as a repairer, borer or (special) ripper and less than 5 years as a collier; no account was taken of the nature of or time spent in any other employment. Even this procedure produced only 11 men, though their periods of service were substantial. In Table XVIII (p. 67) the absolute numbers of abnormalities in these selected repairers are compared with those that would have been expected among them at the rates incurred by colliers after similar lengths of employment.

The observed number of abnormalities among the repairers was, it will be seen, distinctly less than the expected number. For reticulation the ratio of observed to expected was three-fourths, and for consolidation the ratio was less than one-third. It must be stressed that the numbers involved are small and the comparison has no more than suggestive value; so far as conclusions can be drawn, however, these differences suggest that the occupation of repairer, like that of haulier, carried a smaller risk than the occupation of collier. Again, the differences are probably under-estimated, since in selection of the repairers no account was taken of the nature of, or the time spent in, occupations other than the limited period permitted as collier, and these additional occupations give an added risk. In particular, hard-heading work might have accounted for 3 out of the 4 abnormal cases (see footnote to Table XVIII). This table, therefore, cannot indicate the absolute risks of the occupation of repairer, but only provides an estimate—and a rough one—relative to colliers. It would not be justifiable, on the present information, to go further and assess the risk of the occupation of repairer relative to that of haulier.

### (iv) *Hard-heading man; Fireman or shotsman*

It is even more difficult to particularise the risks of hard-heading work, and of the occupations of fireman and shotsman, on account of the predominance of the other employment such men had usually experienced. Indeed, there was no pure hard-heading worker at colliery A.3.

In Table XIX (p. 68) is shown a comparison between hard-heading men and colliers, rather similar to that between repairers and colliers in Table XVIII. The basis of selection of the hard-heading men had, however, to be much wider, and consequently the method of calculating the expected numbers of abnormalities was different.

The basis of selection was that employment should have included one week or more in hard-heading work, less than 20 years as collier, no work as fireman or shotsman, and less than 5 years in other underground occupations taken together. The number thus selected was 37. In calculating the expected numbers, instead of using as basis colliers whose periods on the coal had been similar to the periods in hard headings *only* spent by the present series (the procedure adopted for the repairers), the basis of expectation was colliers who had been on the coal for similar periods to those for which the present series had been in hard headings *or themselves on the coal* (see footnote to table).

Table XIX thus represents a comparison between (1) the effect of a period of work on the coal *plus* a period also in hard headings, and (2) the effect of a period of work on the coal alone equal in length to the sum of the above two periods. The table gives no indication of the absolute risks of the occupation of hard-heading worker, since certain of the abnormalities among the

hard-heading men were probably caused by their own considerable experience as colliers.

From Table XIX it can be seen that the observed number of all abnormalities taken together among the selected hard-heading men was much the same as the expected number. The individual categories, however, showed considerable differences. The number observed with reticulation was less than half the number expected, while the number with consolidation was twice that expected. These results suggest that the time-risk of the occupation of hard-heading worker was greater than that of collier in the production of the changes termed consolidation, the excess being at the expense of a smaller amount of reticulation. The excess of consolidation may well have been greater than that indicated by the figures given, since the periods in hard-heading work were short (less than six years in all but three men—see footnote to table) and tended to be overweighted by the concomitant substantial periods spent as collier that were permitted on the wide basis of selection.

The above evidence that, for similar periods of service, hard-heading work probably carried a greater risk, as regards the more advanced X-ray abnormalities, than did even the occupation of collier, supports the evidence of the special danger of this work that was suggested by Tables XIII and XIV. These tables also suggested that the occupations of fireman and shotsman carried special risks. No further information could, however, be obtained upon the hazard of this latter occupational group, since it was found impossible to isolate its time-risk sufficiently even for comparisons with the occupation of collier, such as have been made above for hard-heading work.

It should be emphasised that, in spite of the probable high time-risk of hard-heading work, the effect manifested at colliery A.3 had not in actual fact been marked, because of the small total periods of service of most of the men who had been engaged in this occupation.

(v) *Surface screens workers ; Other surface workers*

The remaining occupations at colliery A.3 to be considered in this section are work upon the surface screens, and all other surface work taken together. In Table XX (p. 69) are given the incidences (in absolute numbers) of the various X-ray abnormalities among 47 selected screens workers from the colliery working population, grouped according to their total period on the screens. The basis of selection was similar to that used above for the colliers and hauliers, namely, that any other colliery employment should have entailed a presumed low dust hazard. Absolute numbers, and not percentages, are given, because of the small populations in the upper two period-groups, and because of the comparatively few abnormalities.

It is difficult to assess the risks of these selected screens workers, either absolutely or relatively to the selected colliers (Table XV, Part (i)) or hauliers (Table XVI), since only 10 out of the 47 men had worked on the screens for 20 or more years. Four out of these 10 men, however, showed abnormal X-ray films; and, while the single consolidation case and one of the three reticulation cases could be accounted for by occupations outside the industry, the other two reticulations are difficult to explain otherwise than by their actual work on the screens. The 37 men of less than 20 years service on the screens all showed normal films. On the whole, therefore, there is a suggestion that screens work was not without risk after prolonged exposure, but that for equivalent periods of service the risk was much less than that of the collier and probably less than that of the haulier.

In Table XXI (p. 70) are given the incidences (also in absolute numbers) of X-ray abnormalities among 57 selected men from the colliery working population who had been "non-screens" surface workers. The basis of selection and method of tabulation were similar to those in Table XX. It may be seen that all but one man showed normal films. The single abnormal was classed as indefinite,

and if this was caused by colliery work at all it could be accounted for by other occupations (see notes to table). From these results, work on the surface apart from the screens appeared to be without risk as to the two main X-ray changes, reticulation and consolidation, attributable to dust. This conclusion supports the inference drawn from Table XII (see p. 61), that films classed in these two categories have not been confused with appearances found with any degree of frequency in the ordinary male population of the neighbourhood. Otherwise there is no reason why these 57 surface workers, not exposed to significant concentrations of dust, should not have included some with films placed in one or other of these abnormal categories.

In Table V (p. 9), the rather inadequate data derived from rough occupational subdivisions of certified silicosis cases suggested that the chief source of certified silicosis in the anthracite mines, taken as a whole, was the collier, even though the incidence-rate was greater among hard-heading men than among any other occupational class, including that of collier (see p. 4). The relevant X-ray results at colliery A.3, if accepted as applicable to other anthracite mines, support both these suggestions. The collier would thus appear to constitute the main problem of chronic pulmonary disease in the anthracite area.

In concluding this chapter it should be recalled (see p. 32) that at A.3, as at most anthracite collieries where the coal is hand-cut and hand-filled on the longwall stalls system, it is the practice for colliers to do their own face-ripping at the stall roadheads, boring the holes, having the rippings shot down, clearing and packing, all on the coal-getting shift. They are therefore, in a sense, rippers as well as coal-getters, and this must be borne in mind in considering the implications of the present discussion.\*

#### SUMMARY OF CHAPTER 6

(1) The results of the X-ray examinations at colliery A.3, selected as an anthracite colliery with a high incidence of certified silicosis, have been considered in relation to occupation and length of service.

(2) Reticulation, and the changes grouped under the heading consolidation, were the main X-ray deviations from normal at this colliery. The extent of these abnormalities is shown by the fact that of the underground working population, 26 per cent. were classed in the reticulation category, and 19 per cent. as consolidation, i.e. nearly half their radiographs were abnormal. Among men who had worked mainly as colliers and at this mine predominantly ("home-colliers") the incidence of abnormalities was higher; and of those home-colliers who had worked 20 years or more on the coal the percentage classed as showing reticulation films was 26, while the percentage with consolidation was as high as 49, only 23 per cent. of this group showing normal films. The high incidence-rate of cases of certified silicosis reported from colliery A.3 (1931-38) is borne out by the high percentage-incidence of X-ray consolidation shown for its underground workers by the above figures.

(3) The greater part of the X-ray changes at colliery A.3 attributable to dust, including both reticulation and the changes grouped under the heading consolidation, had been contracted at the coalface during the occupation of collier. The occupations on the roadways, such as haulier and repairer, had contributed only to a minor extent to these abnormal changes. Even more important is the fact that the occupations of fireman or shotsman and hard-heading worker—

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\* The terms borer and ripper, used in connection with the occupational group of "repairer, borer or ripper," refer to special men who give their whole time to these operations; such men are relatively infrequent in the anthracite part of the coalfield.

dangerous as they might be—appeared to have had little responsibility for the changes actually met with at this colliery.

(4) Colliers showed a progressive increase in the incidence and degree of X-ray changes with duration of employment at the coalface. Under five years there were no definite changes; thereafter reticulation, nodulation, coalescent nodulation, appeared in that order; there was an apparent transfer of some of the reticulation to nodulation and of the latter to coalescent nodulation; massive and multiple fluffy shadows also seemed to be a late development.

(5) Comparison of the risks of colliers with those of other occupations suggested that both the work of haulier and that of repairer were less risky as to the production of reticulation and consolidation; that work on the surface screens had a still lower—though not negligible—risk; and that surface work apart from the screens was without risk as to these dust changes. On the other hand, the available figures suggested that hard-heading work was more risky in the production of consolidation than the occupation of collier, but that its effect was relatively unimportant at this colliery (see (3) above) simply because there was no pure hard-heading man and few men had done this type of work for any substantial period.

(6) The X-ray results obtained for the group of surface workers who had had little or no exposure to colliery dust show that the categories of reticulation and consolidation have not been confused with X-ray appearances occurring with any notable degree of frequency in the ordinary male population of this area.

(7) If the conclusions drawn from the X-ray examinations at colliery A.3—that, even though hard-heading work may be the more dangerous employment, the occupation of collier was the main source of the pulmonary abnormalities—be applicable to anthracite mines in general, then support is given to similar conclusions suggested (in Chapter 1) from crude occupational subdivisions of certified silicosis figures for the anthracite mines, taken as a whole. The collier appears to constitute the main problem of chronic pulmonary disease among anthracite miners.

(8) Since anthracite colliers usually do their own roof or floor face-ripping, this operation, as well as actual coal-getting, must be considered when seeking for the cause of the risks attached to the occupation of collier.

TABLE XI.

*Percentage incidence of X-ray abnormalities among the registered population, the total working population and the underground working population of colliery A.3*

<i>X-ray category.</i>	<i>Registered population.*</i>	<i>Total working population.</i>	<i>Workers underground.</i>
(a) Normal .. .. .	54.8	59.4	52.5
(b) Reticulation .. .. .	21.6	22.7	26.3
(c-f) Consolidation .. .. .	20.2	15.3	18.7
(c) Nodulation .. .. .	9.3	8.4	10.3
(d) Coalescent nodulation .. .. .	7.5	5.6	6.8
(e) Massive shadows .. .. .	2.1	1.2	1.3
(f) Multiple fluffy shadows .. .. .	1.2	0.2	0.3
(g-h) Indefinite .. .. .	3.4	2.6	2.5
All X-ray categories .. .. .	100.0	100.0	100.0
<i>Total numbers on which percentages are based.</i>	560	502	396

\* For definition of registered population, etc., see p. 33.

TABLE XII

*Age-distribution of underground workers, surface workers and total working population of colliery A.3, and number and incidence of X-ray abnormalities in these groups*

<i>Work at time of examination.</i> (1)	<i>Age-group.</i> (2)	<i>Number of men employed.</i> (3)	<i>Number with abnormal X-rays.*</i> (4)	<i>Per cent. with abnormal X-rays.*</i> (5)
(i) Underground .. ..	15-19	10	0 (0)	} 44.0 (26.9)
	20-39	206	95 (58)	
	40-64	163	85 (41)	} 51.7 (25.6)
	65-79	17	8 (5)	
	All ages	396	188 (104)	47.5 (26.3)
(ii) Surface: at some time underground.	15-19	1	0 (0)	} 10.0 (0.0)
	20-39	9	1 (0)	
	40-64	34	11 (8)	} 33.3 (22.2)
	65-79	2	1 (0)	
	All ages	46	13 (8)	28.2 (17.4)
(iii) Surface: never underground	15-19	6	0 (0)	} 0.0 (0.0)
	20-39	18	0 (0)	
	40-64	27	2 (2)	} 8.3 (5.6)
	65-79	9	1 (0)	
	All ages	60	3 (2)	5.0 (3.3)
(i-iii) Total working population	15-19	17	0 (0)	} 38.4 (23.2)
	20-39	233	96 (58)	
	40-64	224	98 (51)	} 42.9 (22.2)
	65-79	28	10 (5)	
	All ages	502	204 (114)	40.6 (22.7)

\* Unbracketed numbers and percentages refer to men in all abnormal X-ray categories, i.e. (b-h); bracketed figures refer to the reticulation category alone, i.e. (b).



TABLE XIII

*Average duration of employment (years), in different occupations, of men belonging to various X-ray categories at colliery A.3 (colliery working population, total 502 men)*

Occupation.	X-ray category						All X-ray categories.
	(a) Normal.	(b) Reticulation.	(c) Nodulation.	(d-f) Major consolidation.†	(e-f) All consolidation.	(g-h) Indefinite.	
(i) Collier* : Total.. ..	5.6	15.1	17.3	20.0	18.6	13.6	10.0
<i>At A.3</i> .. ..	2.8	8.7	13.8	16.4	15.0	8.1	6.2
<i>Elsewhere</i> .. ..	2.8	6.4	3.5	3.6	3.6	5.5	3.8
(ii) Hard-heading man ..	0.20	0.18	0.45	‡1.48	0.92	0.17	0.30
(iii) Repairer, borer or ripper ..	1.7	2.9	1.2	1.9	1.5	4.7	2.0
(iv) Fireman or shotsman ..	0.3	0.7	0.8	2.6	1.6	0.7	0.6
(v) Haulier or rider ..	3.2	2.7	3.0	1.8	2.5	1.8	3.0
(vi) Other underground work ..	2.7	1.3	0.4	0.7	0.5	4.6	2.1
(ii-vi) Total underground work excluding collier.	8.1	7.8	5.8	8.5	7.0	12.0	8.0
(i-vi) Total underground work ..	13.8	23.0	23.1	28.4	25.5	25.6	18.0
(vii) Surface work on screens ..	1.4	1.4	0.3	1.4	0.8	1.5	1.3
(viii) Other surface work ..	4.6	0.5	0.9	0.1	0.5	4.0	3.1
(vii-viii) Total surface work ..	6.1	1.9	1.2	1.5	1.3	5.6	4.4
(ix) Outside coal industry§ ..	6.4	3.3	2.7	2.7	2.7	10.4	5.2
(i-ix) Total working life ..	26.2	28.2	27.0	32.6	29.5	41.5	27.6
<i>Mean age</i> .. ..	40.0	41.8	40.5	45.8	42.9	54.2	41.2
<i>Number of men</i> ..	298	114	42	35	77	13	502

\* Including assistant collier.

† Comprising categories (d) coalescent nodulation, (e) massive shadows and (f) multiple fluffy shadows.

‡ With omission of 1 man (period 27.5 years), figure would be 0.71 years.

|| With omission of 1 man (period 27.5 years), figure would be 0.57 years.

§ Occupations other than at collieries; and war service, sickness or unemployment.

TABLE XIV

Percentage-distribution of men belonging to the main abnormal X-ray categories at colliery A.3 (colliery working population, total 502 men) according to duration of employment in certain occupations

Occupation.	Percentage that had been in stated occupation for given period.				
	Never.*	1+years.	5+years.	10+years.	20+years.
<i>X-ray category (b) ; Reticulation (114 cases).</i>					
Collier or assistant .. ..	8.8	90.4	84.2	67.5	30.7
Hard-heading man .. ..	82.5	7.9	0.0	0.0	0.0
Repairer, borer or ripper .. ..	61.4	32.5	20.2	9.6	4.4
Fireman or shotsman .. ..	92.1	7.9	4.4	3.5	0.0
Haulier or rider .. ..	66.7	26.3	14.0	11.4	4.4
Surface screens .. ..	67.5	22.8	5.3	3.5	3.5
<i>X-ray categories (c-f) ; All consolidation† (77 cases).</i>					
Collier or assistant .. ..	5.2	92.2	88.3	84.4	46.8
Hard-heading man .. ..	66.2	19.5	5.2	1.3	1.3
Repairer, borer or ripper .. ..	71.4	20.8	11.7	3.9	1.3
Fireman or shotsman .. ..	92.2	7.8	7.8	6.5	5.2
Haulier or rider .. ..	68.8	28.6	11.7	7.8	6.5
Surface screens .. ..	64.9	16.9	1.3	1.3	1.3

\* The percentages in columns "1 +", "5 +", "10 +" and "20 + years" are cumulative to the right, i.e. each includes those to the right of it. The sum of the percentages in columns "Never" and "1 + years" is short of 100 by the percentage (not shown) that had been in the stated occupation for under 1 year. The difference (also not shown) between 100 and the percentage in column "Never" gives the percentage that had been in the stated occupation for any period.

† Comprising categories (c) nodulation, (d) coalescent nodulation, (e) massive shadows and (f) multiple fluffy shadows.

TABLE XV  
Percentage-incidence, according to length of service, of X-ray abnormalities among selected colliers at colliery A.3\*

Occupation.	Total period as collier. (Years)	Percentage in each X-ray category.									All X-ray categories.	Mean period as collier. (Years)	Mean age. (Years)	
		(a) Normal.	(b) Reticulation.	(c) Nodulation.	(d) Coalescent nodulation.	(e) Massive shadows.	(f) Multiple fluffy shadows.	(d-f) Major consolidation.	(e-f) All consolidation.	(g-h) Indefinite.				
(i) All selected colliers† (177 men).	Under 5	100.0	—	—	—	—	—	—	—	—	100.0 (24)§		23.5	
	5-10	75.8	24.2	—	—	—	—	—	—	—	100.0 (33)		27.1	
	10-20	34.4	45.8	14.8	4.9	—	—	4.9	19.7	—	100.0 (61)		33.3	
	20-30	21.6	29.7	35.1	10.8	2.7	—	13.5	48.6	—	100.0 (37)	41.8		
	30-45	22.7	36.4	4.5	22.7	—	4.5	27.2	31.8	9.1	100.0 (22)	52.6		
	All periods ...	46.9 (33)§	31.1 (55)	13.0 (23)	6.8 (12)	0.6 (2)	0.6 (1)	8.0 (14)	20.9 (37)	1.1 (2)	100.0 (177)	34.9		
(ii) "Home-colliers" (91 men).	Under 10	75.0	25.0	—	—	—	—	—	—	—	100.0 (24)	4.5	22.3	
	10-20	28.1	40.6	21.9	—	—	—	9.4	31.3	—	100.0 (32)	14.9	32.7	
	20-45	22.9	25.7	28.6	—	—	—	20.0	48.6	2.9	100.0 (35)	25.8	41.6	
	All periods ...	38.5 (36)	30.8 (28)	18.7 (17)	—	—	—	11.0 (10)	29.7 (27)	1.1 (1)	100.0 (91)	16.3	33.4	
(iii) "Outside-colliers" (31 men).	Under 10	89.5	10.5	—	—	—	—	—	—	—	100.0 (19)	4.4	27.4	
	10-20	71.4	28.6	—	—	—	—	—	—	—	100.0 (7)	14.3	36.4	
	20-40	20.0	60.0	—	—	—	—	20.0	—	—	100.0 (5)	28.4	52.2	
	All periods.	Observed	74.2 (23)	22.6 (7)	—	—	—	—	8.2 (1)	—	—	100.0 (31)	10.6	33.4
		Expected‡	58.1 (17.4)	28.7 (8.9)	—	—	—	—	14.8 (4.6)	—	0.3 (0.1)	100.0 (31.0)	—	—

\* Basis of selection: Collier some period; never hard-heading worker (more than 1 week), fireman nor shotsman; other underground occupations together less than 5 years; set work on surface screens less than 5 years.

† Part (i) includes all the selected colliers (177 men), whether their employment as collier had been at colliery A.3 or at any other mine.

‡ Part (ii) is confined to "home-colliers" (91 men), i.e. to those of the 177 selected colliers who satisfied the following additional criterion: that 90 per cent. or more of their total employment as collier had been spent at colliery A.3 itself, and that they were either colliers at the time of examination (the great majority) or had been so until recently (up to at most 3 years before).

§ Part (iii) is confined to "outside-colliers" (31 men), i.e. to those of the 177 selected colliers who satisfied the following additional criterion: that 20 per cent. or less of their total employment as collier had been spent at colliery A.3.

¶ Expected for home-colliers if the distribution in period-groups were similar to that of the present outside-colliers. The number expected in each X-ray category was obtained by applying the percentages in that category for different periods spent as collier (under 10, 10-20 and 20-45 years) among the home-colliers of Part (ii) to the populations (all X-ray categories) for the same periods in the present Part (iii) of the table.

‡ The figures in brackets and italics below, or at the side of, certain percentages are the absolute numbers.

Expanded data.—Forty-eight of the 177 colliers in Part (i) had not been employed in any other colliery underground occupation or in set work on the surface screens. Their percentage-incidences, all periods, were: normal, 41.7; reticulation, 27.1; consolidation, 31.2 (mean age 36.3 years); and for the 25 men in the 20+ period-group alone were: normal, 16.0; reticulation, 28.0; consolidation, 56.0 (mean age 45.6 years). Of the 48 men, 13 had also worked in non-colliery occupations, but in only 2 were these occupations considered to carry a dust hazard, and in both cases the X-rays were normal.

TABLE XVI

Percentage-incidence, according to length of service, of X-ray abnormalities among 40 selected hauliers at colliery A.3\*†

Total period as haulier or rider. (Years)	Percentage in each X-ray category.				All X-ray categories.	Mean period as haulier or rider. (Years)	Mean age. (Years)	
	(a) Normal.	(b) Reticulation.	(c-f) Consolidation.	(g-h) Indefinite.				
Under 10 .. .. .	100.0	—	—	—	100.0 (11)‡	3.5	25.9	
10-20 .. .. .	72.7	27.3	—	—	100.0 (11)	14.8	36.6	
20-40 .. .. .	66.7	16.7	16.7	—	100.0 (18)	26.8	49.0	
All periods.	Observed ..	77.5 (31)‡	15.0 (6)	7.5 (3)	— (0)	100.0 (40)	17.1	39.3
	Expected§ ..	45.0 (18.0)‡	28.5 (11.4)	25.5 (10.2)	1.0 (0.4)	100.0 (40.0)		

\* Basis of selection: Haulier or rider some period and in this occupation at time of examination (the great majority) or until recently (up to at most 3 years before); never a hard-heading worker (more than 1 week), fireman nor shotsman; other underground occupations (including that of collier) together less than 5 years; set work on surface screens less than 10 years (all but 2 men had worked less than 5 years on the screens).

† Five men in this table are included also in Table XV, Part (i).

‡ The figures in brackets and italics below, or at the side of, certain percentages are the absolute numbers.

§ Expected for men who had been colliers for similar periods to those for which the present series had been hauliers. The number expected in each X-ray category was obtained by applying the percentages in that category for different periods spent as collier (under 5, 5-10, 10-20, 20-30 and 30-45 years) among the men in Table XV, Part (i), to the populations (all X-ray categories) in the present table that had spent corresponding periods as haulier or rider.

*Expanded data.*—(1) Eleven of the 40 hauliers had not been employed in any other colliery underground occupation or in set work on the surface screens. Their periods as haulier or rider were: under 10 years, 1 man; 10-20 years, 5 men; 20 or more years, 5 men. All these 11 men showed normal X-rays; on the collier basis used, only 3.8 would have been expected to be normal.

(2) For 39 of the 40 hauliers the entire period of their employment in this occupation had been in anthracite mines, the remaining man having spent 40 per cent. of his at various steam coal collieries. For 30 of the 39 men 90 per cent. or more, and for 36 of them 50 per cent. or more, of their total employment as haulier had been spent at colliery A.3 itself. Hence the group of selected hauliers can be considered as anthracite hauliers, and, in the main, as "home-hauliers" of A.3.

TABLE XVII

The percentage-incidence, according to length of service, of X-ray abnormalities among (A) 44 men at colliery A.3 who had been occupied as haulier or rider for a substantial period and as collier for only a short period, and (B) 204 men at this colliery who had been occupied as collier for a substantial period and as haulier or rider for only a short period\*

Total period as haulier or rider— Group (A), or as collier— Group (B). (Years)	Group.	Percentage in each X-ray category.				All X-ray categories.	Mean age. (Years)	Mean period as haulier or rider— Group (A), or as collier— Group (B). (Years)
		(a) Normal.	(b) Reticu- lation.	(c-f) Consoli- dation.	(g-h) Indefinite.			
10-20	(A) { Haulier or rider 10+ years Collier — 5 years }	66.7	28.6	4.8	—	100.0 (21)†	41.4	
	(B) { Collier 10+ years Haulier or rider — 5 years }	37.2	36.3	23.9	2.7	100.0 (113)	37.1	
20-45	(A) { Haulier or rider 10+ years Collier — 5 years }	69.6	17.4	13.0	—	100.0 (23)	50.4	26.3
	(B) { Collier 10+ years Haulier or rider — 5 years }	20.9	37.4	37.4	4.4	100.0 (91)	47.8	27.1

\* This table includes some cases analysed also in Tables XV and XVI.

† The figures in brackets and italics are the absolute numbers.

TABLE XVIII

*Observed and expected numbers of X-ray abnormalities among 11 men at colliery A.3 who had been occupied as repairer, borer or ripper for a substantial period and as collier for only a short period*

Occupation.		Number in each X-ray category.				All X-ray categories.
		(a) Normal.	(b) Reticulation.	(c-f) Consolidation.	(g-h) Indefinite.	
Repairer, borer or ripper 10+ years; collier —5 years.	Observed .. ..	7	3	1	—	11
	Expected* .. ..	2.8	4.2	3.5	0.5	11.0

\* Expected for men who had been colliers for similar periods to those for which the present series had been repairers. The number expected in each X-ray category was obtained by applying the percentages in that category for different periods spent as collier (10-20, 20-30 and 30-45 years) among the men in Table XV, Part (i), to the populations (all X-ray categories) in the present table that had spent corresponding periods as repairer, borer or ripper.

*Expanded data.*—The lengths of the periods spent as repairer, borer or ripper were : 11, 17, 17, 24, 27, 30, 33, 39, 40, 41, 45 years. None had been a fireman-shotsman. Only two had worked as colliers (0.5 and 2 years). Five had worked in hard headings among their other occupations, viz., 2 normals (3 and 5 years), 2 reticulations (0.5 and 1 year) and the single consolidation case (6.5 years). Six men had been neither colliers nor hard-heading workers (5 normal, 1 reticulation).

TABLE XIX

*Observed and expected numbers of X-ray abnormalities among 37 men at colliery A.3 who had been occupied in hard-heading work, whether or not they had also been employed as colliers*

Occupation.		Number in each X-ray category.				All X-ray categories.
		(a) Normal.	(b) Reticulation.	(c-f) Consolidation.	(g-h) Indefinite.	
Hard-heading work 0.02+ years and collier -20 years.	Observed .. ..	20	5	11	1	37
	Expected* .. ..	18.0	13.4	5.5	0.1	37.0

\* Expected for men who had been colliers for similar periods to those for which the present series had been hard-heading workers or colliers. The number expected in each X-ray category was obtained by applying the percentages in that category for different periods spent as collier (under 5, 5-10, 10-20 and 20-30 years) among the men in Table XV, Part (i), to the populations (all X-ray categories) in the present table whose periods spent as hard-heading worker plus periods spent as collier were of corresponding length.

*Expanded data.*—The lengths of the periods spent in hard-heading work were less than 1 year in 15 out of the 37 men, less than 3 years in 31, and less than 6 years in 36 of them.

TABLE XX

Number, according to length of service, of X-ray abnormalities among 47 selected surface screens workers at colliery A.3\*†

Total period on screens. (Years)	Number in each X-ray category.				All X-ray categories.	Mean age. (Years)
	(a) Normal.	(b) Reticulation.	(c-f) Consolidation.	(g-h) Indefinite.		
Under 10 . . . .	31	—	—	—	31	31.3
10-20 .. .. .	6	—	—	—	6	46.7
20-45 .. .. .	6	3	1	—	10	67.7
All periods .. ..	43	3‡	1§	—	47	38.9

\* Basis of selection : Set work on surface screens, some period ; never a hard-heading worker (more than 1 week), fireman nor shotsman ; other underground occupations (including that of collier) together less than 5 years.

† This table includes some cases analysed also in Tables XV, XVI and XXI.

‡ Other occupations of these 3 cases had been : (1) Stonedresser at flour mills (16 years) and gardener ; (2) labourer (2 years) and grocer and fruiterer ; (3) collier (3 years) and farmer.

§ Other occupation had been mason (13 years).

*Expanded data.*—Thirty-five of the 47 screens workers had not been employed in any colliery underground occupation. The results of these were : Under 10 years, 21 men (all normal) ; 10-20 years, 5 men (all normal) ; 20-45 years, 9 men (6 normal, 2 reticulation, 1 consolidation (massive shadow)) ; all periods, 35 men (32 normal, 2 reticulation, 1 consolidation).



TABLE XXI

*Number, according to length of service, of X-ray abnormalities among 57 selected non-screens surface workers at colliery A.3\*†*

<i>Total period on surface work other than screens. (Years)</i>	<i>Number in each X-ray category.</i>				<i>All X-ray categories.</i>	<i>Mean age. (Years)</i>
	<i>(a) Normal.</i>	<i>(b) Reticulation.</i>	<i>(c-f) Consolidation.</i>	<i>(g-h) Indefinite.</i>		
Under 10 ..	25	—	—	—	25	27.7
10-20 .. ..	11	—	—	—	11	39.1
20-45 .. ..	20	—	—	1	21	55.3
All periods ..	56	—	—	1	57	40.1

\* Basis of selection: Surface work other than on screens, some period; set work on screens, less than 5 years; never a hard-heading worker (more than 1 week), fireman nor shotsman; other underground occupations (including that of collier) together less than 5 years.

† This table includes some cases analysed also in Tables XV, XVI and XX.

*Expanded data.*—Twenty-seven of the 57 men had not been employed in any set work on the screens or in any colliery underground occupation. Their periods in surface work other than on the screens were: Under 10 years, 10 men; 10-20 years, 3 men; 20-45 years, 14 men. All these 27 men showed normal X-ray appearances.

## CHAPTER 7

**Incidence of X-ray Abnormalities attributable to Dust among Colliers in representative Anthracite and Non-Anthracite Mines in Different Parts of the South Wales Coalfield (based upon Findings at 16 Collieries)**

In the previous chapter pulmonary X-ray changes attributable to dust in one anthracite colliery (A.3) were considered in relation to occupation and length of service. It was found that both the abnormality termed reticulation and the changes grouped under the heading consolidation occurred mainly among colliers; that their incidence varied with length of exposure at the coalface; and that reticulation was the earliest change to appear. The present chapter is concerned with the incidence of these X-ray changes in different parts of the South Wales coalfield, and since the occupational class most affected in anthracite mines appeared to be the collier, it is the incidence among colliers at the different mines that is mainly considered. In other words, whereas in Chapter 6 various occupational classes were considered in one class of colliery (anthracite), in this chapter one occupational class (collier) will be considered in different classes of mine (anthracite and non-anthracite).

The X-ray examinations considered are of selected colliers at 16 collieries (including colliery A.3), representative of various aspects of the South Wales coalfield; the data from 15 of them (i.e. all but colliery A.3) were obtained during the second stage of the medical survey. The whole group comprised eight anthracite and eight non-anthracite collieries; of the latter, five were steam coal and three were bituminous coal mines. The anthracite collieries were A.1-A.8 (A.1-A.4 mining high rank, and A.5-A.8 mining lower rank, anthracite). The steam coal collieries were S.1-S.5 (S.1-S.3 mining carbonaceous and S.4 and S.5 semi-bituminous coal). The bituminous coal collieries were B.1-B.3. The colliers examined at these mines were men selected from their respective colliery "working populations" who had been engaged for different periods in this occupation. Briefly, the basis of selection was that a man's employment as collier should have been predominantly at the colliery under examination, that he should be in this occupation at the time of examination or have been so until recently, and that any other colliery occupations he had had should have entailed a presumed low dust hazard; these selected colliers will be described as "home-colliers" of the different mines (see p. 38). In this way a total of 1,496 home-colliers, selected from the 16 collieries, was obtained for examination.\*

In Tables XXII and XXIII (pp. 90 and 91-94) the selected home-colliers from each mine are grouped according to the total period employed on the coal; the percentage-incidences of the various X-ray appearances are given for each such period-group. Table XXII shows the *average* percentage-incidences for each of the three colliery groups, anthracite, steam coal and bituminous coal, while Table XXIII gives the incidences at each of the 16 individual mines.

Certain remarks must be made about these tabulations:—

(1) In Table XXII the percentages are weighted averages, the weights being proportional to the total numbers of men from the individual collieries in the particular period-group. The use of unweighted averages (i.e. averages of the *rates* at the different mines) would, however, have made little difference for the purpose of comparison of the three colliery groups. It will be noted that only in the 20+ years period-group are the averages derived from all the mines in each group. In the under 10 years period-group they came from five of the eight anthracite collieries, and from only one each of the five steam coal and three bituminous coal mines. Hence comparisons for this period-group are less reliable than for the older groups.

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\* This total includes 104 home-colliers extracted from the population examined at colliery A.3. This group is the group of 91 home-colliers of Table XV (p. 64), Part (ii), enlarged by the addition of 13 men who satisfied the same criteria as the other 91 except that each had worked in hard headings for a period altogether not exceeding one year.

(2) In Table XXIII it will be seen that in some collieries the numbers of men in the 20+ years group are small; percentages based on them (in brackets) must therefore be accepted with caution.

(3) Just as, for convenience, collieries were divided arbitrarily into those with high, medium or low incidences of certified silicosis (Tables IV and VI, pp. 8 and 43-46), so an arbitrary classification of the incidence of radiological abnormalities is desirable. The method has been to provide for each of the 16 collieries a single figure for the relative incidence of each X-ray category. The method of obtaining it for a given mine was as follows. The percentage-incidence of each X-ray category was first calculated for the eight anthracite mines, taken as one group, for men of under 10, 10-20 and 20 or more years of employment as collier. These three rates were then applied to the total numbers of men of each length of employment who were examined at the given mine. The results show how many men at this mine would have been expected to belong to a particular X-ray category if the mine in question had had the same incidence-rates as the whole anthracite group. The number actually observed at the mine in each X-ray category, expressed as a percentage of this calculated expectation, shows its position relative to the other collieries similarly treated. In other words, the anthracite group has been used as a standard against which to weigh the experiences of each separate mine, anthracite or non-anthracite.

In Table XXIII (columns (11) and (12)) the figures for observed per cent. of expected for the categories of "all consolidation," and of "all abnormal" (i.e. including reticulation), are given; and the eight anthracite, five steam coal and three bituminous coal collieries are placed—in Parts (i), (ii) and (iii)—in order of decreasing incidence of X-ray abnormalities as determined by their consolidation rating. (It may be noted that were the arrangement to follow the rating of all abnormal (column (12)), instead of that of consolidation alone (column (11)), the order of tabulation would be very similar.) On the basis of these figures of consolidation observed per cent. of expected, the collieries have been divided arbitrarily into four classes of incidence of X-ray abnormality (Table XXIII, column (13)): "high," consolidation observed 150 or more per cent. of expected; "medium," 150-75 per cent. of expected; "low-medium," 75-25 per cent. of expected; and "low," consolidation observed less than 25 per cent. of expected.

The figures in Tables XXII and XXIII, and in further tables developed from these, will now be discussed from various aspects.

#### A. THE INCIDENCE OF X-RAY ABNORMALITIES AMONG "HOME-COLIERS" IN THE 16 COLLIERIES TAKEN IN GROUPS AND AS INDIVIDUAL UNITS

Table XXII shows considerable differences between the average incidences of X-ray abnormalities among the home-colliers in the three groups of collieries. For each of the three employment periods, the percentage of men in the normal category was highest in the bituminous, intermediate in the steam coal, and lowest in the anthracite group. Conversely, the percentages of men in the categories of nodulation, major consolidation, and all consolidation together, were highest in the anthracite, intermediate in the steam coal, and lowest in the bituminous group—in the last of which there were observed no cases of major consolidation. For reticulation a contrast similar to that for consolidation is shown for the two younger employment periods; but in the 20+ years period-group, although the incidence was, as for the younger periods, higher in the steam coal than in the bituminous group of collieries, it was intermediate, instead of being highest, in the anthracite group. This reduction in the last group, as will be shown later, was probably due to the transfer of reticulation to nodulation at later ages in some of the higher-incidence anthracite collieries.

Table XXIII, columns (11) and (12), shows that the average group-figures of Table XXII naturally conceal variations in incidence of X-ray abnormalities in the individual mines. This variation was considerable within the anthracite group, less marked within the steam coal group, and only slight within the bituminous group. In the anthracite group (Table XXIII, Part (i)), the arbitrary radiological basis of division already mentioned (column (13)) gives three mines of high incidence (and their incidences would have been even higher if collier compensation cases had been included), two of medium incidence, one of low-medium incidence, and two of low incidence. A wide range of variation

is thus evident. In the steam coal group (Table XXIII, Part (ii)), two mines are classed as medium incidence, two as low-medium, one as low incidence, and there are no high incidence mines. Finally, in the bituminous group (Table XXIII, Part (iii)), one mine is classed as low-medium incidence, two as low incidence, and there are no high or medium incidence mines.

Columns (3)–(8) of Table XXIII show the variations in incidence of X-ray abnormalities in greater detail. Particularly striking are the contrasts between the high incidence anthracite mines A.1 and A.3, the low incidence anthracite mines A.2 and A.5, and the low incidence bituminous mines B.3 and B.2. In more detail, there was at collieries A.1 and A.3, taking all periods into consideration, a high incidence both of reticulation and consolidation; at colliery A.2 there was a considerable, and at colliery A.5 a moderate, incidence of reticulation, but in these mines consolidation was respectively very rare and absent; at collieries B.3 and B.2 reticulation was infrequent and consolidation again very rare or absent.

Throughout the 16 collieries the variation in incidence is apparently less for reticulation than for consolidation, for reasons which will be evident when the development of these various changes is considered later. For comparison of consolidation incidence the older employment period-groups are probably the best, more especially the 10–20 years period, on account of the larger total numbers of men examined. It may be seen that the incidences of the two main subdivisions of consolidation, viz. nodulation and major consolidation, vary similarly from one mine to another. For comparison of reticulation incidence, the under 10 and 10–20 years employment period-groups are probably the best. It may be seen that at these two periods the reticulation incidences at collieries A.2 and A.5 were the lowest among the anthracite mines, and at B.3 and B.2 were the lowest among all the 16 collieries, thus showing similar contrasts to the consolidation incidences.

To summarise this section (A), there is a strong twofold contrast in incidence of X-ray abnormalities, firstly, between the anthracite and the bituminous collieries as a whole, and secondly, between the individual anthracite collieries.

#### B. THE DIFFERENCES IN INCIDENCE OF X-RAY ABNORMALITIES AT THE 16 COLLIERIES CONSIDERED IN RELATION TO CERTAIN NATURAL FACTORS

Having thus found considerable variation in the incidence of X-ray abnormalities from one individual colliery to another, it is clearly important to see whether these differences can be correlated with such broad natural characteristics as the geographical position of the collieries, the rank of the coal mined, the depth and humidity of the underground workings, and the position in the coal series of the seams worked. Consideration of their possible relation to extrinsic or artificial factors, such as systems of work or the use of blasting, is deferred to Chapter 11; while more detailed contrasts in the composition of the coal and rock strata, dusts, etc., will be considered in the environmental part of the field survey, which is to form the subject of a separate publication.

##### (i) *Geographical position of the collieries*

The geography of the South Wales coalfield was outlined in Chapter 2, and the position of the present 16 collieries was shown in Fig. 1 (p. 11). This figure is reproduced in the present chapter (Fig. 11), without the indications of the types of coal, but with the addition of the relative incidence of X-ray abnormalities (from Table XXIII, column (13)) found at each of the collieries. Inspection of Fig. 11 suggests that there is a decreasing incidence of radiological changes attributable to dust as one passes across the coalfield from west to east, but that the change is gradual and continuous, with no sharp demarcation. Moreover, there are considerable differences in incidence even within the western part of the field. Since, as pointed out in Chapters 1 and 2, the anthracite mines are situated in the western part of the coalfield and the bituminous mines towards its eastern part, the

decreasing incidence of radiological abnormalities among coalface workers across the field is likely to be due to the distribution of the types of coal, rather than to geographical situation as such. This relationship with coal rank must now be studied, so far as the present small sample permits.

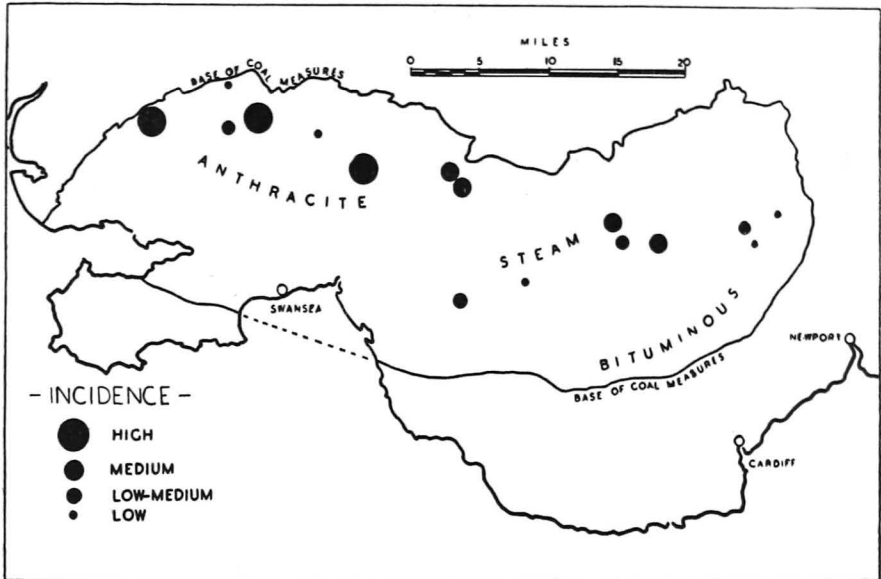


FIG. 11.—Map of the South Wales coalfield, showing the relative incidence of X-ray abnormalities at each of the 16 collieries (cf. Fig. 1, p. 11).

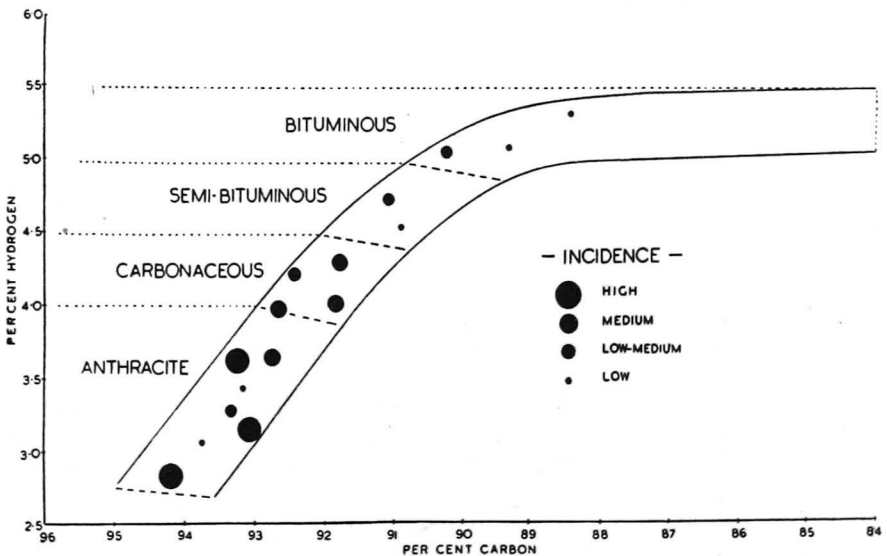


FIG. 12.—Relation between rank of coal and relative incidence of X-ray abnormalities at the 16 collieries (cf. Fig. 3, p. 16).

(ii) Rank of the coal mined

The great excess of the incidence-rate of certified silicosis in the anthracite mines of South Wales over that in the non-anthracite mines, which was demonstrated in Chapter 1 (Tables III-V), itself suggests a rough association between

incidence of pulmonary change and rank of coal mined. This association is supported by the differences in average percentage-incidence of radiological abnormalities among home-colliers in the three groups of collieries—anthracite, steam coal and bituminous (Table XXII)—but the use of the 16 collieries as individual units allows it to be examined in greater detail. In Table XXIV (p. 94) these collieries are placed in descending order of coal rank (following Fig. 3, p. 16, and Table VI, p. 43), and the class of incidence of X-ray abnormalities is set against each colliery. In addition, the estimated depth and reputed moisture conditions of the workings at each colliery are shown (from Table VI), because these characteristics were factors leading to the selection of the collieries for examination. Furthermore, in order to exclude the influence of a possible second variable, the two collieries whose face conditions were reputedly damp rather than dry are entered in italics. In Fig. 12 the comparison between coal rank and incidence of X-ray abnormalities is made diagrammatically. This figure is a reproduction of Fig. 3 of Chapter 2 (p. 16), giving the South Wales "coal band," but with the incidence classes of the 16 collieries shown at the appropriate carbon-hydrogen horizons.

From Table XXIV and Fig. 12 it will be seen that the incidence of radiological abnormalities tends to decrease from high incidence at the anthracite to low incidence at the bituminous end of the scale of rank. This tendency is more clearly shown if the two damp mines in the anthracite group, both of which had low incidences, are disregarded. Further support is therefore provided for the hypothesis that differences in rank of the coal mined is one important factor to which the differences in incidence of radiological abnormalities are related. It should be noted that the change in incidence of abnormalities is gradual as one passes from high rank anthracite through lower rank anthracite, carbonaceous and semi-bituminous, to the lowest rank of the coalfield, namely, bituminous coal. As with the relation to geographical situation of the collieries, there is no sharp line of demarcation in incidence.

Although a relationship is thus suggested between incidence of pulmonary abnormality and rank of coal, it would obviously be unwise to infer that it is differences in the coal itself that *produce* the differences in incidence, or, indeed, that the coal itself necessarily has any causative role in the pulmonary abnormalities. Some other variable, correlated both with rank of coal and with incidence of pulmonary abnormalities—such as the composition of the adjacent rock strata or the quality or quantity of the air-borne coalface dust—might be the responsible factor.

### (iii) *Depth and atmospheric humidity of the underground workings*

Differences in rank of coal could not account for the wide variations in incidence of radiological abnormalities within the anthracite group itself, and the preceding subsection suggests the advisability of enquiring further as to a possible relationship between differences in this incidence and differences in moisture conditions of the underground workings. Measurements of the relative humidity of the atmosphere (by Dr. T. Bedford and Dr. C. G. Warner) are used for the comparison, but the estimated depths of the workings are also included, since shallow mines are in general damp, and deep mines are usually dry.\* To remove as far as possible the influence of the rank of coal, the examination is limited to comparisons within the anthracite group, since it had been made a general condition in the

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\* Relative humidity is used because it is the nearest measure of the sensation of dampness. It may be noted that as the temperature falls in these mines the relative humidity increases, thus accounting for the correlation between working depth and relative humidity. (The influence of moisture conditions upon dust concentration will be discussed in the report upon environmental studies by Drs. Bedford and Warner.)

selection of the non-anthracite mines that each should be relatively dry and deep on the classification employed, so as to be comparable with those anthracite mines selected on account of their high incidence of certified silicosis (see p. 38).

In Table XXV (p. 95) the eight anthracite collieries are therefore placed in order of decreasing incidence of X-ray abnormalities among home-colliers, and the working depths and the average relative humidities at the coalface (the latter for only six of them) are shown alongside. Although, evidently, a sample of eight observations is too slender a basis to support any great weight of conclusions, from this table it appears that there is some correlation between the incidence of X-ray abnormalities and the depth of, and atmospheric relative humidity in, the underground workings. The high and medium incidence anthracite mines have, on the whole, smaller relative humidities and greater working depths than have the mines with low or low-medium incidences of X-ray abnormalities.

This suggested correlation of incidence of X-ray abnormalities among colliers with working depth and humidity receives some support from certified silicosis incidence-rates for South Wales anthracite mines in general. Of the 23 anthracite mines classed as having high or medium incidences of certified silicosis, the great majority have workings that are reputedly dry rather than damp, while of the 22 anthracite mines classed as having low incidences of certified silicosis, as many as half are reputed to be damp (see p. 37).

(As with rank of coal, the finding of a relationship between incidence of pulmonary abnormalities and depth and humidity does not, of course, necessarily imply that these characteristics themselves are even partly responsible for the production of the differences in incidence. As already pointed out, there might be some other, more directly involved, factor, such as some variation in the coal or rock strata or dust, which, being itself related to differences in working depth or humidity, could have indirectly produced the relationship between the latter characteristics and the incidence of pulmonary abnormalities.)

(iv) *Position in the coal series of the seams worked*

It is conceivable that differences in the identity or the horizon of the seams might account for the variation in incidence of X-ray abnormalities at the 16 collieries. This possibility can, however, be ruled out, for, with the exception of the Red Vein at collieries A.5 and A.6, the principal relevant seams at these collieries (as judged from the histories of the men examined) were situated in the lower part of the Lower Coal Series, and fairly close to one another in vertical sequence (see Fig. 2, p. 14, and Table VI, p. 43). Moreover, in nine of them the Nine Feet or one of its correlatives was included among the more important seams; and, besides the pair of mines in which the Red Vein was the chief seam, there were collieries A.1 and A.2 with the Lower Pumpquart as the main seam at each—and in each of these pairs one member was in the near vicinity of the other. Yet, in spite of this continuity of seams from one mine to another, the Nine Feet series of collieries included all variations in incidence of X-ray abnormalities between the extremes of collieries A.3 and B.2; furthermore, one member, both of the Red Vein and of the Lower Pumpquart pair of mines, had a high incidence and the other a low incidence of abnormalities (though it will be recalled that with each of these contrasts within the anthracite group there was also a contrast in working depths and in humidities). It appears, therefore, that the same or an equivalent seam can be associated in one mine with a high incidence of pulmonary abnormalities and in another with a considerably lower incidence.

Having discussed the varying incidences associated with the same or equivalent seams in different mines, it is relevant to consider whether there is a variation or a similarity in incidence between different seams in the same mine. Of the 16 collieries, A.1, A.2, A.5, A.6, B.1 and B.2 need not be considered, since only one seam at each was important in

the histories of the men examined. At A.3, the greater part of the X-ray changes found among colliers had been contracted in one or both of the two chief seams, the Stanlyd and the Little, but it was impossible to differentiate the time-risks of these two seams, since too few men had worked predominantly in either for more than ten years. Both these seams were likewise important (among others) at colliery A.4, but here again their influence could not be satisfactorily separated. At collieries A.7, A.8, S.2, S.3, S.4, S.5 and B.3, however, it was possible to assess separately, and to compare, the incidences of X-ray abnormalities in two or more seams. The procedure was to compute, for the usual periods of service, the incidence of abnormalities among home-colliers who had worked predominantly in particular defined seams. (For example, at colliery A.8 the Nine Feet was compared with the Yard seam; at S.4 the Two Feet Nine with the Three Feet Ten; and at colliery B.3 the Black with the Meadow Vein.) These comparisons (figures not tabulated) must be treated with caution, since the total numbers of men at risk are in some cases quite small. There was, however, no striking difference in the incidence of X-ray abnormalities among colliers working on different seams in the same colliery. Such differences as were found were insufficient to place the incidence for either seam more than one class above or below the class assigned to the whole colliery in Table XXIII, column (13). This much smaller variation in incidence of X-ray abnormalities between different seams in the same colliery than between different collieries may be due, in part, to the deliberate selection for examination of those collieries whose chief seams were fairly close together, for the figures suggest that such differences in incidence as were found between seams of the same colliery were probably largest when the seams were furthest apart in vertical sequence, the deeper seam having a somewhat higher incidence than the shallower.

To summarise this section (B), certain natural characteristics of the mines have been found to be correlated with the incidence of X-ray abnormalities. Of those characteristics examined, the most important appears to be the rank of the coal, the highest incidences of X-ray changes being found at the anthracite, and the lowest at the bituminous end of the scale, with a gradual change through the range of mines between. Other correlated characteristics are the depth and humidity of the underground workings, which appear to be associated in particular with the variations in incidence within the anthracite group of mines.

### C. RELATIONSHIP BETWEEN INCIDENCE OF CERTIFIED SILICOSIS AND INCIDENCE OF X-RAY ABNORMALITIES AT THE 16 COLLIERIES

The present series of mines offers an opportunity of comparing the incidence of X-ray abnormalities with the incidence of certified silicosis, though the former is based upon home-colliers and the latter upon total underground working population, and the former is the incidence found at a given time and the latter the annual incidence-rate. The comparison is made in Table XXVI (p. 96), in which the mines of each class of coal are placed in descending order of incidence of certified silicosis, and the relative incidences of X-ray abnormalities are placed alongside. In examining this table it should be recalled (p. 37) that in the selection of anthracite mines for the present survey, one of the primary indications was that they should have either high or low incidences of certified silicosis, and the 25 per cent. of anthracite mines that had medium incidences were deliberately omitted. On the other hand, all the non-anthracite collieries selected for the survey had low incidences of certified silicosis, since over 90 per cent. of the South Wales non-anthracite mines fell into this class. Consequently, the range of incidences of certified silicosis in Table XXVI is deficient; certain conclusions can, however, be drawn.

It can be seen that the three mines with high incidences of certified silicosis had also high incidences of X-ray abnormalities. On the other hand, of the remaining 13 mines, all of which had low incidences of certified silicosis, the incidence of X-ray abnormalities was low in only five, being medium in four and low-medium in another four. This variability between the two measures applies to the anthracite mines with low incidences of certified silicosis, as well as to the non-anthracite groups. It should be noted that it was in the two anthracite mines of which the workings were shallow or medium in depth and



were reputedly damp (A.2 and A.5) that the certified silicosis and X-ray abnormality incidences were both low.

From these results it may be inferred that, while a high certified silicosis incidence probably indicates a high incidence of X-ray abnormalities, a low certified silicosis incidence either may indicate a low incidence of X-ray abnormalities or, on the other hand, it may, both in anthracite and in non-anthracite mines, be associated with a medium incidence of abnormalities. While, therefore, there is a rough correspondence between the incidence of certified silicosis and the incidence of X-ray abnormalities among home-colliers, the former measure provides a less efficient estimate than the latter of the distribution of the incidence of pulmonary abnormality across the coalfield. Certified silicosis suggests a sudden change in incidence from anthracite to non-anthracite (Table IV, p. 8), whereas radiological examination indicates that the change is gradual from anthracite through steam to bituminous coal.

#### D. CHARACTERISTIC INCIDENCE OF RADIOLOGICAL ABNORMALITIES AMONG SOUTH WALES ANTHRACITE, STEAM COAL AND BITUMINOUS COAL COLLIERS IN GENERAL; AND CHOICE OF REPRESENTATIVE MINES WITH CONTRASTING INCIDENCES FOR ENVIRONMENTAL STUDY

It is important to consider how far the data in the preceding sections permit of generalisations applicable to the whole South Wales coalfield. A combination of statistics of certified silicosis incidence-rates with the present X-ray findings is of great assistance for this purpose.

It may be recalled that in Table IV (p. 8) all the South Wales mines of any size were grouped, on the basis of their figures for certified silicosis, into "high," "medium" and "low" incidences, and on p. 37 the anthracite mines were further subdivided into those whose underground workings were reputedly dry rather than damp, and those reputedly damp rather than dry; the latter are (p. 75) mainly mines of medium or shallow working depth. In the present chapter the 16 collieries have been further classified, on the basis of their figures for consolidation, into "high," "medium," "low-medium" and "low" incidences of X-ray abnormalities.

In Table IV the number of anthracite collieries, or units of combined collieries, employing 100 or more men underground was given as 45. Of these, 12 have high incidences of certified silicosis, and all of the 12 are classed as dry mines. The three representatives examined have now been shown (Table XXVI) to have also high incidences of X-ray abnormalities among their home-colliers. There are 22 collieries with low incidences of certified silicosis, half of which are classed as dry, and half as damp mines, the latter being mainly shallower in depth. The three reputedly dry mines of low certified silicosis incidence investigated were the only anthracite collieries of this class that satisfied the criteria of suitability outlined on p. 37, the reasons for rejection of the others being in most cases such as tend to make the certification figures misleading. These three mines have proved, on examination, to have medium or low-medium incidences of X-ray abnormalities among their home-colliers. On the other hand, the two reputedly damp anthracite mines of low certified silicosis incidence investigated—of which class several alternative representatives could have been found—have proved to have low incidences of X-ray abnormalities as well. The remaining 11 of the 45 anthracite collieries have medium incidences of certified silicosis on the arbitrary classification, the great majority (9 of the 11) being dry rather than damp. None of these mines has been included in the present survey.

Since typical dry anthracite mines with high incidences of certified silicosis have shown high incidences of X-ray abnormalities among their colliers, and the only suitable dry anthracite mines of low certified silicosis incidence have shown medium incidences of X-ray abnormalities, it may be suggested that the great majority, if not all, of the reputedly dry mines (whether of high, low or medium certified silicosis incidence) in the South Wales anthracite area are high or medium incidence mines radiologically. Further, if the two damp mines of low certified silicosis incidence examined can be accepted as typical of their class, one may suggest the generalisation that, apart from shallow and reputedly damp mines (whatever this appellation may connote), it is characteristic for South Wales *anthracite colliers* to show high or medium

incidences of X-ray abnormalities. The anthracite mines with low incidences of X-ray abnormalities (i.e. damp mines)—in the minority as to number—are thus regarded as the exception to the rule.

With regard to the South Wales non-anthracite collieries, Table IV gave the number employing 100 or more men underground as 138: of these, only two have high incidences of certified silicosis, both of which work the Red Ash or Tillery seam at the base of the Pennant Coal Series, and only six have medium incidences; clearly such incidences of certified silicosis are the exception, and none has been included in the present survey. The eight representatives actually investigated out of the 130 non-anthracite mines of low certified silicosis incidence are classed as dry and deep. The five steam coal mines have shown two medium, two low-medium and one low incidences of X-ray abnormalities among their home-colliers, and the three bituminous coal mines have shown two low and one low-medium incidences of X-ray abnormalities. Subdividing the steam coal mines further, the incidence of X-ray abnormalities among colliers in the three carbonaceous steam coal mines was medium in two and low-medium in the third, while in the two semi-bituminous steam coal mines the incidence was low-medium in one and low in the other.

From these considerations it would seem permissible to generalise that it is characteristic for South Wales *non-anthracite colliers* (working in seams in the Lower Coal Series) to show a medium or low incidence of X-ray abnormalities, the tendency being for colliers in steam coal of carbonaceous rank to have the medium, and for those in bituminous coal to have the low, incidences of these X-ray changes. Considering this generalisation together with that made above for anthracite mines, the following conclusion can be drawn: that the evidence from certified silicosis figures (Chapter I), namely, that the problem of chronic pulmonary disease in South Wales is mainly, though by no means entirely, in its anthracite area, has been supported—in respect of colliers—by X-ray examination of statistically selected groups. Apart from the anthracite mines, the problem—again in respect of colliers—would appear to lie more in the steam coal than in the bituminous coal area.

Before concluding this section it is desirable to decide which mines from the present series of 16 could best provide typical and pivotal medical contrasts in incidence of pulmonary abnormality, to serve as a basis for the subsequent studies of the various environmental conditions to which colliers are exposed at the coalface (e.g. the detailed nature of the strata, air-borne dust, nitrous fumes, etc.), so that factors which could account for the medical differences between the mines might possibly be discovered. The preceding paragraphs show that such medical contrasts should clearly include high incidence, dry mines against low incidence, damp mines, within the anthracite area of the coalfield, as well as high incidence, dry and deep anthracite mines against low incidence, dry and deep bituminous mines. In the present series suitable contrasts are provided, within the anthracite area, by collieries A.1 and A.3 (high incidence, dry) against A.2 (low incidence, damp), and also by colliery A.6 (high incidence, dry) against A.5 (low incidence, damp); they are further provided, as between anthracite mines and non-anthracite mines, by A.1, A.3 and A.6 (high incidence, anthracite, dry and deep) against S.4 (low incidence, steam coal, dry and deep) and B.2 and B.3 (low incidence, bituminous coal, dry and deep). Certain other features make these salient mines peculiarly suitable for contrast. The rank of the coal at the collieries A.3, A.1 and A.2 is very similar, as also is that at A.6 and A.5. The Lower Pumpquart is the chief seam at both A.1 and A.2, and the Red Vein at both A.6 and A.5. Geographical differences as such are excluded by the proximity of these contrasting mines, while the racial types and character of home surroundings are not obviously dissimilar. As regards the contrasts between anthracite and non-anthracite mines, the Nine Feet seam or equivalent is an important seam at A.3 (Stanllyd seam), B.2 (Black Vein) and B.3 (Black Vein).

### E. NATURAL HISTORY OF DEVELOPMENT OF THE DIFFERENT TYPES OF X-RAY CHANGE ACCORDING TO LENGTH OF EMPLOYMENT AT THE COALFACE

In the present section the natural history of development of the various types of X-ray change is considered according to length of employment at the coalface at the different collieries of the present series, and the relation of one type of change to another (e.g. reticulation to nodulation) is discussed.

#### (i) *Types of X-ray change found at the different collieries*

From Tables XXII and XXIII (pp. 90 and 91), the two main types of abnormal X-ray change which, in Chapter 6, were demonstrated at anthracite colliery A.3, i.e. reticulation and the composite category consolidation, were found to be general in this series of collieries, though the amounts varied greatly; no other pulmonary abnormalities were present in significant quantity. Reticulation was present to some degree at all the 16 collieries, and consolidation was found as well at 14 of them, i.e. at all except collieries A.5 (anthracite) and B.2 (bituminous), in both of which the incidence of reticulation was also relatively low. Subdividing consolidation into nodulation and major consolidation, the former was the commoner change and was present at all these 14 collieries, the latter was found as well at all those mining anthracite, but at only half of the steam coal group, and at none of the bituminous group; in the last two colliery groups the incidence of "all consolidation" and of "all abnormal" tended to be low. Subdividing major consolidation still further for the nine mines at which it occurred (Table XXIII, notes), the most frequent of its three component categories was coalescent nodulation, which was found at all of these nine mines; while one or other of the remaining categories (massive shadows and multiple fluffy shadows) was found in most of the seven that were anthracite, and in one of the two that were steam coal mines.

Looking at Table XXIII from the quantitative aspect, it can be seen that at the high incidence mines of the anthracite group—A.1, A.3 and A.6—reticulation, nodulation and major consolidation were all found in considerable amount; at the medium incidence anthracite mines, A.8 and A.7, reticulation and nodulation were present in considerable amount, but major consolidation was rare though not entirely absent, and the findings were similar at medium incidence colliery S.3 of the steam coal group; at the low-medium incidence mines, A.4 of the anthracite group, as well as S.2 and S.5 of the steam coal group and B.1 of the bituminous coal group, reticulation was found in considerable or moderate quantity, but nodulation itself was uncommon though still present, and major consolidation was rare or absent; at the low incidence mines, A.2 and A.5 of the anthracite group, and also S.4 of the steam coal group, reticulation was again present in considerable or moderate amount, but nodulation was rare or absent; and at the low incidence bituminous mines, B.3 and B.2, nodulation was again rare or absent and reticulation itself was uncommon.

Finally, it appears that at mines where massive and fluffy shadows were not found, the other and chief category of major consolidation—coalescent nodulation—was itself less frequent than at the other mines, or was also absent; further, that at those mines at which coalescent nodulation was absent the incidence of nodulation was reduced, while at those mines at which nodulation was not found the incidence of reticulation was lower than at most of the other mines. In other words, as the incidence of abnormalities decreases, massive and fluffy shadows, coalescent nodulation, nodulation, reticulation, tend to drop out in that order.

Allowing for the differences in *incidence* of X-ray abnormalities from one mine to another, there seems, therefore, to be a consistency in the *types* of

X-ray appearance among the colliers at the 16 collieries (including A.3), in spite of the major differences in rank of coal. The X-ray differences are of degree rather than of kind, and there is no sudden change in passing from the anthracite to the steam coal or from the latter to the bituminous coal. The types of abnormality found at a given non-anthracite mine can be approximately matched with those at an anthracite mine, and the absence of a particular type of appearance at a mine is in most cases related to the general level of incidence of abnormalities prevailing there.

(ii) *Development of the various X-ray abnormalities at the different collieries*

In considering the natural history of development of the X-ray changes according to length of employment at the coalface, it will be assumed that the incidence figures for the different length-of-employment groups for each mine, as shown in Table XXIII, illustrate the trend of X-ray changes in a generation of colliers as it passes through its working life, i.e. that the 10-20 years group represents a fair sample of the under 10 generation of ten years earlier, and that, in the same way, the 20 + years group represents a 10-20 generation of ten years earlier.

In this connection, it will be noted that in many of the 16 collieries there is a considerable drop in total population between the 10-20 years period-group and the 20 + years group, and a similar drop would have been shown between the under 10 years group and the 10-20 years group had the former consisted of the total men suitable, and not of a sampled fraction of them, at the seven mines where this group was included. At first sight this drop in the total population might disturb the assumption of continuity made above, for if the older groups represented the survival of the fittest they might include too high a proportion of normals, the disabled having been partially removed (disablement under the head of compensation would not seriously affect any but the high incidence collieries). The drop in total population is, however, comparatively little accounted for by such natural loss through disability, and—in these particular mines—little by emigration of the men. It is mainly accounted for artificially, by the criteria of suitability adopted for selecting the home-colliers for examination (see note to Table XXIII). In general, the older the collier the more likely is he to have a mixed occupational history, and the more likely also to have had experience as a collier in outside collieries. In other words, while the great majority of the available men of under 10 years experience as collier satisfied the criteria of suitability for selection as home-colliers for the present examination, a considerable proportion (differing of course with each mine) of those with 10-20 and 20 + years experience had to be rejected on account of their mixed occupational histories or the amount of their experience as colliers elsewhere. Since there seems no reason to believe that this artificial restriction of population suitable for examination represents any selective process towards differentiation on health grounds, it seems justifiable to regard the incidence of the various X-ray changes at different periods of service among those persons who were actually examined as indicative of the trend in a generation of colliers as it passes through its working life.

Other difficulties are encountered in tracing the development of the various types of abnormality at these collieries with increasing length of employment at the coalface. One is the small total number of men in the 20 + years group in certain mines (percentages are bracketed when this total is less than 20). Another is the difficulty of showing the earliest point at which changes first appear; to assist with this decision, the incidence of each X-ray category among colliers of less than five years experience is given in a note to Table XXIII. A third difficulty is that all three period-groups were represented in the data from only seven of the 16 collieries, the 10-20 and 20 + years groups being represented alone at eight of them, and the 20 + years group alone at one mine (A.6). To overcome to some extent the absence of the under-10-years period-group, the 10-20 years group has been split into 10-15 and 15-20 years (notwithstanding the reduction in total numbers), and the two new series of percentages are shown in a note to the table. Comparison of the two quinquennial percentages for a given category will be taken as indicative of the trend in incidence between the under 10 and the 10-20 years periods that would have been shown had the former period-group been actually represented. The data from the mine A.6 are obviously inadequate for the present purpose, and the following discussion is confined, therefore, to 15 collieries.

From Table XXIII it may be seen that in six of the seven mines providing data for all three length-of-employment periods, there was a progressive decrease

in the incidence of normal X-rays in passing from colliers of short experience to those of many years standing (the exceptional trend at A.8 is probably a chance variation, for only 18 men were examined in the 20+ years group). Moreover, in six of the eight mines with data for only the two older employment periods, there was a decreased incidence of normals between the two period-groups, in spite of the small numbers of men involved in many cases. Further, in five of these six mines, splitting of the 10-20 years period-group suggests that the decrease in normals would also have been evident between the under 10 and the 10-20 years periods if the former period-group had been represented.

It may be concluded, therefore, that, in the main, the colliers at these mines showed a progressive increase in the incidence of total X-ray abnormalities with increasing duration of employment. To study the development of the individual abnormal changes, each period-group must be considered in turn.

In men with less than five years experience as colliers, in the seven mines for which data were obtained, there were either no recorded changes of any kind or only a very occasional reticulation. The shortest period of employment on coal after which this change was recognised was one year (in one case). In the whole under-10-years period-group, reticulation was present at six of the seven mines, the exception being B.3, one of the lowest incidence mines; consolidation (categories *c-f*) was absent or relatively uncommon.

With 10-20 years of work as collier, reticulation had increased, and consolidation had appeared or increased, at the above six mines (both changes being absent still at the seventh, B.3); as regards the other eight mines also, from the results of splitting their 10-20 years data into 10-15 and 15-20 years, reticulation may be assumed either to have appeared, or to have increased over its incidence at under 10 years, in at least seven, and consolidation in at least five (at low incidence mines A.5 and B.2, as at B.3, consolidation was absent in the 10-20 years period-group). At practically every mine the incidence of consolidation at 10-20 years was less than that of reticulation.

Up to this point the collieries have shown a general similarity in development of the X-ray changes. In the trends of incidence of reticulation and consolidation between the 10-20 and the 20+ years periods, however, they show interesting differences, and may be divided into two development groups. In group (1), consisting of five mines (A.1, A.3, A.7, A.4 and S.5), the incidence of consolidation showed a further increase from 10-20 years to 20+ years; in group (2), consisting of seven mines (A.2, A.5, S.3, S.1, S.2, S.4 and B.3), the incidence of consolidation remained about the same (on account of the exceptional trends of their normal incidences, three mines—A.8, B.1 and B.2—have been omitted from these groupings). In group (1) the incidence of reticulation, in contrast to its previous increase, either showed a decrease between 10-20 years and 20+ years (A.3, A.7 and A.4) or remained about the same (A.1 and S.5), so that in four mines of this group consolidation now exceeded reticulation; in group (2), on the other hand, reticulation, in the main, continued its increase, its incidence remaining more than that of consolidation. It may be noted that group (1) included two high incidence mines but none with low incidence of X-ray abnormalities (classification of Table XXIII), whereas group (2) contained four low incidence mines but none with high incidence. The decrease in reticulation that accompanied the increase in consolidation, in passing from the 10-20 to the 20+ years period, in certain of the mines of group (1), would seem to be due, at least in part, to transference of the former change to the latter, for the converse association in the mines of group (2) shows that it was unlikely to be due to actual recovery from the reticulation. Looked at another way, the rise in consolidation seems to be due in part to transference from reticulation, because if it were due entirely to transference from normals, one would not expect an associated fall in the incidence of reticulation. On this explanation, the continued increase in the incidence of reticulation after

long periods of service in the mines of group (2) would be due to continued production of that change without much transference to consolidation.

The above analysis deals with consolidation as a whole: Table XXIII shows that, when this is subdivided into nodulation and major consolidation, the trends of the former are very similar to those of the composite category "all consolidation"; some indication of a parallel course is given also for major consolidation, though the numbers are too small to be definite. Comparison of the percentages of nodulation with those of major consolidation at the different collieries—particularly at A.8, A.4 and S.2, where the major consolidation was absent at the earlier but present at later periods—indicates that major consolidation was a later change than nodulation. Subdivision of major consolidation still further into its individual components is provided in a note to Table XXIII. Since coalescent nodulation was by far the most frequent component, the preceding remarks apply principally to it; but examination of a similar note to Table XXII indicates that massive and multiple fluffy shadows are at least as late in the order of development as the category of coalescent nodulation.

Summarising the most notable points in this analysis, it appears that both in the anthracite and in the non-anthracite mines reticulation was the commonest X-ray abnormality among the younger colliers; that it was the earliest deviation from normality, and that consolidation, where it occurred, developed later (with some transference of reticulation to consolidation, so that the latter may be considered to have been derived in part at least from the former); and that probably the components of consolidation termed "major consolidation" were later developments than nodulation. Where the development of consolidation was such as to produce a progressive increase in its incidence throughout the employment periods, a reduction in the incidence of reticulation might occur at the later periods, on account of the amount of the transference; where the incidence of consolidation remained much the same at the later periods, the incidence of reticulation continued to rise. In the low incidence mines, reticulation was the predominant abnormality among the older colliers, as it was among the younger; in the high incidence mines, while forming still a fair proportion of the total abnormalities in the older group, it was exceeded in frequency by consolidation.

In the previous subsection (i), the consistency of types of X-ray appearance among the colliers at the 16 collieries was pointed out, and the absence of a particular type of appearance at a mine was related to the general level of incidence of abnormalities prevailing there. The present analysis of development of the X-ray appearances supports this conclusion; for since the incidence of total abnormalities increases progressively with duration of employment at the coalface—reticulation, nodulation, major consolidation, appearing in that order—the absence or relative infrequency of the later changes in the lower incidence mines in Table XXIII could be accounted for by a smaller hazard of a nature similar to that present in the high incidence mines, without the necessity of assuming a different kind of hazard—i.e. the difference might be one of quantity rather than of quality.

It is of interest to see how far the findings under discussion, which were derived from a varied series of mines, agree with and supplement the similar analysis, in Chapter 6, of the whole group of 177 selected colliers (including others besides home-colliers) at the high incidence anthracite colliery A.3 alone. These results, summarised on p. 55, were as follows: (1) no definite abnormalities under five years and no consolidation changes under 10 years; (2) reticulation, nodulation, coalescent nodulation, appearing in that order, with massive and multiple fluffy shadows developing late; (3) apparent transfer of part of reticulation to nodulation, and of nodulation to coalescent nodulation; (4) decrease of the consolidation group as a whole in later years, presumably due to removal of affected men with compensation. Taking these points in

turn, (1) is approximately confirmed for those of the 16 mines in which the under-10-years length-of-employment group was represented, for reticulation was rarely found under five years and consolidation was uncommon under 10 years; (2) is also confirmed (allowing for the smaller number of period-groups used, which makes the time of development of some of the individual components of consolidation more difficult to study than in the larger group of colliery A.3); (3) is supported and extended, for the observation at some collieries besides A.3 of a decrease in reticulation in later years associated with an increase in consolidation, together with the finding at other collieries of a continued increase in reticulation associated with a non-increase in consolidation incidence at the later periods, provides stronger evidence of the transfer of part of reticulation to consolidation, where the latter occurs, than could the earlier group of A.3 alone: (the necessarily smaller number of period-groups precludes the further investigation of the transfer of some of nodulation to coalescent nodulation suggested by the earlier results from A.3); (4) was not confirmed, even in other high incidence mines where the number of men removed through compensation for silicosis was relatively large: (the reason is probably again the smaller number of period-groups, since the late decrease in consolidation was not shown even for the home-colliers of A.3, although it applied to the larger group of the latter colliery, where two period-groups were given for men of 20 and more years of service).

Although the present statistical analysis shows that consolidation is a later change than reticulation, and that it is derived in part at least from the latter and not entirely direct from normals, it cannot by itself decide the very important question whether this transference of reticulation supplies more than part of the incidence of consolidation. With the help of other evidence, obtained from examination of individual X-ray films, this point can, however, be assessed with a high degree of probability. In Chapter 5 it was stated that in almost all the films from colliery A.3 classed as nodulation and coalescent nodulation, and in the majority of the films classed as massive shadows and multiple fluffy shadows, reticulation was also visible; consequently, for practical purposes, the consolidation category refers to consolidation *plus* reticulation, while the reticulation category refers to reticulation without any of the changes of consolidation. Examination of the films of the home-colliers at the other mines of the present series agrees with these earlier findings at colliery A.3. The deduction from this X-ray evidence, together with the above statistics, is that consolidation in colliers is *almost confined* to persons who already show reticulation and would have been originally classed in that category; and that, therefore, the main or essential path from normal to consolidation is by way of reticulation. In other words, reticulation constitutes a phase in the time-sequence of the X-ray lung changes attributable to dust. It does not necessarily follow, however, that reticulation actually represents an early *stage* in the pathological process that may lead to the lesion which is the basis of the X-ray appearances termed consolidation (i.e. really consolidation *plus* reticulation), since the two types of change when present together might be no more than co-existent. On the other hand, the above considerations do suggest the likelihood that these two changes are related in pathological development. Additional evidence of an inter-relationship is provided in subsection (iii) below.

It has been stated on p. 83 that at the low incidence mines (anthracite and non-anthracite) reticulation was the predominant abnormality throughout the working life of the colliers, but that in the high incidence (anthracite) mines reticulation among the older colliers was exceeded in frequency by consolidation. If the men whose films showed consolidation had all passed through the phase of reticulation, then it follows that in the low incidence mines the majority of films showing reticulation remained as such, but that

in the high incidence mines the majority of films in this category had passed on to consolidation before the end of a normal working life.

(iii) *Parallelism of reticulation and consolidation incidences from one colliery to another*

Hypothetically, both the group of radiological changes termed consolidation and the change called reticulation might be due to a specific factor in dust, or either or both of them might be non-specific foreign-body reactions to mineral dust of any kind. If reticulation and consolidation were both caused by the same kind of dust hazard—non-specific or specific—a parallelism from one mine to another in the incidences of the two X-ray changes would be expected. If, on the other hand, reticulation were a non-specific change caused by dust of any kind, while consolidation was due to a specific hazard, a parallelism would again be expected so long as the total quantity of dust, causing reticulation, varied from mine to mine in proportion to the quantity of the specific factor causing consolidation; but a dissociation between the two incidences would occur in mines where the total quantity of the dust and the amount of the specific factor in the dust did not vary together. It follows that the finding of a dissociation between the incidence of reticulation and that of consolidation from one mine to another would be against a common origin (non-specific or specific), while evidence of parallelism could be no more than consistent with such origin, or suggestive of a related cause, unless there was also knowledge of the comparative concentrations of total dust in the different mines.

In the examination for evidence of parallelism between the incidence of reticulation and that of consolidation from one mine to another, two difficulties arise. One is that in mines with a high incidence of consolidation and a low incidence of normals, reckoned on the basis of *percentage of total population examined*, there may be insufficient room for a high incidence of reticulation to show up on such a percentage basis; the reticulation being, as it were, "crowded out."

The other difficulty (mentioned earlier) arises because the incidence of reticulation is affected in one direction by the production of fresh cases, and in the other by the transference of cases to consolidation. Thus, in a mine with consolidation rapidly increasing, with length of service, to a high incidence (e.g. A.3), the large amount of transference to that category may reduce the apparent incidence of reticulation after its initial increase, while in a mine with a lower incidence of consolidation (e.g. A.2 or A.5), the smaller amount of such transference would tend to keep the incidence of reticulation relatively high, apart from any other, directly produced, changes in the latter incidence. (This could account for the variation from mine to mine in reticulation incidence appearing to be smaller than that in consolidation incidence, and also for the earlier employment period-groups being better than the later groups for comparing reticulation incidences between individual mines or between different classes of mine.) This inverse inter-relationship between the incidence of reticulation and that of consolidation tends to obscure any fundamental parallelism between the two that might be due to identity or correlation of causative factors; and if the two incidences are compared from one mine to another merely as they stand, the reticulation that has been transferred to consolidation is excluded.

To overcome these difficulties, ratios of the numbers of men showing consolidation and reticulation, respectively, to the number with normal radiographs, at each mine, have been used as measures of the incidences of these two abnormalities. Further, since it appears that most, if not all, consolidation cases have passed through the phase of reticulation, the ratio of reticulations-plus-consolidations to normals has also been calculated. These figures are given in Table XXVII (p. 97). In Part (i) of this table the ratios for a given mine are, as just stated, the numbers of (a) consolidations, (b) reticulations and (c) consolidations plus reticulations to each normal man in that mine (all lengths of employment, unstandardised). In Part (ii) allowance is made for differences in distribution of the men in the three length-of-employment groups in the various mines, by standardisation; each of the observed ratios of Part (i) is related to its corresponding expected ratio, by expressing the former as a percentage of the latter. In deriving these expected ratios, the method of calculating the expected number of men in a given X-ray category was that used for Table XXIII and described on page 72; it was based upon the percentage-incidences of the given category among the men of different length-of-employment groups in the eight anthracite mines taken as one unit, and upon the total numbers examined of these period-



groups in the mine under consideration. This standardisation probably makes the figures in Part (ii) more useful than those in Part (i).

Table XXVII thus enables the relation of reticulation to consolidation incidence in the 16 mines to be adequately studied. The mines are placed in descending order of consolidation incidence as measured in the two ways (and the orders are fairly similar); it will be seen that the range indicated by this incidence (columns (3) and (8)) is very wide. Inspection of the table shows, in both Parts (i) and (ii), that the reticulation and consolidation incidences are positively correlated. Where the consolidation incidence is high (e.g. in collieries A.1 and A.3), the reticulation incidence also tends to be high, in spite of transference; where the consolidation incidence is low or nil (e.g. in collieries B.3 and A.5), reticulation also is comparatively infrequent, though in no case is it absent in this series. If reticulation and consolidation were entirely dissociated, one would expect the incidence of reticulation to be at least as high in some of the mines where consolidation was infrequent as where it was plentiful, instead of being itself also much reduced.

The similarity which the trend of reticulation incidence shows to the trend of consolidation incidence, from the mines with the highest to those with the lowest incidence of consolidation, is increased when consolidation *plus* reticulation is used as a more complete measure of the total reticulation produced at a mine than the reticulation figure as it stands. This increased parallelism is significant, and not merely due to one variable now containing the other, for the original correlation between incidence of reticulation and incidence of consolidation shows that the sum of these incidences is a function of each, and not only of one of them.

As stated in the preceding subsection (ii), statistical evidence that reticulation appears earlier at the coalface than consolidation, and that transference of part of it to consolidation occurs when the latter change is found, together with the X-ray evidence that reticulation can generally also be identified in films classed as consolidation, indicates that consolidation is practically entirely derived from normals by way of reticulation; it further suggests that the two changes are related in pathological development, as well as being connected in time-sequence. The finding of a parallelism between the incidence of reticulation and that of consolidation among colliers from one mine to another provides additional evidence of an inter-relationship, by suggesting that the two changes are due to similar or related causes.

It is not possible to draw any further conclusions about the aetiology of reticulation and consolidation without knowing the relation of their incidences in different mines to the concentrations of air-borne dust at the coalfaces. These concentrations will be given in the reports upon the environmental part of the field survey, to be published separately.

#### SUMMARY OF CHAPTER 7

(1) The results of the X-ray examinations of 1,496 selected colliers at 16 South Wales collieries have been considered. The collieries comprised eight anthracite (793 men), including colliery A.3 (already discussed in Chapter 6), five steam coal (465 men) and three bituminous coal (238 men). In nine of the mines the Nine Feet seam or one of its correlatives was included among the more important of the seams worked. The colliers selected at each mine were "home-colliers," i.e. men who had worked mainly as colliers and whose employment in this capacity had been predominantly at the mine under study.

(2) Considerable variations in the incidence of X-ray abnormalities attributable to dust, as judged mainly from the amount of consolidation, were found among the home-colliers from one mine to another. The contrast was twofold, firstly, between the anthracite and the bituminous collieries as groups, and secondly,

between certain of the individual anthracite collieries themselves. The order of collieries within each of the three groups (anthracite, steam and bituminous) was much the same whether the incidence was assessed by the amount of all X-ray abnormalities (i.e. including reticulation), or by the amount of consolidation only. On the basis of consolidation, the collieries were divided arbitrarily into four classes of incidence of X-ray abnormalities—"high," "medium," "low-medium" and "low."

(3) Certain broad natural characteristics in these mines were found to be correlated with the variations in X-ray incidence. (a) There was, on the whole, a decrease in incidence of abnormalities from west to east across the coalfield, judged by the present small sample, the change being gradual and continuous; but there were also differences within the western part of the field itself. This association between incidence of X-ray abnormalities and geographical position of the collieries is considered probably to be indirect, and secondary to the inter-relation between the latter variable and the rank of the coal mined, anthracite being situated in the western, and bituminous coal towards the eastern part of the coalfield. (b) Rank of coal is, in fact, the most important obvious natural factor found to be related to the varying incidence of X-ray abnormalities among colliers at these different mines. The highest incidences were found at the anthracite, and the lowest at the bituminous end of the scale of rank (the latter comprising coals of the lowest rank in South Wales), and the change was fairly gradual with descending rank between the extremes. If anthracite collieries in which the reputed moisture conditions at the coalface were damp rather than dry are treated as special cases, and their two representatives in this series (both with low incidences) are disregarded for the present comparison, the relation between incidence and coal rank becomes stronger. (c) Working depth and atmospheric moisture conditions at the coalface—the latter judged by measurements of relative humidity—are two other characteristics for which a relationship with incidence of X-ray abnormalities was suggested. Differences in depth and atmospheric humidity (these characteristics being fairly closely correlated) appeared in particular to be associated with the variations in incidence within the anthracite group of mines, the high and medium incidence anthracite mines having smaller relative humidities and greater working depths than the mines of the same class with low or low-medium incidences. This suggested relationship for X-ray abnormalities in the present series was supported by certified silicosis incidence figures for the anthracite mines in general.

(4) There was a rough correspondence between incidence of certified silicosis (based upon total underground population) and incidence of X-ray abnormalities (based upon home-colliers only) from one of the 16 mines to another, but in certain mines a low incidence of certified silicosis was actually associated with a medium incidence shown by the X-ray. Certified silicosis incidences provide a less complete estimate than the incidences of X-ray abnormalities among colliers, of the distribution of pulmonary abnormality at the coalface in various parts of the coalfield. Certified silicosis incidences suggest that the change from anthracite to non-anthracite is sudden, whereas in fact it is gradual and continuous.

(5) From a combination of the statistics of certified silicosis incidence in South Wales mines in general, with the present X-ray findings at the 16 collieries, the conclusion was reached that, apart from shallow and reputedly damp mines (whatever this appellation may connote), it is characteristic for South Wales anthracite colliers to show a high or medium incidence of X-ray abnormalities, and for non-anthracite colliers to show a medium or a low incidence; in carbonaceous steam coal the incidence tends to be medium, and in bituminous coal it tends to be low. Pulmonary abnormality among colliers in South Wales is therefore mainly concentrated in the anthracite area, though its

incidence in the steam coal mines of the non-anthracite parts of this coalfield cannot be neglected. From these considerations, the main problem of the environmental part of the present field survey is to explain (by examinations of the rock and coal strata, of the air-borne dust at the coalface, of the nitrous fumes, etc.) why the incidence of pulmonary abnormality is characteristically higher in the anthracite than in the non-anthracite mines. Low incidence anthracite mines (by X-ray), in the minority as to number, are regarded as a special case; and the explanation of their medical difference from the characteristic, and the reason for their coinciding in general with anthracite mines whose underground workings are comparatively damp and shallow, form special problems of the environmental studies.

(6) Allowing for the marked differences, mentioned in (2), in incidence of X-ray abnormalities from one mine to another, the main types of abnormality described for anthracite colliery A.3 were found at most of the other collieries investigated, in spite of major differences in rank of the coal mined. The X-ray differences between mines appeared to be of degree rather than of kind, and there was no sudden change in passing from the anthracite to the steam coal, nor from the steam to the bituminous coal. The two main types of change were, as at colliery A.3, reticulation and the composite category consolidation.

(7) Statistical analysis of the development of the various X-ray changes with progressive exposure at the coalface at the 16 collieries indicates that, both at anthracite and at non-anthracite mines, reticulation is the commonest X-ray abnormality among the younger colliers. In the low incidence mines it is also the predominant abnormality found among the older colliers, but in the high incidence mines, while forming still a fair proportion of the total abnormalities in this group, it is exceeded in frequency by consolidation. Reticulation is an earlier X-ray appearance than consolidation, and transference of some of the reticulation to consolidation takes place if and when the latter change develops, so that the consolidation may be considered to have been derived in part at least from the reticulation, and not entirely from normals direct. Where the components of consolidation termed major consolidation occur, these are probably later developments than nodulation.

In mines in which the development of consolidation is such as to produce a progressive increase in its incidence throughout the employment periods, a reduction in the incidence of reticulation at the later periods may result from the amount of the transference. On the other hand, in mines in which the incidence of consolidation remains much the same at the later employment periods, the incidence of reticulation continues to rise.

These conclusions, based upon colliers at the 16 collieries, confirm and extend those based upon the examination of colliers at anthracite colliery A.3 alone (Chapter 6).

(8) From the findings just quoted, together with the observation that when consolidation is seen on the X-ray film reticulation is usually visible in addition, it is inferred that consolidation in South Wales colliers is practically entirely—and not just in part—derived from normals by way of reticulation, i.e. that reticulation constitutes an essential phase in the time-sequence of the X-ray lung changes attributable to dust. It does not follow that reticulation actually represents an early *stage* in the pathological process that may lead to the lesion which is the basis of the X-ray appearance classed as consolidation (i.e. really consolidation *plus* reticulation), since the two types of change, when present together, might be no more than co-existent. The likelihood that there is such a relationship in pathological development as well as the connection in time-sequence is, however, certainly suggested by the above considerations.

From the further finding that in the high incidence mines reticulation is exceeded by consolidation among the older colliers, it may be inferred that at these mines the majority of men who develop reticulation appearances will

have passed on to the consolidation category before the end of a normal working life. On the other hand, in the low incidence mines reticulation remains as such in the majority of these men.

(9) Comparisons were made between the incidence of consolidation and the incidence of reticulation among colliers at the 16 South Wales collieries. The incidences of these abnormalities at a mine were measured by the ratios of their numbers to the number of normals, instead of by their percentages based upon the total examined ; and, as a more complete measure of the total reticulation produced, the sum of consolidation *plus* reticulation was used, as well as the reticulation figure as it stood.

When the 16 collieries were placed in order of their incidence of consolidation—from a very high level to nil—the figures representing reticulation incidence were found to show a broadly similar trend. In mines in which the incidence of consolidation was high, reticulation incidence was high also, in spite of the large amount of transference that had taken place from reticulation to consolidation ; in mines in which the incidence of consolidation was low or nil, reticulation also was comparatively infrequent, contrary to what might have been expected if its production were independent of consolidation. From no mine of this series, however, was reticulation entirely absent.

The parallelism between the respective incidences of reticulation and consolidation among colliers from one mine to another in the present series supports the view that there is a basic inter-relationship between these two types of abnormality, by suggesting that they are due to similar or related causes. Further inferences as to causation are not possible without a knowledge of the variations in concentration of air-borne coalface dust from one mine to another, in relation to the corresponding differences in the incidences of reticulation and consolidation.

TABLE XXII

The average incidence, according to length of service, of X-ray abnormalities among selected colliers ("home-colliers") at (i) 8 anthracite collieries (793 men), (ii) 5 steam coal collieries (465 men), and (iii) 3 bituminous coal collieries (238 men)

Total period as collier. (Years) (1)	Class of colliery group.* (2)	Percentage (and number) in each X-ray category.						All X-ray categories. (9)
		(a) Normal. (3)	(b) Reticulation. (4)	(c) Nodulation. (5)	(d-f) Major consolidation† (6)	(c-f) All consolidation. (7)	(g-h) Indefinite. (8)	
Under 10 .. ..	(i) Anthracite (5)† ..	79.1 (182)§	16.1 (37)	3.5 (8)	0.4 (1)	3.9 (9)	0.9 (2)	100.0 (230)§
	(ii) Steam (1) .. ..	88.6 (31)	11.4 (4)	— (0)	— (0)	— (0)	— (0)	100.0 (35)
	(iii) Bituminous (1) ..	100.0 (29)	— (0)	— (0)	— (0)	— (0)	— (0)	100.0 (29)
10-20 .. ..	(i) Anthracite (7) ..	39.5 (134)	41.6 (141)	14.2 (48)	4.4 (15)	18.6 (63)	0.3 (1)	100.0 (339)
	(ii) Steam (5) .. ..	65.4 (183)	23.9 (67)	9.6 (27)	0.7 (2)	10.4 (29)	0.4 (1)	100.0 (280)
	(iii) Bituminous (3) ..	86.0 (98)	10.5 (12)	3.5 (4)	— (0)	3.5 (4)	— (0)	100.0 (114)
20 + .. ..	(i) Anthracite (8) ..	36.6 (82)	32.6 (73)	20.5 (46)	8.5 (19)	29.0 (65)	1.8 (4)	100.0 (224)
	(ii) Steam (5) .. ..	42.7 (64)	39.3 (59)	14.0 (21)	2.7 (4)	16.7 (25)	1.3 (2)	100.0 (150)
	(iii) Bituminous (3) ..	87.4 (83)	8.4 (8)	3.2 (3)	— (0)	3.2 (3)	1.1 (1)	100.0 (95)

\* The three classes of colliery, (i), (ii) and (iii), correspond to Parts (i), (ii) and (iii) of Table XXIII.

† The figure in brackets and italics following each entry in this column (2) is the number of collieries from which the X-ray figures on that line were derived.

‡ Comprising categories (d) coalescent nodulation, (e) massive shadows and (f) multiple fluffy shadows.

§ The figures in brackets and italics following the percentages in columns (3)-(9) are the absolute numbers.

Expanded data.—The figures for the individual categories of major consolidation (column (6)) were as follows:—Under 10 years, anthracite, coalescent nodulation, 0.4 per cent. (1 case), steam and bituminous, nil; 10-20 years, anthracite, coalescent nodulation, 3.8 per cent. (13 cases), multiple fluffy shadows, 0.6 per cent. (2 cases), total, 4.4 per cent. (15 cases), steam, coalescent nodulation, 0.7 per cent. (2 cases), bituminous, nil; 20+ years, anthracite, coalescent nodulation, 4.9 per cent. (11 cases), massive shadows, 3.1 per cent. (7 cases), multiple fluffy shadows, 0.5 per cent. (1 case), total, 8.5 per cent. (19 cases), steam, coalescent nodulation, 2.0 per cent. (3 cases), multiple fluffy shadows, 0.7 per cent. (1 case), total, 2.7 per cent. (4 cases), bituminous, nil.

TABLE XXIII

Percentage-incidence, according to length of service, of X-ray abnormalities among selected colliers ("home-colliers") at each of 16 South Wales collieries (1,496 men). (The collieries in each part of the table are placed in descending order of incidence of X-ray abnormalities as measured by the figures in column (11))

Part (i)—Eight anthracite collieries (793 men).

Colliery. (1)	Total period as collier. (Years) (2)	Percentage in each X-ray category.						All X-ray categories. (9)	Mean period as collier. (Years) (10)	Observed X-ray abnormalities per cent. of expected (all periods).		
		(a) Normal. (3)	(b) Reticulation. (4)	(c) Nodulation. (5)	(d-f) Major consolidation. (6)	(e-f) All consolidation. (7)	(g-h) Indefinite. (8)			(c-f) All consolidation. (11)	(b-h) All abnormals. (12)	Incidence class. (13)
A.1 .. ..	Under 10	67.7	22.6	6.4	3.2	9.7	0.0	100.0 (31)	5.0	} 233	148	High
	10-20	12.5	40.6	31.3	12.5	43.8	3.1	100.0 (32)	14.6			
	20+	(0.0)	(40.0)	(60.0)	(0.0)	(60.0)	(0.0)	100.0 (6)	24.2			
A.6 .. ..	Under 10	..	..	..	..	..	..	..	..	} 176	127	High
	10-20	..	..	..	..	..	..	..	..			
	20+	19.5	29.3	31.7	19.5	51.2	0.0	100.0 (41)	23.4			
A.8 .. ..	Under 10	73.1	26.9	0.0	0.0	0.0	0.0	100.0 (26)	4.4	} 172	123	High
	10-20	29.7	35.1	24.3	10.8	35.1	0.0	100.0 (37)	14.9			
	20+	19.5	26.8	29.3	22.0	51.2	2.4	100.0 (41)	25.3			
A.8 .. ..	Under 10	73.9	17.8	6.8	0.0	6.8	1.4	100.0 (73)	4.8	} 146	129	Medium
	10-20	18.7	50.0	25.0	8.8	33.3	0.0	100.0 (69)	14.1			
	20+	(33.3)	(50.0)	(16.7)	(0.0)	(16.7)	(0.0)	100.0 (18)	23.4			
A.7 .. ..	Under 10	..	..	..	..	..	..	..	..	} 95	112	Medium
	10-20	84.1	53.4	11.4	1.1	12.5	0.0	100.0 (88)	14.6			
	20+	22.2	25.9	40.7	3.7	44.4	7.4	100.0 (27)	23.6			
A.4 .. ..	Under 10	86.1	12.3	1.5	0.0	1.5	0.0	100.0 (65)	5.3	} 55	82	Low-medium
	10-20	49.1	45.3	5.7	0.0	5.7	0.0	100.0 (53)	14.7			
	20+	(35.7)	(28.6)	(28.6)	(7.1)	(35.7)	(0.0)	100.0 (14)	22.3			
A.2 .. ..	Under 10	91.4	5.7	0.0	0.0	0.0	2.9	100.0 (35)	4.9	} 12	57	Low
	10-20	70.0	25.0	2.5	2.5	5.0	0.0	100.0 (40)	14.5			
	20+	53.6	46.4	0.0	0.0	0.0	0.0	100.0 (28)	24.1			
A.5 .. ..	Under 10	..	..	..	..	..	..	..	..	} 0	41	Low
	10-20	86.2	13.8	0.0	0.0	0.0	0.0	100.0 (29)	14.6			
	20+	68.0	80.0	0.0	0.0	0.0	2.0	100.0 (50)	28.9			

TABLE XXIII—continued.

## Part (ii)—Five steam coal collieries (465 men).

Colliery. (1)	Total period as collier. (Years) (2)	Percentage in each X-ray category.						All X-ray categories. (9)	Mean period as collier. (Years) (10)	Observed X-ray abnormalities per cent. of expected (all periods).		
		(a) Normal. (3)	(b) Reticulation. (4)	(c) Nodulation. (5)	(d-f) Major consolidation. (6)	(g-f) All consolidation. (7)	(g-h) Indefinite. (8)			(o-f) All consolidation. (11)	(b-h) All abnormals. (12)	Incidence class. (13)
S.3 .. ..	Under 10	46.9	25.5	21.8	4.8	25.6	0.0	100.0 (47)	15.9	} 110	95	Medium
	10-20	89.8	37.5	20.8	6.9	27.1	2.1	100.0 (48)	29.9			
S.1 .. ..	Under 10	50.0	28.6	21.4	0.0	21.4	0.0	100.0 (28)	14.1	} 87	69	Medium
	10-20	84.6	46.2	19.2	0.0	19.2	0.0	100.0 (26)	30.9			
S.2 .. ..	Under 10	65.6	21.9	12.5	0.0	12.5	0.0	100.0 (32)	14.6	} 80	71	Low-medium
	10-20	(85.7)	(50.0)	(7.1)	(7.1)	(14.3)	(0.0)	100.0 (34)	28.8			
S.5 .. ..	Under 10	88.6	11.4	0.0	0.0	0.0	0.0	100.0 (35)	5.2	} 85	64	Low-medium
	10-20	62.5	32.8	8.2	0.0	8.2	0.0	100.0 (36)	14.6			
S.4 .. ..	Under 10	84.4	11.7	2.6	0.0	2.6	1.8	100.0 (77)	13.5	} 12	41	Low
	10-20	58.4	38.5	2.6	0.0	2.6	2.6	100.0 (39)	26.2			

## Part (iii)—Three bituminous coal collieries (238 men).

B.1 .. ..	Under 10	66.7	23.1	10.3	0.0	10.3	0.0	100.0 (39)	15.5	} 39	46	Low-medium
	10-20	78.6	10.7	7.1	0.0	7.1	3.6	100.0 (28)	23.4			
B.3 .. ..	Under 10	100.0	0.0	0.0	0.0	0.0	0.0	100.0 (29)	5.4	} 4	8	Low
	10-20	100.0	0.0	0.0	0.0	0.0	0.0	100.0 (43)	14.9			
B.2 .. ..	Under 10	90.6	9.4	0.0	0.0	0.0	0.0	100.0 (32)	14.3	} 0	13	Low
	10-20	(100.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	100.0 (5)	21.9			

(For Notes to Table XXIII, see next page)

Notes to Table XXIII

General:— Basis of selection: Collier (or assistant collier) some period, and in this occupation at time of examination (the great majority) or until recently (up to at most 3 years before); 90 per cent. or more of total employment as collier spent at colliery under examination; never a fireman-shotsman; hard-heading worker not more than 1 year altogether; other underground occupations together less than 5 years; set work on surface screens less than 5 years. (For colliery B.1, there was the additional criterion that 80 per cent. or more of the period spent as collier at that mine should have been in the Upper Rhas Llas seam; and for colliery B.2, there was the additional criterion that 70 per cent. or more of the period spent as collier at that mine should have been under the "clift" roof in the Black Vein. At collieries A.5 and S.1, periods worked as collier at the similar neighbouring colliery in each case were counted as periods at the colliery under examination.)

Columns:—

- (3)-(9). Two dots (..) indicate that no observation was made. Percentages are bracketed when the total in column (9) is less than 20.
- (6). Major consolidation comprises categories (d) coalescent nodulation, (e) massive shadows and (f) multiple fluffy shadows.
- (9). The figures in brackets and italicised are the absolute numbers.
- (11)-(13). Expected for men who had been colliers for similar periods to those of the men at the colliery concerned, but had been subjected to the incidences of the whole anthracite group of collieries taken together. The number expected in each X-ray category for a given colliery was obtained by applying in turn the percentages in that category for different periods spent as collier (under 10, 10-20 and 20+ years) among the men in Table XXII, Part (i), to the totals examined (all X-ray categories) for the same periods at the given colliery shown in the present table, column (9), and by computing the total.
- (11). Total number (all periods) of all observed cases with consolidation (column (7)) at the given colliery, expressed as percentage of total expected.
- (12). Total number (all periods) of all observed cases with abnormal X-rays (columns (4), (7) and (8)), expressed as percentage of total expected.
- (13). Arbitrarily classed as high, medium, low-medium and low incidences, as follows:—High, all consolidation observed per cent. of expected (column (11)) = 150 or more; medium, percentage = 150-75; low-medium, percentage = 75-25; low, percentage = under 25.

Expanded data of Table XXIII

(1) Of the 1,496 total men in the table, 98 (6.6 per cent.) had been hard-heading workers more than 1 week but not more than 1 year: (A.1, 2 (2.9 per cent.); A.6, 1 (2.4 per cent.); A.3, 13 (12.5 per cent.); A.8, 6 (4.0 per cent.); A.7, 2 (1.7 per cent.); A.4, 7 (5.3 per cent.); A.2, 25 (24.3 per cent.); A.5, 5 (6.3 per cent.); S.3, 1 (1.1 per cent.); S.1 and S.2, nil; S.5, 19 (12.3 per cent.); S.4, 4 (3.4 per cent.); B.1, 1 (1.5 per cent.); B.3, 10 (7.5 per cent.); B.2, 2 (5.4 per cent.).

(2) The following are the numbers with reticulation, their periods of employment, and the totals examined (all X-ray categories), for men with under 5 years total period as collier, at those collieries at which the under 10 years period is represented:—

A.1, 1 (3 years) of 13; A.3, 1 (4.9 years) of 12; A.8, 3 (4.8, 3.3 and 3.3 years) of 39; A.4, 1 (1 year) of 27; A.2, nil of 17; S.5, nil of 15; B.3, nil of 11.

(3) The following are the percentages in each X-ray category for men with total periods as collier of 10-15 and 15-20 years, respectively, at those collieries in which the under 10 years period is not represented:—

A.7.—Normal, 10-15 years, 44.9; 15-20 years, 20.5. Reticulation, 10-15 years, 49.0; 15-20 years, 59.0. Nodulation, 10-15 years, 6.1; 15-20 years, 17.9. Major consolidation, 10-15 years, nil; 15-20 years, 2.6. All consolidation, 10-15 years, 6.1; 15-20 years, 20.5. Indefinite, 10-15 years and 15-20 years, nil. Total cases: 10-15 years, 49; 15-20 years, 39.

A.5.—Normal, 10-15 years, 88.2; 15-20 years, 83.3. Reticulation, 10-15 years, 11.8; 15-20 years, 16.7. Nodulation, major consolidation, all consolidation and indefinite, nil. Total cases: 10-15 years, 17; 15-20 years, 12.

S.3.—Normal, 10-15 years, 47.6; 15-20 years, 50.0. Reticulation, 10-15 years, 38.1; 15-20 years, 15.4. Nodulation, 10-15 years, 9.5; 15-20 years, 30.8. Major consolidation, 10-15 years, 4.8; 15-20 years, 3.8. All consolidation, 10-15 years, 14.3; 15-20 years, 34.6. Indefinite, 10-15 years and 15-20 years, nil. Total cases 10-15 years, 21; 15-20 years, 26.



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S.1.—Normal, 10–15 years, 62.5; 15–20 years, 33.3. Reticulation, 10–15 years, 18.8; 15–20 years, 41.7. Nodulation, 10–15 years, 18.8; 15–20 years, 25.0. Major consolidation, 10–15 years and 15–20 years, nil. All consolidation, 10–15 years, 18.8; 15–20 years, 25.0. Indefinite, 10–15 years and 15–20 years, nil. Total cases: 10–15 years, 16; 15–20 years, 12.

S.2.—Normal, 10–15 years, 76.5; 15–20 years, 53.3. Reticulation, 10–15 years, 17.6; 15–20 years, 26.7. Nodulation, 10–15 years, 5.9; 15–20 years, 20.0. Major consolidation, 10–15 years and 15–20 years, nil. All consolidation, 10–15 years, 5.9; 15–20 years, 20.0. Indefinite, 10–15 years and 15–20 years, nil. Total cases: 10–15 years, 17; 15–20 years, 15.

S.4.—Normal, 10–15 years, 89.8; 15–20 years, 75.0. Reticulation, 10–15 years, 6.1; 15–20 years, 21.4. Nodulation, 10–15 years, 4.1; 15–20 years, nil. Major consolidation, 10–15 years and 15–20 years, nil. All consolidation, 10–15 years, 4.1; 15–20 years, nil. Indefinite, 10–15 years, nil; 15–20 years, 3.6. Total cases: 10–15 years, 49; 15–20 years, 28.

B.1.—Normal, 10–15 years, 81.3; 15–20 years, 56.6. Reticulation, 10–15 years, 12.5; 15–20 years, 30.4. Nodulation, 10–15 years, 6.3; 15–20 years, 13.0. Major consolidation, 10–15 and 15–20 years, nil. All consolidation, 10–15 years, 6.3; 15–20 years, 13.0. Indefinite, 10–15 and 15–20 years, nil. Total cases: 10–15 years, 16; 15–20 years, 23.

B.2.—Normal, 10–15 years, 94.1; 15–20 years, 86.7. Reticulation, 10–15 years, 5.9; 15–20 years, 13.3. Nodulation, major consolidation, all consolidation and indefinite, nil. Total cases: 10–15 years, 17; 15–20 years, 15.

(4) The numbers of cases in the individual categories (all periods) of major consolidation were as follows:—

A.1, coalescent nodulation, 4; multiple fluffy shadows, 1; total, 5. A.6, coalescent nodulation, 3; massive shadows, 4; multiple fluffy shadows, 1; total, 8. A.3, coalescent nodulation, 11; massive shadows, 2; total, 13. A.8, coalescent nodulation, 4; multiple fluffy shadows, 1; total, 5. A.7, coalescent nodulation, 1; massive shadows, 1; total, 2. A.4, coalescent nodulation, 1. A.2, coalescent nodulation, 1. S.3, coalescent nodulation, 4; multiple fluffy shadows, 1; total, 5. S.2, coalescent nodulation, 1.

TABLE XXIV

*Comparison of the incidence of X-ray abnormalities among home-colliers with the rank of the coal mined, at the 16 South Wales collieries (the collieries being placed in descending order of coal rank)*

Collieries in order of rank. (From Table VI)		Coal rank. (From Table VI)	Incidence of X-ray abnormalities. (From Table XXIII)	Reputed moisture conditions and estimated depth of workings. (From Table VI)	
(1)		(2)	(3)	(4)	
HIGH RANK ↑	A.1 ..	Anthracite : high rank	High .. ..	Dry and deep	
	A.2 ..		Low .. ..	<i>Damp and shallow*</i>	
	A.3 ..		High .. ..	Dry and deep	
	A.4 ..		Low-medium ..	Dry and medium depth	
	A.5 ..	Anthracite : lower rank	Low .. ..	<i>Damp and medium depth*</i>	
	A.6 ..		High .. ..	Dry and deep	
	A.7 ..		Medium .. ..	Dry and deep	
	A.8 ..		Medium .. ..	Dry and deep	
↓	S.1 ..	Steam : carbonaceous	Medium .. ..	Dry and deep	
	S.2 ..		Low-medium ..	Dry and deep	
	S.3 ..		Medium .. ..	Dry and deep	
	S.4 ..	Steam : semi-bituminous	Low .. ..	Dry and deep	
	S.5 ..		Low-medium ..	Dry and deep	
	LOW RANK	B.1 ..	Bituminous	Low-medium ..	Dry and deep
		B.2 ..		Low .. ..	Dry and deep
B.3 ..		Low .. ..		Dry and deep	

\* Collieries classed as damp are italicised.

TABLE XXV

Comparison of the incidence of X-ray abnormalities among home-colliers with the moisture conditions and the estimated depth of workings at the eight anthracite collieries (the collieries being placed in descending order of incidence of X-ray abnormalities as measured by the figures in column (2))

Colliery. (1)	Total observed X-ray abnormalities per cent. of expected. (From Table XXIII)			Moisture conditions of workings.*		Estimated depth of workings. (Ft.) (From Table VI)			
	All consolidation. (2)	All abnormal. (3)	Incidence class. (4)	Reputed conditions. (5)	Average relative humidity (per cent.). (6)	Minimum. (7)	Maximum. (8)	Average. (9)	Class. (10)
A.1	233	148	High .. ..	Dry ..	71	750	2,550	1,650	Deep
A.6	176	127	High .. ..	Dry ..	...	1,750	2,160	1,950	Deep
A.3	172	123	High .. ..	Dry ..	83	1,000	1,900	1,350	Deep
A.8	146	129	Medium .. ..	Dry ..	77	500	2,265	1,500	Deep
A.7	95	112	Medium .. ..	Dry ..	84	300	1,500	900	Deep
A.4	55	82	Low-medium ..	Dry ..	89	150	800	550	Medium
A.2	12	57	Low .. ..	Damp ..	84	20	750	400	Shallow
A.5	0	41	Low .. ..	Damp ..	...	150	1,140	700	Medium

\* The reputed conditions are taken from Table VI; the average relative humidity is from averages based upon all observations made at the coalface during the period, January, 1938, to October, 1940, and roughly weighted according to the number of men then working in different parts of the mines (observations by Dr. T. Bedford and Dr. C. G. Warner). The figures may be compared with that for a bituminous mine (B.3), which was 85 per cent.

TABLE XXVI

Comparison of the incidence of X-ray abnormalities among home-colliers with the incidence of certified silicosis among all employed underground at the 16 South Wales collieries (the collieries being first grouped by class of coal and then placed in descending order of incidence of certified silicosis as measured by the figures in column (3))

Class of coal. (1)	Certified silicosis.*		Colliery. (4)	Total observed X-ray abnormalities per cent. of expected. (From Table XXIII)			Reputed moisture conditions and estimated depth of workings. (From Table VI) (8)	
	Incidence class. (2)	Annual rate. (3)		All consolidation. (5)	All abnormal. (6)	Incidence class. (7)*		
Anthracite ..	High ..	23.8	A.1	233	148	High ..	Dry and deep	
		23.4	A.3	172	123	High ..	Dry and deep	
		14.7	A.6	176	127	High ..	Dry and deep	
	Low ..	3.2	A.2	12	57	Low ..	Damp and shallow	
		3.0	A.7	95	112	Medium ..	Dry and deep	
		2.3	A.4	55	82	Low-medium	Dry and medium depth	
			A.8	146	129	Medium ..	Dry and deep	
			A.5	0	41	Low ..	Damp and medium depth.	
	Steam ..	Low ..	1.0	S.5	35	64	Low-medium	Dry and deep
			0.6	S.1	87	93	Medium ..	Dry and deep
0.5			S.3	110	95	Medium ..	Dry and deep	
0.2			S.2	60	71	Low-medium	Dry and deep	
			S.4	12	41	Low ..	Dry and deep	
Bituminous ..	Low ..	0.8	B.1	39	46	Low-medium	Dry and deep	
		0.2	B.2	0	13	Low ..	Dry and deep	
			B.3	4	8	Low ..	Dry and deep	

\* The incidence class is taken from Table VI; the annual rate is the average annual incidence of certified silicosis, per 1,000 employed underground, for the period 1931-38. (Rate for colliery S.1 includes that of an adjoining colliery, and rate for B.2 is approximate.)

TABLE XXVII

(17520) Comparison of the incidence of reticulation with the incidence of consolidation among home-colliers at the 16 South Wales collieries (the collieries being placed in Parts (i) and (ii) in descending order of incidence of consolidation as measured by the figures in columns (3) and (8), respectively)

Part (i).					Part (ii).				
Colliery. (1)	Ratio of observed* number in stated X-ray category to observed number in normal category (all employment periods).				Colliery. (6)	Observed ratios of Part (i) expressed as percentages of corresponding expected† ratios.			
	Normal. (2)	Consolidation. (3)	Reticulation. (4)	Consolidation + reticulation.‡ (5)		Normal. (7)	Consolidation. (8)	Reticulation. (9)	Consolidation + reticulation. (10)
A.6	1	2.63†	1.50	4.13	A.1	100	363	172	230
A.3	1	0.89†	0.82	1.71	A.6	100	332	168	245
A.1	1	0.80	0.88	1.68	A.3	100	226	125	163
A.7	1	0.64	1.50	2.14	A.8	100	183	153	162
S.3	1	0.64	0.77	1.41	A.7	100	118	147	137
S.1	1	0.48	0.87	1.35	S.3	100	102	79	88
A.8	1	0.40	0.74	1.14	S.1	100	78	89	85
S.2	1	0.23	0.54	0.77	A.4	100	47	86	74
B.1	1	0.13	0.25	0.38	S.2	100	41	54	49
A.4	1	0.10	0.41	0.51	S.5	100	26	57	47
S.5	1	0.09	0.41	0.50	B.1	100	22	25	24
A.2	1	0.03	0.33	0.36	A.2	100	10	56	40
S.4	1	0.03	0.28	0.31	S.4	100	5	28	20
B.3	1	0.01	0.04	0.05	B.3	100	2	6	4
A.5	1	0.00	0.32	0.32	A.5	100	0	34	20
B.2	1	0.00	0.09	0.09	B.2	100	0	9	6

\* The number observed in each X-ray category was derived from Table XXIII, columns (3)-(9).

† Expected for men who had been colliers for similar periods to those of the men at the colliery concerned, but had been subjected to the incidences of the whole anthracite group of mines taken together. The number expected in each X-ray category was calculated as described on p. 72 in connection with Table XXIII.

‡ The large difference between the consolidation ratios for these two mines is mainly artificial, due to the colliers examined at A.6 having all had 20 or more years service, whereas those examined at A.3 represented all lengths of employment (see Table XXIII).

§ Column (5) is the sum of columns (3) and (4).

## CHAPTER 8

**Incidence of X-ray Abnormalities among Workers from Colliery Surface Screens, and among Hauliers exposed to Shale Stone-Dust**

During the second stage of the medical survey a small investigation was made of two other groups of colliery workers whose occupations exposed them to air-borne dust. The findings in both groups have a bearing on the collier problem.

## A. WORKERS ON SURFACE SCREENS

At most large collieries in South Wales the trams (or tubs) of coal, on reaching the surface, travel by gravity to a weighbridge where, after being weighed, the coal is emptied by tippler attendants, by means of mechanically operated revolving tipplers, down chutes on to bar screens, referred to locally as "billy" bars. The small coal (culm) (approx.  $1\frac{1}{2}$ -0 in.) is thus separated from the large coal. The latter is often further screened on jiggling screens, adjusted in size to meet market conditions, before passing on to slow-moving belts where slag pickers are employed in picking off shale or other adventitious material ("dirty coal"). The clean large coal is eventually delivered directly into trucks under the screens.

The small coal, separated from the large coal by means of the bar screens, is sometimes delivered into wagons and sold as it is; but more usually, together with the coal removed by the jiggling screens, it is conveyed to a washery where it is cleaned, and then sized into various grades, such as (washed) cobbles, nuts, beans, peas and duff. At the anthracite collieries it is generally the practice to size the small coal before washing, and the duff ( $\frac{3}{16}$ -0 in.) is not treated; at many such collieries, too, the cobbles and large nuts are cleaned by hand-picking in the same way as the large coal is cleaned, the other sizes being treated in wet washers.

Because of the big demand for sized coals, it has long been necessary in the anthracite field to break the large coal, and sometimes the larger of the sized coals, in crushers, in order to augment the supply of the smaller sized coals. In recent years it has been necessary to adopt this procedure at many of the steam coal collieries also. The broken coal from the crushers is usually treated in the same way as the small coal referred to above.

The layouts of the coal treatment surface-plants, and the details of the screening and cleaning, are many and varied, and the above is but a broad generalisation.

In general, the main exposure to coal dust on the colliery surface is suffered by the workers employed in these operations, and for convenience they are here all termed screens workers. As a group they may be considered to be exposed mainly to dust derived from the coal as it is won at the coalface, but without the underground environment. The freshly wrought coal will consist of the coal from the seam and, in varying degree, of adventitious material; the latter may include clod from immediately above the seam, or from partings in the seam, and shale from the cliff roof or fireclay from the floor at the face, although so far as possible the collier removes this "rubbish" and casts it into the waste (gob). (See Chapter 3 for explanation of these terms.)

The method of selection, from the colliery "working populations", of the screens workers to be examined was described on p. 39, a total of 49 such men with long service in this occupation, and with little or no underground experience, being finally available. Thirty-four of them came from various anthracite collieries of the series (including 16 men from A.3, from Table XX, 10-20 and 20-45 years employment periods), and 15 from the steam and bituminous coal collieries. The results of their X-ray examinations, grouped according to length

of service, are given in Table XXVIII (p. 101), which brings out the following points :—

(1) A number of X-ray abnormalities similar to those seen in colliers were found among these screens workers. The changes included both consolidation and reticulation, the latter being found more frequently. As in colliers, the abnormalities increased in both frequency and degree with length of service.

(2) As indicated in the notes to the table, none of the three men classed as showing consolidation, and only two of the eight with reticulation, had been employed in any colliery underground occupation; and only one of the consolidation cases and three of the reticulation cases had been engaged in any other occupation at all that could be regarded as suspect. The evidence is therefore in favour of the majority of the X-ray abnormalities having been produced on the colliery surface.

(3) A note to the table shows that the incidence of X-ray abnormalities was higher among the 34 anthracite screens workers than among the 15 men who had worked on the screens at the non-anthracite collieries. This difference, which agrees with that found for colliers, must, however, be treated as no more than a suggestion, owing to the small numbers in the two sub-groups.

#### B. HAULIERS EXPOSED TO SHALE STONE-DUST

In non-anthracite mines an incombustible stone-dust is applied systematically to the underground roadways right up to the coalface, to reduce the effects of possible explosions. This practice has been carried out at some collieries since 1910, but has become general since the regulations of 1920. Stone-dusting is not carried out in anthracite mines.

The stone-dust used has differed from one mine to another, and in some mines it has been changed at various times. The three chief types have been shale, limestone, and, less frequently, fuller's earth. The shales are usually of local origin, their source being often the strata adjacent to one of the coal seams at the colliery itself; they are also usually crushed and prepared locally. The limestone and fuller's earth are obtained from outside suppliers. There has been, on the whole, a tendency to discontinue the use of fuller's earth, and to replace shale by limestone. These variations and changes, as they apply to the eight steam and bituminous coal mines of the present series, are shown in Table VI (p. 44), column (16). It may be seen that only two of these mines, both bituminous, were using shale at the time of the investigation; they had used it exclusively, or mainly, throughout the whole period of stone-dusting.

The collier at the face in such mines is exposed to this stone-dust in addition to the coal and stone-dust that he himself produces in the course of getting the coal and ripping the roof or floor of his working place. While no harmful effect has been attributed to limestone dust, it has been suggested that shale may introduce an additional deleterious factor. That this is unlikely, so far as colliers are concerned, is shown by the present inquiry, since at the two bituminous mines, B.1 and B.2, in which the dusts used over the whole period of stone-dusting practice have been mainly shales, the incidence of X-ray abnormalities found among the colliers was comparatively low. Nevertheless, it was decided to make some examinations of hauliers and riders on the roadways of these two collieries, since such men would be expected to be exposed continually to the applied shale dust—disturbed by the feet of men and horses and by the movement of traffic—and with less admixture of coalface dust than in the case of the air-borne dust inhaled by the colliers themselves.

The method of selection and procedure of examination of these hauliers was described on p. 40. A total of 60 men who had been employed for substantial periods in this occupation in non-anthracite (mainly bituminous) mines using shale for stone-dusting, and whose other colliery occupations had

entailed a presumed low dust hazard, was selected from the "working populations" of collieries B.1 and B.2 (which were combined for this analysis). The results of the X-ray examinations are given in Table XXIX (p. 102), the men being grouped according to total period spent as haulier or rider *exposed to the shale dust*.

It can be seen that there were nine cases of reticulation among the 60 men of ten or more years exposure, but that there was none of consolidation. The incidence of abnormalities was thus comparatively low. These results do not suggest any considerable hazard in the inhalation of shale dust under these conditions. Such risk as is indicated may, moreover, be exaggerated, owing to the inclusion of men who had spent up to ten years as colliers, which might account for some, at least, of the abnormalities found. On the other hand, few of these men had been exposed to shale dust for more than 20 years, and the effect of more prolonged exposure could not be studied, owing to the limited period during which stone-dusting had been a general practice in non-anthracite mines.

It should be emphasised that the present results refer to the risks from exposure to shale dust incurred by hauliers who had worked principally in bituminous mines. Generalisation to other non-anthracite mines would be unwise, since it is conceivable that an examination of hauliers exposed to shale dust from the strata adjoining steam coal seams might give different results.

An attempt was also made to compare the risks of hauliers in bituminous mines with those in anthracite mines. A sub-group of 37 men was taken from the above 60, as satisfying more stringent criteria regarding other occupations permitted; their X-ray results are given in Table XXX (p. 102), the men being grouped according to the total period spent as haulier or rider and not, as in Table XXIX, as haulier or rider *exposed to shale dust*.\*

Selected and grouped in this way, these 37 men are comparable with the 29 anthracite (mainly A.3) hauliers of 10 or more years service in Table XVI (p. 65). Although the numbers examined were small, comparison of Table XXX with Table XVI suggests that the risk of the occupation of haulier in bituminous mines was certainly no greater, and was possibly less, than that of haulier in anthracite mines.

#### SUMMARY OF CHAPTER 8

(1) Examination of 49 long-term surface screens workers, with little or no experience in underground work, selected from the 16 South Wales collieries, showed a number of X-ray abnormalities similar to those found among colliers underground. The frequency and degree of the changes were greater among men of 20 or more years service on the screens than among those of 10-20 years service. There was a suggestion that anthracite screens workers had a higher incidence of abnormalities than non-anthracite screens workers, in conformity with the definite differences previously found in colliers.

(2) Examination of a group of 60 underground hauliers selected from two of the bituminous coal collieries of the series, B.1 and B.2, who had been for substantial periods in these or any other non-anthracite mines (actually, mainly bituminous) where shale was the material employed for stone-dusting, did not suggest any considerable hazard in the inhalation of the shale dust under these conditions. The period of exposure to the shale dust was, however, for the most part between 10 and 20 years, and no study of the effect of longer exposure was possible, owing to the limits fixed by the date of the introduction of the practice of stone-dusting, and owing to the use in many mines of limestone dust as an alternative to shale.

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\* This difference in grouping accounts for the number and mean period in the older period-group being much greater than in Table XXIX. For not all the period during which a man had been haulier had been spent at a shale-dusted mine, nor had he been exposed to shale dust during the whole of the period spent at such a mine, since for some periods the roads might have been watered as an alternative treatment.

No generalisation concerning non-anthracite mines other than bituminous should be made from these results.

(3) Comparison of the risks of a sub-group of 37 of the 60 hauliers from collieries B.1 and B.2, with a comparable group selected from anthracite colliery A.3 (studied in Chapter 6), suggested that the occupation of haulier in non-anthracite mines (mainly bituminous) carried a risk no greater, and possibly less, than the occupation of haulier in anthracite mines (mainly A.3). Both these groups of hauliers included men whose service in this occupation had been of great length.

TABLE XXVIII

*Number, according to length of service, of X-ray abnormalities among 49 long-term surface screens workers from the 16 South Wales collieries\**

Total period on screens. (Years)	Number in each X-ray category.				All X-ray categories.	Mean period on screens. (Years)
	(a) Normal.	(b) Reticulation.	(c-f) Consolidation.	(g-h) Indefinite.		
10-20	16	2	—	—	18	15.4
20-45	21	6	3	1	31	27.7
10-45	37	8†	3‡	1	49	23.2

\* Basis of selection: This was, originally, at all collieries except A.3, 20 or more years set work on surface screens, and no underground occupation; but about a third of the men so selected were found to have spent only 10-20 years on the screens, and a few had spent quite short periods in underground occupations. These are, however, included in the table, as well as 16 screens workers of A.3 (from Table XX) with 10 or more years experience on screens and less than 5 years underground experience. Hence the basis of selection of the screens workers from all the 16 collieries may be best described as: 10 or more years on surface screens; less than 5 years all underground occupations (including collier) together; never a hard-heading worker nor fireman-shotsman.

† One man had been also a stone-dresser at a flour mill (16 years), and 2 had worked underground (as colliers) for 3 years; but the other occupations of the remaining 5 men were not deemed to have carried a dust risk.

‡ Comprising 1 nodulation and 2 major consolidations (both massive shadows). One man had also been a mason for 13 years (massive shadows); but the other occupations of the remaining 2 men (1 nodulation, 1 massive shadows) did not appear likely to have carried a dust risk.

*Expanded data.*—(1) Of the 49 screen workers, 39 had not been employed in any colliery underground occupation. The results of these were:—10-20 years, 15 men (13 normal, 2 reticulation); 20-45 years, 24 men (17 normal, 4 reticulation, 3 consolidation (1 nodulation, 2 massive shadows)); 10-45 years, 39 men (30 normal, 6 reticulation, 3 consolidation).

(2) The results for the collieries separately were:—A.1, 2 men (1 reticulation, 1 massive shadows); A.3, 16 men (12 normal, 3 reticulation, 1 massive shadows); A.8, 3 men (2 normal, 1 reticulation); A.7, 4 men (3 normal, 1 reticulation); A.4, 4 men (2 normal, 1 reticulation, 1 nodulation); A.2, 3 men (all normal); A.5, 2 men (1 normal, 1 indefinite); total anthracite, 34 men (23 normal, 7 reticulation, 3 consolidation, 1 indefinite). S.3, 4 men (3 normal, 1 reticulation); S.2, 1 man (normal); B.1, 4 men (all normal); B.3, 6 men (all normal); total non-anthracite, 15 men (14 normal, 1 reticulation).



TABLE XXIX

*Number, according to length of exposure to shale used for stone-dusting, of X-ray abnormalities among 60 hauliers from the two bituminous coal collieries, B.1 and B.2, combined\**

Total period as haulier or rider exposed to shale dust. (Years)	Number in each X-ray category.				All X-ray categories.	Mean period as haulier or rider exposed to shale dust. (Years)
	(a) Normal.	(b) Reticu- larion.	(c-f) Consoli- dation.	(g-h) Indefinite.		
10-20	46	7	—	—	53	15.5
20-25	5	2	—	—	7	22.5
10-25	51	9	—	—	60	16.3

\* Basis of selection: Haulier or rider, 10 or more years at either B.1 or B.2 or at any other non-anthracite mine employing shale for stone-dusting; haulier or rider at B.1 or B.2 at time of examination; never a hard-heading worker, fireman nor shotsman; less than 10 years a collier, and less than 5 years a repairer or underground labourer; less than 10 years on surface screens. (The other shale-dusted mines were actually mainly bituminous, as were B.1 and B.2.)

TABLE XXX

*Number, according to length of service, of X-ray abnormalities among 37 hauliers from the two bituminous coal collieries, B.1 and B.2, combined\**

Total period as haulier or rider. (Years)	Number in each X-ray category.				All X-ray categories.	Mean period as haulier or rider. (Years)
	(a) Normal.	(b) Reticu- larion.	(c-f) Consoli- dation.	(g-h) Indefinite.		
10-20	9	3	—	—	12	17.4
20-50	21	4	—	—	25	28.7
10-50	30	7	—	—	37	

\* Basis of selection: As for Table XXIX, except less than 5 years all underground occupations (including that of collier) together. The 37 men in this table are thus included also in Table XXIX.

## CHAPTER 9

### Character and Incidence of X-ray Abnormalities attributable to Dust among Anthracite and Non-Anthracite Coaltrimmers in South Wales

Coaltrimmers are employed on the dockside at coal-exporting ports. Their work may be classed as casual labour, though they do no other work. They work in gangs, usually of about seven men, one gang being allocated to each ship, under the supervision of a deck foreman.

The coal is tipped from railway trucks, generally of 10/12 tons capacity, down chutes; and it pours through the hatches into the ship's hold. This operation is directed by the foreman on the deck; while the trimmers are usually in the hold, ready with short-handled shovels to cast the coal into every available space, so that the greatest quantity possible may be carried, and so that the cargo may not shift and make the ship unseaworthy. These operations, termed trimming, are carried out in an atmosphere of dust created

when the coal pours through the hatches and during its distribution by the trimmers in the hold.

The amount of dust varies with the rank of the coal being shipped, i.e. steam, bituminous or anthracite, and with its particular commercial grade. With regard to the latter, it is stated that unwashed "dry steam" "through coal" (the run of the mine), culm (small coal), duff (smallest coal) and "bunkers," and anthracite duff, produce the heaviest dust concentrations; that unwashed steam and anthracite large coal (hand-picked free from shale and other adventitious matter) and sized coals create less dust; and that washed sized coals create the least dust.

To reduce in some degree the air-borne dust, an attempt at watering during the tipping of the coal has latterly become prevalent.

Trimmers may be considered to be exposed to the dust derived from coal as marketed. Some of the grades, e.g., through coal and unwashed small coal, often contain considerable amounts of adventitious mineral matter, while other grades, e.g. washed sized coals, are comparatively free from this. The amount of adventitious mineral matter inhaled by the trimmer, therefore, varies considerably with the grade of coal handled, although, however clean the latter may be, there is always some (inherent) mineral matter present.

Obviously an inquiry into the possible effects of the inhalation of dust during coaltrimming is of great relevance to the problem of chronic pulmonary disease among colliers. It was considered particularly desirable to parallel the survey of colliers working different classes of Welsh coal by a similar survey of trimmers handling these different coals in their various commercial forms.

X-ray examinations of coaltrimmers were therefore carried out, as the third stage of the medical field survey, at four of the five principal coal ports of South Wales. At one of these ports—PA—the coal handled over the past 30 years or so had been mainly anthracite; at two of them—PSa and PSb—it had been chiefly steam coal; and at the remaining port—PB—it had been mainly bituminous. The coaltrimmers examined (470 in all) were men selected from the total coaltrimmer "working populations" who had worked in this occupation for a considerable time. No men of under 10 years service—and at ports PA, PSb and PB none of under 20 years experience—were examined; men with coalmining experience were excluded (see p. 40, and Table VII, p. 46).

Many of the X-ray films of these coaltrimmers were found to show abnormal appearances, the character and types of the changes being similar to those described for coalminers, though there were some slight differences. Thus, the proportion of atypical reticulation cases, with network of wider mesh and thicker strands than the average (see p. 48, footnote), was greater in the coaltrimmers than in the miners. Consolidation films also tended to be "dirtier" in appearance than similar films of miners, and the snowstorm effect of generalised nodulation was less evident. Lastly, the proportion of "normal" and reticulation films that had homogeneous or patchy shadows (? tuberculous, ? pneumokoniotic) at one or both apices (p. 48) was considerably greater than among the colliers. In spite of these differences, however, the X-ray changes were sufficiently like those in the miners, and unlike appearances found with any frequency in the ordinary population, to justify the use of the classification described in Chapter 5.

The incidence of X-ray abnormalities in these trimmers is given in Table XXXI (p. 107) for all four ports combined, and also for the individual ports, the men in each case being grouped according to the total period spent in this occupation. For the individual ports, in addition to the incidence for each length-of-employment group, a single figure is given for consolidation observed per cent. of expected, and for all abnormalities observed per cent. of expected, so that the relative incidence of X-ray abnormalities (all lengths of employment) at each port can be assessed conveniently. The expected cases are those which the

port would have had if the men in each of the three length-of-employment groups had experienced the same incidence-rates as the men of the corresponding lengths of employment when all the four ports are put together. The method of calculation is similar to that for the 16 collieries in Chapter 7.

Table XXXI brings out the following points:—

(1) Taking all ports and all employment periods together (Part (i)), the most frequent abnormality was reticulation, present in 28·5 per cent. of the men; the composite category consolidation—the other main change—was present in 10·1 per cent. Subdividing the latter, the incidence of major consolidation (6·2 per cent.) was greater than that of nodulation (3·9 per cent.). Subdividing major consolidation still further into its three component categories (see note to table), massive shadows and multiple fluffy shadows were found more frequently than coalescent nodulation.

(2) Taking the four ports individually (Part (ii)), the incidence of abnormalities varied considerably. The percentage of normal X-rays among trimmers at the two steam coal ports was lower, and the percentages of nodulation, major consolidation and all consolidation, higher, than at either the bituminous coal or the anthracite port. Similar differences are apparent for reticulation in the 20–30 years period-group, though not for the older groups, probably on account of transfer of part of the reticulation to consolidation. The strongest contrast in these abnormalities is between one of the steam coal ports, PSa—where consolidation as well as reticulation was present in fair amount and included major consolidation—and the anthracite port, PA, at which there was very little consolidation, no case of major consolidation, and the abnormalities found were practically confined to reticulation.

Assessing the relative incidence of X-ray abnormalities at the different ports by the single figures in columns (12) and (13), it will be seen that on the basis either of consolidation or of all abnormals observed per cent. of expected, the ports fall into the following order: PSa (steam coal), PSb (steam coal), PB (bituminous coal), PA (anthracite). Again the widest contrast is between steam coal port, PSa, with the highest, and anthracite port, PA, with the lowest, incidence of X-ray abnormalities, and the contrast is best shown in the consolidation figures.

(3) At each port there was a progressive decrease in the incidence of normal X-rays with duration of employment, i.e. a progressive increase in the incidence of total abnormalities. Taking the two main types of abnormality separately, there was a progressive increase of reticulation at three ports, and at the two ports of higher incidence there was an increase in consolidation up to the 30–40 years period, but no further increase thereafter. At all ports reticulation was a more frequent abnormality than consolidation throughout the employment periods, and its incidence indicated that it was the earlier change. At PSa, the only port at which the 10–20 years period-group was represented (data given in a note to the table), consolidation had not yet made its appearance at this period, although reticulation was present.

The figures of Table XXXI show a general resemblance to those for home-colliers at the 16 collieries (Chapter 7). There are, however, two important differences, the second of which is of great interest in the problem of the colliers. The first difference is in the relative frequencies of the individual categories that make up consolidation. Among colliers, films classed as nodulation or coalescent nodulation were more frequent than those classed as massive shadows or as multiple fluffy shadows; among trimmers the reverse was the case (compare Table XXII with Table XXXI). The second difference is in the relative incidence of abnormalities at mines and ports concerned with different types of coal. For colliers, the anthracite mines as a group showed the highest incidence, and the bituminous mines the lowest, the steam coal group being intermediate; i.e. the anthracite mines had, as a group, a distinctly higher

incidence than the non-anthracite mines. For coaltrimmers, on the other hand, the anthracite port showed the lowest incidence, and the steam coal ports the highest, the bituminous coal port being intermediate, i.e., the anthracite port had a *lower* incidence than the non-anthracite ports. This paradox immediately raises the question whether the incidence among anthracite trimmers was unexpectedly low compared with that in anthracite colliers, or whether the incidence among non-anthracite trimmers was unexpectedly high compared with that in non-anthracite colliers.

Unfortunately, comparison of the incidence of X-ray abnormalities among the trimmers after different lengths of employment, with the incidence for similar lengths of employment among the home-colliers, cannot easily be made. The hours per shift for trimmers in South Wales were slightly more than those for miners. This is, however, more than counterbalanced by the fact that during the past 20 years or more (wars excepted), a full week of shifts had not been regularly worked by the trimmers—largely owing to conditions of trade. As a rough approximation, it may be taken that in a year of working life a trimmer had worked two-thirds to three-quarters of the shifts of a miner in full employment. Because of this difference, comparison between trimmers and colliers tends to *under-estimate* the relative risk incurred by the former. On the other hand, the age-composition of the South Wales coaltrimmer working populations was older than that of the selected colliers; thus, the mean period of employment on the coal of the selected trimmers of 20 or more years service was greater than that of the colliers of 20 or more years service selected from any of the 16 collieries. This difference would tend to make the relative risk of trimming, *over-estimated* in a comparison with the occupation of collier.

Probably the most informative way of comparing the incidence of X-ray abnormalities among the trimmers with that among the home-colliers is to use, for each port, figures of total consolidation observed per cent. of expected, and of total abnormalities observed per cent. of expected. For this purpose the totals expected at the ports were recalculated on the same basis as previously used for the colliers at each mine (Table XXIII), i.e. on the basis of the incidence-rates for the eight *anthracite mines* taken together (instead of for the four ports together); these rates were applied to the total numbers of men in the same length-of-employment groups who were examined at the individual ports. When the resulting figures (not tabulated) were compared with the corresponding figures for the different collieries shown in Table XXIII, it was found that the two steam coal ports would be classed as having low-medium incidences of X-ray abnormalities on the arbitrary classification adopted for collieries (see p. 72), and that the anthracite and the bituminous coal ports would be classed as having low incidences. For the steam and bituminous coal ports, medium and low incidences are not remarkably different from the characteristic incidences for the corresponding classes of colliery. On the other hand, the low incidence for the anthracite port is exceptional as compared with the characteristically high or medium incidence for anthracite collieries. It seems, therefore, that the paradox of the anthracite trimmers having a lower incidence of abnormalities than the non-anthracite trimmers, in contrast to the anthracite colliers having, as a group, a higher incidence than the non-anthracite colliers, arises from an unexpectedly low incidence among the anthracite trimmers rather than from an unexpectedly high incidence among the steam or bituminous coal trimmers.

It has been stated already that commercial grades of coals differ in their dust-forming propensities and in their content of adventitious mineral matter. Export statistics suggest that, over a period of time, the coals handled by trimmers at these coal ports will, in fact, have differed not only in class (anthracite, steam, bituminous, and their finer subdivisions of rank), but also in the proportions of the commercial grades handled (through, large, small, sized, etc.), the anthracite showing a differential tendency towards washed and

sized grades. It is possible, therefore, that the explanation of the paradoxical findings among anthracite trimmers lies in differences between the *commercial grades* of coals mainly handled at the anthracite port PA and those at the other three ports, such differences bringing the incidence of pulmonary abnormalities among the anthracite trimmers below that which would have been expected from the incidence among the anthracite colliers, but leaving the incidences of abnormalities among the steam and bituminous coal trimmers much the same as those among the corresponding classes of collier. To pursue this question further it would be necessary to determine in detail the absolute and relative amounts of the grades of coals shipped from each port over a period of years, noting any differential trends, and also to make analyses of the concentration and composition of the air-borne dust in the holds of an adequate sample of ships. It has not been practicable to carry out these further statistical and analytical environmental investigations within the limits of the present inquiry.

#### SUMMARY OF CHAPTER 9

(1) An investigation has been made, by chest X-ray and industrial history, of 470 coaltrimmers selected from four of the five principal South Wales coal ports. At one of these ports the coal handled was mainly anthracite, at two mainly steam coal, and at one mainly bituminous coal. None of the men examined had been trimmers for less than 10 years, and at three ports none had been in this occupation for less than 20 years.

(2) Apart from minor differences, the X-ray appearances conformed in type to those found among colliers, the chief pulmonary abnormalities being reticulation and the composite category, consolidation. Of 435 trimmers of 20 or more years service, reticulation was found in 124 (28·5 per cent.) and consolidation in 44 (10·1 per cent.). Division of the latter group showed, however, that it differed from the finding in the colliers, in that massive shadows and multiple fluffy shadows were more frequent than nodulation and coalescent nodulation. (In the post-mortem study by Gough (1940), trimmers with the X-ray appearances of advanced consolidation showed gross fibrotic changes similar in type to those found in colliers, in the present inquiry, by Belt.)

(3) The incidence of X-ray abnormalities (best shown in respect of consolidation) was highest among trimmers at the two steam coal ports, intermediate among those at the bituminous coal port, and lowest at the anthracite port, whereas at the 16 mines investigated, the incidence of abnormalities tended to be relatively high among anthracite colliers, and to be lower among steam and bituminous coal colliers.

(4) As with colliers, the X-ray changes among trimmers increased in frequency and degree with the length of employment.

(5) Possible reasons for the paradoxical finding of a higher incidence of pulmonary X-ray abnormalities among the non-anthracite compared with the anthracite trimmers, in direct contrast to the generally higher incidence of abnormalities among anthracite compared with non-anthracite colliers, are briefly discussed. It is shown that the paradox probably arises from the incidence of abnormalities among the anthracite trimmers being low in relation to what might have been expected from the findings among anthracite colliers, rather than from the incidence of abnormalities among the trimmers handling steam and bituminous coal being peculiarly high.

On *prima facie* grounds it is tentatively suggested that differences in the proportion of the various *commercial grades* of coals exported from these ports might explain this reversal of the incidence levels that, with colliers, appeared to be related to the *rank* of the coal mined. It might be that the dustiness or dust-forming propensity of the chief grades shipped from the anthracite port was considerably less than of those shipped from the steam coal ports.

TABLE XXXI

Incidence, according to length of service, of X-ray abnormalities among 470 coaltrimmers from 4 South Wales coal ports

Part (i)—The ports taken together.

Coal port. (1)	Rank of coal mainly handled. (2)	Total period as coaltrimmer. (Years) (3)	Percentage (and number) in each X-ray category.						All X-ray categories. (10)
			(a) Normal. (4)	(b) Reticulation. (5)	(c) Nodulation. (6)	(d-f) Major consolidation (7)	(c-f) All consolidation. (8)	(g-h) Indefinite. (9)	
All ports .. ..	Various .. ..	20-30	68.1 (87)	22.7 (27)	3.4 (4)	2.5 (3)	5.9 (7)	3.4 (4)	100.0 (119)
		30-40	56.5 (126)	28.5 (69)	5.4 (12)	6.7 (15)	12.1 (27)	4.9 (11)	100.0 (223)
		40+	41.9 (39)	40.9 (38)	1.1 (1)	9.7 (9)	10.8 (10)	6.5 (6)	100.0 (93)
		20+	56.6 (246)	28.5 (124)	3.9 (17)	6.2 (27)	10.1 (44)	4.8 (21)	100.0 (436)

Part (ii)—The ports taken individually.

Coal port. (1)	Rank of coal mainly handled. (2)	Total period as coal- trimmer. (Years) (3)	Percentage in each X-ray category.						All X-ray categories. (10)	Mean period as trimmer. (Years) (11)	Observed X-ray abnormalities per cent. of expected (all periods 30 + years).		
			(a) Normal, (4)	(b) Reticulation, (5)	(c) Nodulation, (6)	(d-f) Major consolidation, (7)	(c-f) All consolidation, (8)	(g-h) Indefinite, (9)			(c-f) All consolidation, (12)	(b-h) All abnormals, (13)	
PA ..	Anthracite ..	20-30	70.4	18.5	3.7	—	3.7	7.4	100.0 (27)	27.0	} 29	81	
		30-40	68.6	23.5	3.9	—	3.9	3.9	100.0 (51)				34.4
		40+	47.8	47.8	—	—	—	4.3	100.0 (23)				44.9
PSa ..	Steam coal ..	20-30	66.7	23.3	3.3	3.3	6.7	3.3	100.0 (30)	26.6	} 176	124	
		30-40	41.1	35.7	7.1	16.1	23.2	—	100.0 (56)				34.6
		40+	33.3	42.9	—	19.0	19.0	4.8	100.0 (21)				42.8
PSb ..	Steam coal ..	20-30	59.8	33.3	3.7	3.7	7.4	—	100.0 (27)	26.2	} 132	106	
		30-40	54.2	20.3	5.1	10.2	15.3	10.2	100.0 (59)				36.2
		40+	47.1	29.4	5.9	11.8	17.6	5.9	100.0 (17)				42.6
PB ..	Bituminous ..	20-30	74.3	17.1	2.9	2.9	5.7	2.9	100.0 (25)	25.7	} 65	90	
		30-40	63.2	26.8	5.3	—	5.3	5.3	100.0 (57)				34.8
		40+	40.6	40.6	—	9.4	9.4	9.4	100.0 (32)				44.7

(For notes to Table XXXI, see next page.)

*Notes to Table XXXI*

- General (1). Basis of selection: Coaltrimmer, 20 or more years (at port PSa, 10 or more years); no coalmining experience; not a supervisor nor deck foreman at time of examination; not on short-time for a long period; not too fat for satisfactory X-ray. Period of work in column (3) excludes any time spent as tipper, waterman, call-boy, lamp-boy or screensman.
- (2). Period-group 10-20 years is omitted from the table, since it was only represented in port PSa. The percentage-incidences of X-ray abnormalities among the 35 men in this period-group examined at port PSa were as follows: Normal, 85.7; reticulation, 14.3; other categories, nil (mean period as trimmer, 14.4 years).
- Columns (4)-(10). Figures in brackets and italics at the side of percentages are the absolute numbers.
- (7). Major consolidation comprises categories (d) coalescent nodulation, (e) massive shadows and (f) multiple fluffy shadows.
- (12)-(13). Expected for men who had been coaltrimmers for similar periods to those of the men at the port concerned, but had been subjected to the incidences of the men at the 4 ports taken together. The number expected in each X-ray category for a given port was obtained by applying in turn the percentages in that category for different periods spent as trimmer (20-30, 30-40 and 40+ years) among the men in Table XXXI, Part (i), to the totals examined (all X-ray categories) for the same periods at the given port shown in Part (ii), column (10), and by computing the total.
- (12). Total number (all periods 20+ years) of all observed cases with consolidation (column (8)) at the given port, expressed as percentage of total expected.
- (13). Total number (all periods 20+ years) of all observed cases with abnormal X-rays (columns (5), (8) and (9)), expressed as percentage of total expected.

*Expanded data of Table XXXI*

The numbers of cases in the individual categories of major consolidation (all ports together, Part (i)) were as follows:—20-30 years, coalescent nodulation, 1.7 per cent. (2 cases); multiple fluffy shadows, 0.8 per cent. (1 case); total, 2.5 per cent. (3 cases). 30-40 years, coalescent nodulation, 0.9 per cent. (2 cases); massive shadows, 2.7 per cent. (6 cases); multiple fluffy shadows, 3.1 per cent. (7 cases); total, 6.7 per cent. (15 cases). 40+ years, massive shadows, 6.5 per cent. (6 cases); multiple fluffy shadows, 3.2 per cent. (3 cases); total, 9.7 per cent. (9 cases). 20+ years, coalescent nodulation, 0.9 per cent. (4 cases); massive shadows, 2.8 per cent. (12 cases); multiple fluffy shadows, 2.5 per cent. (11 cases); total, 6.2 per cent. (27 cases)

The numbers of cases in these individual categories (all periods) for the ports taken individually (Part (ii)) were as follows:—PSa, coalescent nodulation, 1; massive shadows, 4; multiple fluffy shadows, 9; total, 14. PSb, coalescent nodulation, 2; massive shadows, 5; multiple fluffy shadows, 2; total, 9. PB, coalescent nodulation, 1; massive shadows, 3; total, 4.

## CHAPTER 10

### Respiratory Disability and other Clinical Manifestations among South Wales Coalminers and Coaltrimmers in relation to their X-ray Abnormalities

The chief object of the clinical examinations made in this inquiry was to determine the degree and frequency of functional disability associated with each definable type of radiological change that had been observed. For this purpose an extensive clinical examination of the entire population (i.e. the "registered population") of the anthracite colliery A.3 was made during the first stage of the medical field survey. Lung volume determinations and tuberculin tests were also carried out upon a selection of these men. More limited clinical data, but of similar type, were obtained from the examinations of the selected colliers at the other 15 collieries (during the second stage of the field survey), and of the selected trimmers at the coal ports (during the third stage). These data will be discussed in turn.

### A. RESPIRATORY DISABILITY\* AND OTHER CLINICAL MANIFESTATIONS, IN RELATION TO X-RAY APPEARANCES, AMONG A.3 COLLIERY POPULATION

A colliery population is exposed to other environmental factors besides dust that might contribute to the production of adverse clinical effects, particularly respiratory disability. Such possibly harmful factors include rapid temperature changes, draughts and fumes. The question of suitable normal X-ray controls for clinical comparison with the men showing abnormal X-ray appearances requires, therefore, some discussion.

An attempt was made to find a suitable non-mining population which could be used as a control to the colliery population. There were no factories in the vicinity and, apart from mining, agriculture was the chief occupation of the county. Local farms or building projects were too small to yield sufficient men, and it did not seem advisable to use local townsmen in sedentary occupations. It was also deemed inadmissible to use groups obtained further afield in Wales, owing to the possible effect of racial differences; for example, many of the dockside workers in Swansea had a different physical build. The attempt to find a group of non-mining controls for clinical examination was therefore considered impracticable, and members of A.3 colliery population itself whose X-ray pictures were normal (X-ray category (a)) were used for comparison with the abnormal X-ray groups.

This arrangement had the inevitable potential disadvantage—which, however, would also have been present had non-mining controls been used—that the distribution of working environment was not the same among the normal and the abnormal X-ray groups. Thus, the proportion working on the colliery surface was greater for the normal X-ray category than for the abnormal categories. As a second control, therefore, figures for clinical findings for "normal X-rays, underground workers only" (X-ray sub-category (a')), are included in certain tables. It does not follow that sub-category (a') is necessarily a better normal control than category (a), even though it is confined to workers underground, since the underground environment of a colliery is far from uniform, quite apart from variations in dust hazard. For example, the population in X-ray sub-category (a') contained a greater proportion of non-colliers than did the population in the abnormal X-ray categories; and it is conceivable that these men might be more exposed, in the course of work on the roadways, to such factors as draughts—which are possibly accessory in the production of bronchitis and of disability—than were the colliers occupied at the coalface, who formed the main source of the abnormal X-ray groups. From these considerations, it is difficult to decide which is the more suitable normal X-ray control with which to compare the various clinical findings among men in the different abnormal X-ray categories; and in the tables where both the normal X-ray category (a) and its sub-category (a') are included, the former is used primarily for the comparisons, and the underground normals are regarded as supplementary.

The analyses of the clinical data in the present section are considered under the following headings: (i) physical measurements; (ii) respiratory disability; (iii) blood pressure; (iv) physical signs in the chest; (v) clinical modes of death; (vi) sputum examination; (vii) tuberculin test; (viii) lung volume determinations.

#### (i) *Physical measurements*

It is of some interest to quote physical measurements, to indicate the average stature and build of the population of colliery A.3. The figures tabulated below are based upon 66 of the clinically and radiologically normal members of the colliery population. Their ages ranged from 19 to 63 years (39 being aged 39 or under and 27 being aged 40 or over), and their heights from 60 to 71 in. Both surface and underground workers were included. The figures for this normal group are taken from Aslett, Hart and McMichael

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\* Respiratory disability is used here in a medical sense to mean some degree of impairment, respiratory in nature, of physical capacity for strenuous activity. Such disability can, of course, be slight or severe.



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(1939), where the detailed criteria of normality to which the subjects conformed are to be found.

Characteristic.	Mean.	Standard deviation.	Coefficient of variation. (Per cent.)
Age (years) .. .. .	38.3	9.6	25.1
Standing height (in.) .. .. .	65.8	2.3	3.5
Sitting height (in.) .. .. .	35.0	1.3	3.8
Weight (lb.) .. .. .	142.0	18.8	13.2
Surface area (sq. m.) .. .. .	1.71	0.13	7.5
Chest circumference (full insp.) (in.) .. .. .	36.3	2.3	6.3
Chest circumference expansion (in.) .. .. .	1.94	0.58	29.9

The mean age, 38.3 years, and the age-distribution indicate that the sample was representative of the span of working life. The mean height, weight, surface area and chest circumferential expansion were lower than would be expected in population groups in certain other parts of Great Britain, these differences probably being due to Welsh racial characteristics.

A question sometimes raised is whether mining and non-mining Welshmen differ in stature. During his study of changes in racial character of the population of the Llandeibie district in Wales, Daniel (1937) made a variety of physical measurements, of which standing height was obtained by a method similar to that used in the present series. Dr. Daniel, 1940 (personal communication), has re-analysed his Llandeibie figures, so as to compare the mean height of men engaged in mining at the time of examination with the mean height of those in non-mining occupations. The new figures are based upon 151 out of 156 adult males aged 15-65 years, of whom 60 are classed as mining and 91 as non-mining. The mean standing height of the mining sub-group is 1,657.5 mm., with standard deviation 63.6 mm., and of the non-mining sub-group 1,664.8 mm., with S.D. 73.5 mm. The difference between these two means, divided by the standard error of the difference, is 0.7, and is therefore statistically insignificant.

Daniel's study was made in a district close to colliery A.3, and at about the same time, and his population may perhaps be considered racially comparable with that of the population of this colliery. The mean standing height of the 66 selected normals from colliery A.3, converted into metric measure, is 1,671.3 mm., with S.D. 58.4 mm. This figure is slightly higher than the means both of the mining and of the non-mining sub-groups of Daniel's series, though the excess is statistically insignificant (difference, divided by S.E. of difference, between A.3 normals and mining sub-group is 1.3, and between A.3 normals and non-mining sub-group is 0.6).

An additional comparison may be made between Daniel's series and the whole population of colliery A.3 (560 men). The mean standing height of the latter is 1,662.2 mm., with S.D. 59.9 mm. This figure is intermediate between the means of the mining and of the non-mining sub-groups of Daniel's series and does not differ statistically from either (difference, divided by S.E. of difference, between A.3 whole population and mining sub-group is 0.5, and between A.3 whole population and non-mining sub-group is 0.3).

The mean heights of these various mining groups and of the non-mining group are shown together in the following tabulation, from which the similarity of the values is obvious:—

	Number of men.	Mean height.	S.D.
		mm.	
Daniel's series, non-mining .. .. .	91	1,664.8	73.5
Daniel's series, mining .. .. .	60	1,657.5	63.6
Colliery A.3 (mining), normals .. .. .	66	1,671.3	58.4
Colliery A.3 (mining), whole population .. .. .	560	1,662.2	59.9

There is in these figures no evidence that mining Welshmen are either shorter or taller than non-mining Welshmen from the same area. It is possible that comparisons of mining and non-mining Welshmen in general would reveal a significant difference, but such a difference might be due simply to the varying geographical distribution and racial composition of the mining and non-mining populations of this country.

It has been contended that it is practicable, by means of physical or anthropometric examination, to detect proclivity towards certain forms of pneumokoniosis, and it has become the practice of some authorities to base selection of entrants to the mining industry upon such attempted differentiation of constitutional types.

The Miners' Phthisis Medical Bureau, Johannesburg, has found such type-division of much practical value (see Irvine, 1938); others, however (e.g. Tsukata, 1938, in Japan), have been unable as yet to confirm its practical usefulness. The limited anthropometric data of the population of colliery A.3, particularly of 86 colliers who had a time-exposure at the coalface of not less than 15 years, have been submitted to statistical analysis from this aspect; and it is concluded that "according to our data, there is a slight correlation between an anthropometric type and susceptibility to pneumokoniosis, but it is not possible to forecast with any degree of accuracy that one particular examinee is more likely than another to develop pneumokoniosis" (Aslett, Hart, Martin and Russell, 1941). It may also be mentioned that among the sample of normal men from colliery A.3 whose lung volumes were determined by Dr. J. McMichael (Aslett, Hart and McMichael, 1939), obesity, and also the broad or hypersthenic type of chest, were associated with a reduction in the value of the reserve air, with a corresponding gain in the complementary air. It is, however, impossible to say whether this is advantageous or disadvantageous.

There is, in fact, little knowledge of why, after apparently similar exposures to a harmful dust, some individuals contract pneumokoniosis and others escape. The selection may be due to variation in individual susceptibility (e.g. peculiar constitutional type or difference in tissue response), but, alternatively, it may be due to unappreciated differences in the dose received; probably both factors play their parts. It seems doubtful whether differentiation of men on the score of the supposed individual factor is at present justifiable as a practical procedure in pre-employment selection (see also U.S. Department of Labor, 1938, and Gardner, 1940).

It is relevant here to mention the suggestion that the high incidence of pneumokoniosis in western Wales is associated in part with the racial composition of its inhabitants. The present inquiry provides evidence against the importance of this factor:

(1) Within a few miles of colliery A.3, in which the incidences of certified silicosis and X-ray abnormalities are among the highest in the area, is A.2, where both these incidences are classed as low. Similarly, not far from high incidence colliery A.6 is low incidence A.5. These facts show that under relatively favourable environmental conditions the population of this locality can have a low incidence of pneumokoniosis after many years of mining.

(2) A number of the men at colliery A.3 were of English parentage. The X-ray findings in a selection of these, numbering 30, were analysed. Of the total of 30, 17 showed normal films, seven had reticulation, five were classified as consolidation (one nodulation, three coalescent nodulation, one massive shadows), and one was classed as indefinite. The numbers in these categories did not differ from those expected on the basis of the incidences at similar ages in the general population of this colliery.

### (ii) *Respiratory disability*

The assessment of respiratory disability was made independently upon three bases: (a) the presence or absence of chronic breathlessness on exertion, judged from the medical history; (b) the exercise tolerance, judged from a simple test; and (c) various types of cough.

The incidence of respiratory disability associated with each type of X-ray abnormality was determined, and could be compared with the corresponding incidence for normal X-rays. These figures are based upon the colliery registered population (i.e. the entire population of 560), including both surface and underground workers and also 37 silicosis compensation cases (see p. 33). For (a) and (c) above, they refer to all the 560 men, but for (b) the exercise test was contra-indicated in 27 men with deformities of the lower limbs, and the figures therefore refer to 533 men. The incidence of respiratory disability is considered in three age-groups, namely, 20-39, 40-64, and the wide inclusive age-group 15-79.

(a) *Chronic breathlessness on exertion*, and (b) *Impaired exercise tolerance*.

In Tables XXXII (p. 126) and XXXIII (p. 127) are set out the incidences of breathlessness on exertion and of impaired exercise tolerance, respectively, among the men at colliery A.3 showing different X-ray abnormalities, in comparison with the incidences among those showing normal X-ray pictures. The symptom of chronic breathlessness on exertion was judged solely from the medical history, and in preparing Table XXXII the subjects were divided into two groups, breathlessness present and breathlessness absent; no subdivision of the breathless according to the severity of the symptom was made. The exercise tolerance, on the other hand, was judged entirely upon the result of the exercise test, and not from the medical history; and in preparing Table XXXIII the subjects were divided into three classes—class A (normal), class B (abnormal) and class C (abnormal)—individuals in classes B or C being regarded as having impaired exercise tolerance (see pp. 34-35).

The tabulation of the X-ray categories in Tables XXXII and XXXIII conforms to that used throughout this report, but in addition to the usual normal category (a), a sub-category (a') composed of normals, underground workers only, is included, for the reasons already given. The composite consolidation category (c-f) is shown both undivided and also subdivided into nodulation (c) and major consolidation (d-f), but the latter is not further subdivided into its three components, coalescent nodulation, massive shadows and multiple fluffy shadows. Of the grand total of 560 men in the inclusive age group 15-79, 307 (55 per cent.) were classified in the normal X-ray category, 208 of these being underground workers; 121 (22 per cent.) were classed as reticulation; 113 (20 per cent.) as consolidation (52 being nodulation and 61 major consolidation); and 19 (3 per cent.) were classed as having indefinite films (see Table XXXII).

In Table XXXII the comparison of incidence of breathlessness between the various X-ray categories is made in two ways. The first method is to use the observed percentage-incidences (columns (5), the figures being bracketed, to indicate necessity for caution in interpretation, where the corresponding totals were less than 20). The second method is to compare the observed numbers of breathless in an X-ray category with those expected at the age-rates exhibited by men with normal X-rays (using 5-year age-groups), expressing the former as a percentage of the latter (columns (6), the figures being bracketed, again to indicate questionable reliability, where the corresponding observed numbers breathless were less than five). In Table XXXIII the comparison of incidence of impaired exercise tolerance between the various X-ray categories is made similarly (columns (5), (6), (9) and (10)). Of these two methods of comparing incidences of breathlessness and impaired exercise tolerance, the tabulation of observed per cent. of expected has the possible advantage over the observed percentage-incidences that it allows for differences in age-distribution of the men in the different X-ray categories even within each of the three main age-groups used. This advantage would of course be greatest in the wide age-group 15-79. On the other hand, small age-periods, such as five years, tend to permit chance variations in the standardising percentages to manifest themselves and influence the results.

In comparing incidences from one group to another of the same population, it is necessary to apply tests of statistical significance, and in the lower sections of Tables XXXII and XXXIII the differences between percentages in two members of certain pairs of X-ray categories, divided by the standard errors of these differences, are shown. The resulting ratios are regarded as significant if they equal 2.0 or more.

The results in Tables XXXII and XXXIII are so similar that they can be described together; the relevant columns are those in heavy type, namely, Table XXXII, columns (5) and (6), and Table XXXIII, columns (5), (6), (9) and (10):—

(1) There was little difference between the incidences of breathlessness, and of exercise tolerance classes B+C or C only, among men in the normal X-ray category (a) (all normals) and among those classed in its sub-category (a') (normals, underground workers only). All the important results for the abnormal X-ray categories, using category (a) as normal control, would still be evident if sub-category (a') were to be used.

(2) The incidence of breathlessness and of impaired exercise tolerance was higher, for every X-ray category, at ages 40-64 than at ages 20-39. Thus, the incidence of breathlessness increased for normals from 7.9 per cent. to 26.7 per cent., for reticulation from 10.2 per cent. to 43.9 per cent., for nodulation from

26.9 per cent. to 37.5 per cent., for major consolidation from 33.3 per cent. to as high as 83.7 per cent., and for all consolidation from 29.3 per cent. to 67.2 per cent. Again, for normals, the percentage of men in exercise tolerance classes B+C increased from 7.2 to 37.7 and in class C alone from 0.7 to 9.0; for reticulation, the percentage in classes B+C increased from 8.6 to 53.9 and in class C from nil to 15.4; for nodulation, the increase was from 20.0 per cent. to 60.9 per cent. for classes B+C and from 4.0 per cent. to 17.4 per cent. for class C only; for major consolidation, from 33.3 per cent. to 74.4 per cent. for classes B+C and from 6.7 per cent. to as much as 44.2 per cent. for class C; while for all consolidation, the percentage in classes B+C increased from 25.0 to 69.7 and in class C from 5.0 to 34.8.

(3) In the wide age-group, 15-79, the percentage of men with breathlessness and with impaired exercise tolerance both increased progressively in the succeeding X-ray categories—normal, reticulation, nodulation and major consolidation. The percentages in these categories were: breathlessness, 15.6, 26.4, 32.7 and 70.5; exercise tolerance classes B+C, 22.8, 30.7, 38.8 and 65.0; exercise tolerance class C only, 4.4, 8.8, 10.2 and 35.0. A similar progressive increase was shown by the numbers observed with these disabilities per cent. of those expected, the respective percentages being 100 (base), 145, 170 and 321 for breathlessness, 100 (base), 122, 168 and 203 for exercise tolerance classes B+C, and 100 (base), 156, 238 and 512 for class C. The differences in incidence of breathlessness between reticulation and normal, nodulation and normal, and all consolidation and normal, and between reticulation and all consolidation, were, respectively, 2.4, 2.5, 7.3 and 4.3 times the standard errors of these differences, and therefore more than would be likely to be due to chance. The corresponding ratios for exercise tolerance classes B+C were 1.6, 2.2, 5.7 and 3.5, three of which are again statistically significant, and the fourth, i.e. that between reticulation and normal, is slightly below the level of significance (2.0).

(4) In the younger age-group, 20-39, the percentage of men with breathlessness in the category reticulation (10.2) was only slightly in excess of the percentage among the normals (7.9), but for the consolidation category the figure (29.3 per cent.) was much in excess of the normal incidence. The corresponding figures for breathlessness observed per cent. of expected were in agreement: normal 100, reticulation 107, consolidation 194. Similarly, the percentage of men in exercise tolerance classes B+C in the reticulation category (8.6) exceeded only slightly the percentage among the normals (7.2), but the percentage in the consolidation category (25.0) showed a definite excess. The corresponding figures for observed numbers in classes B+C per cent. of those expected were also in agreement: normal 100, reticulation 104, consolidation 227. Finally, the differences in incidence of breathlessness bore the following relationship to their standard errors: reticulation and normal 0.5, nodulation and normal 2.1, consolidation and normal 2.9, reticulation and consolidation 2.4. The first of these ratios, i.e. between reticulation and normal, is statistically insignificant, but for the other three pairs of categories the ratios are significant. The corresponding ratios for exercise tolerance classes B+C were 0.3, 1.5, 2.5 and 2.1, the first of which is again insignificant, the second suggestive, and the others significant.

(5) In the older age-group, 40-64, the percentage of men with breathlessness in the reticulation category (43.9) was definitely in excess of the percentage among the normals (26.7); for the consolidation category the percentage (67.2) was still higher. The corresponding figures for breathlessness observed per cent. of expected showed the same trend: normal 100, reticulation 155, consolidation 263. Similarly, the percentage of men in exercise tolerance classes B+C, and in C only, in the reticulation category (53.9 and 15.4) exceeded these percentages among the normals (37.7 and 9.0), and the

percentages in the consolidation category (69·7 and 34·8) showed a still greater excess. The corresponding figures for numbers observed with impaired exercise tolerance per cent. of numbers expected were again in agreement: these percentages were normal 100, reticulation 133, consolidation 193 for classes B+C, and normal 100, reticulation 148, consolidation 442 for class C only. Finally, the differences in incidence of breathlessness bore the following relationship to their standard errors: reticulation and normal 2·3, nodulation and normal 1·0, all consolidation and normal 5·9, reticulation and all consolidation 2·7. These ratios are statistically significant for each pair of categories, except between nodulation and normal (possibly a chance finding, since the percentage breathless in the nodulation category was, exceptionally, smaller than that for reticulation—see (6) below). The corresponding ratios for exercise tolerance classes B+C were 2·0, 2·1, 4·5 and 1·8, all of which are near or above the level of significance.

(6) In Table XXXII, age-group 15-79, while a higher incidence of breathlessness was found for nodulation (32·7 per cent.) than for reticulation (26·4 per cent.), the difference was not marked, and it was much less than the difference in incidence between major consolidation (70·5 per cent.) and nodulation. In the age-group 40-64, the incidence of breathlessness for nodulation was also not very different from that for reticulation (actually it was slightly less—probably a chance variation since nowhere else, either in this table or in Table XXXIII, did this occur), but the difference between major consolidation and nodulation was again considerable. Similarly, in Table XXXIII, age-groups 15-79 and 40-64, while the incidences of exercise tolerance classes B+C, and of C only, were higher for nodulation than for reticulation, the excess was less than that for major consolidation over nodulation.

(7) If the lower sections of both Tables XXXII and XXXIII (showing the degrees of statistical significance of the more important differences in incidence of disability) be examined together and taken as a whole, significant differences are seen between reticulation and normal at ages 40-64, and for the entire age-group 15-79, and between nodulation and normal at ages 20-39, 40-64, and for the inclusive age-group; and even where the differences do not reach the formal level of significance (2·0), these abnormal categories occupy their usual positions in the ascending scale from normal to major consolidation. Highly significant differences are seen, in each age-group, between all consolidation (i.e. nodulation *plus* major consolidation) and normal, and significant differences are also shown between reticulation and all consolidation.

From the above description it appears that, although the presence of breathlessness and impaired exercise tolerance have been assessed by separate means, the results of Tables XXXII and XXXIII are, in the main, very similar and support each other in all important respects.

These tables embody results bearing upon one of the most important objects of the present inquiry, and since breathlessness on exertion and impaired exercise tolerance are used here as the principal estimates of respiratory disability, it seems desirable at this point to summarise the most salient of the conclusions. These are as follows: (1) There is an increase of respiratory disability with age for each X-ray category, reaching very high proportions for major consolidation in the older age-group. (2) There is a progressive increase in incidence of respiratory disability (best seen in the inclusive age-group 15-79) in the succeeding categories—normal, reticulation, nodulation and major consolidation, the order of which ascending scale is the same as that in which these different X-ray changes have been shown (Chapters 6 and 7) to develop; the positions occupied by these X-ray categories in the scale are, moreover, what might reasonably be expected from the character of the different types of appearance on the film (see Chapter 5). (3) An excess over the incidence of disability among normals is shown in both the age-groups

20-39 and 40-64 for the composite category consolidation, the differences having high levels of statistical significance. (4) For reticulation, there is a very small excess of disability over normal incidence in the age-group 20-39, but a definite excess—though not as great as that for consolidation—is found in the age-group 40-64; in this older age-group the differences in incidence between reticulation and normal on the one side, and between reticulation and all consolidation on the other, are twice the standard errors of these differences and can therefore be regarded as significant, thus indicating that reticulation is distinguishable, in its associated frequency of disability, both from consolidation and from normals. (5) Although the incidence of disability for the nodulation component of the consolidation group is (with one doubtful exception) higher than that for reticulation, the difference is not marked; whereas the incidence for major consolidation is considerably higher than that for nodulation or reticulation. (6) In a proportion of the men in each of the chief abnormal X-ray categories, no respiratory disability is detected from the history or by the simple exercise test used here; and while such proportions are not inconsiderable for reticulation and nodulation, a small number of men, even in the advanced category major consolidation, may fail to show evidence of disability by such methods. Only in the relatively infrequent and most advanced of the three components of major consolidation, namely, massive shadows and multiple fluffy shadows, has disability almost invariably been present.

Perhaps the most important conclusion, so far as the inquiry is concerned, is that, as regards associated frequency of disability, reticulation occupies a position between normal and consolidation, not much below the nodulation component of the latter composite category but considerably below its more advanced component, major consolidation. Even where, in these tables, the difference between reticulation and normal does not reach the formal level of significance, it still occupies its expected position in the ascending scale of X-ray categories. Like consolidation, reticulation appears, therefore, to indicate a pulmonary condition which may cause respiratory disability, though the frequency of such disability is less in the latter case and it occurs mainly in the second half of life. The implications of this conclusion will be considered against the background of the whole inquiry in the general discussion in Chapter 13.

Tables XXXII and XXXIII include all the subjects examined at this colliery, no exclusion being made for potential non-pulmonary causes of respiratory disability, such as cardiac disease or hypertension. To test whether this procedure was likely to have biased the results, those men who were in arbitrary blood pressure class *c* (systolic 180 mm. or over, or diastolic 100 mm. or over, or both—see later), or whose hearts were clinically abnormal or radiologically enlarged, were excluded, and the incidences of breathlessness and impaired exercise tolerance in the X-ray categories for the three age-groups were re-calculated without them. The men thus excluded numbered 83, and since these were fairly equally distributed among the different X-ray categories, their exclusion would be expected to make little difference to the incidences; and actually the results (not tabulated) were found to be substantially the same as the unrestricted incidences of Tables XXXII and XXXIII.

A further small analysis may be mentioned here. To see if any distinguishable type of reticulation film is particularly associated with disability, the reticulation films of colliery A.3 population were subdivided according to apparent differences of density and heaviness of the markings. There was a tendency for films with denser or heavier shadowing to be found more frequently at later ages, but there was no definite differential association between the denser films and either breathlessness or impaired exercise tolerance. Such subdivision, however, may possibly be partly artificial, due to slight variability of technique.

(c) *Various types of cough.* In Table XXXIV (p. 129) is set out the incidence of chronic coughs, assessed in three ways, among the men at colliery A.3 showing different X-ray appearances. (The three methods of assessment are explained in the notes to the table.) The main points are as follows:—

(1) As with the incidences in the previous tables, the incidences of cough were slightly higher for normal sub-category (*a'*) than for the whole normal

category (*a*). This might be because underground workers as a whole were more liable to coughs than were colliery workers in general, in which case sub-category (*a'*) might be the better control for the abnormal categories, most of the men in which were working underground. Alternatively, this slight excess might be because non-colliers working on the underground roadways, who formed a greater proportion of the underground normals than of the underground abnormals, were more liable to coughs than were men working at the actual coalface, in which case sub-category (*a'*) might be considered a less satisfactory control than category (*a*). In view of this uncertainty, the usual normal category (*a*) is, as before, used principally for the comparisons, and its sub-category is treated as supplementary (see also p. 109).

(2) As with breathlessness and impaired exercise tolerance, the incidence of each type of cough in each X-ray category was higher at ages 40-64 than at ages 20-39.

(3) In the age-group 20-39, the incidence of the various types of cough among men in the abnormal X-ray categories (except in the most advanced of them, major consolidation) showed no definite excess over the incidence among normals.

(4) In the age-group 40-64, and also to some extent in the inclusive age-group 15-79, there was a progressive increase in the incidence of coughs in the different X-ray categories, similar to that shown for breathlessness and impaired exercise tolerance. Thus the percentages, at ages 40-64, recorded as "all coughs" (column (3)) were: normal 24.4, reticulation 31.6, nodulation 37.5, major consolidation 72.1 (all consolidation 59.7); and the percentages, at the same ages, with "continual cough and chest colds" (column (4)) were: normal 1.5, reticulation 7.0, nodulation 12.5, major consolidation 16.3 (all consolidation 14.9).

(5) The difference in incidence of coughs between nodulation and reticulation was not marked and was, in the main, considerably smaller than the differences between both of them and major consolidation.

Allowing for its greater limitations, the results of Table XXXIV support those of Tables XXXII and XXXIII. In frequency of associated coughs, as with the other estimates of respiratory disability, reticulation is in a position between normal and consolidation and not much below the nodulation component of the latter. Again the effect appears to occur mainly in the second half of life.

### (iii) *Blood pressure*

The examinations of the population of colliery A.3 offered an opportunity to see whether a raised blood pressure was associated with the development of any of the main changes in the pneumoconiosis of coalminers. The figures, based upon the entire population of 560 men, less a few not tested, are given in Table XXXV (p. 130).

The blood pressures are tabulated in two ways. Columns (3) and (4) show the mean systolic and diastolic pressures, while columns (5) and (6) show the percentages of men in certain classes of pressure. The division of the blood pressure readings into three classes was arbitrary. It was as follows (see also p. 34): class *a*, systolic under 160 mm. with diastolic under 95 mm.; class *b*, systolic under 160 mm. with diastolic 95 to 99 mm., or systolic 160 to 179 mm. with diastolic under 100 mm.; class *c*, systolic 180 mm. or over, or diastolic 100 mm. or over, or both. Class *a* was regarded as normal, and classes *b* and *c* as abnormal, for the purpose of comparisons. Columns (5) give the percentages of men in classes *b* + *c*, and columns (6) the percentages in class *c* only.

Table XXXV fails to show any consistent and regular progressive increase, either in mean blood pressure or in percentage of men with hypertension,\* in the different X-ray categories, such as was found in the previous tables

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\* "Hypertension" abnormally increased blood pressure.

for respiratory disability. Nor was any definite excess shown by the "major consolidation" or "all consolidation" groups over the figures for normals.

Calculations were also made of expected means and percentages for each of the age-groups, using the values for the normal category at different five-year age-periods within the particular age-group, and the populations for the same age-periods in the X-ray category under consideration. The observed means and percentages were then expressed as percentages of the corresponding expected figures, and the resulting figures (not tabulated) were compared as between the different X-ray categories. The results of this comparison were substantially similar to those of the simple means and incidences shown in Table XXXV, there being no definite progressive increase of systolic or diastolic pressure accompanying the advance of the X-ray changes.

The evidence from the present results, therefore, is that, at least during its chronic ambulatory stages, the pneumokoniosis found in South Wales coal-miners does not produce a raised blood pressure—certainly not a progressive rise in pressure.

#### (iv) *Physical signs in the chest*

It was not found, as a result of this inquiry or of the previous clinical experience of one of the medical investigators (E. A. A.) that any particular physical signs, or group of physical signs, could be relied upon as indicating the presence of X-ray abnormalities directly attributable to dust. Physical signs are perhaps of greatest value in the detection of complicating or associated pulmonary conditions, such as emphysema\* or tuberculosis.

Gross clinical emphysema was found in a considerable number of men at colliery A.3, including many with accompanying abnormal X-ray appearances, but also some without. Not infrequently the syndrome of the "en bloc" chest—in which the chest wall moves up and down as a whole, or in a block, without showing the normal progressive expansion (best detected visually)—was associated with the emphysema. Since the "en bloc" chest was usually accompanied by considerable disability, it was studied in some detail, and the results are summarised below. Consideration is limited to subjects aged 40–64.

Among the 269 men aged 40–64 of the registered population of colliery A.3 there were 45 who definitely showed the "en bloc" chest. Of these, 26 were classed as showing it in slight and 19 in marked degree. The 45 cases were analysed in relation to (1) age, (2) chest expansion, (3) breathlessness and impaired exercise tolerance, and (4) X-ray category.

(1) As would be expected, the incidence of "en bloc" chests increased with age. The syndrome was shown in 11 out of 125 men aged 40–49 (9 per cent.), 21 out of 111 men aged 50–59 (19 per cent.), and in 13 out of 33 aged 60–64 (39 per cent.). A similar increase was indicated when the normal, reticulation and consolidation X-ray categories were taken separately.

(2) The chest expansion was reduced, on the average, in men with the "en bloc" syndrome. Using the 48 men aged 40–64 years who were clinically and radiologically normal as a standard for calculating expected means for the "en bloc" cases, the observed mean chest circumferential expansion of the whole "en bloc" group was found to be 1.31 in., as against an expected figure of 1.66 in. Similarly, the observed mean chest antero-posterior expansion was 0.82 in., as against an expected figure of 1.04 in.

(3) Respiratory disability was found with considerably greater frequency among the men showing the "en bloc" chest than among those whose chests did not show this syndrome (X-ray differences being ignored). The percentage of breathlessness in the whole "en bloc" group (45 men) was 73, and among the marked cases alone (19 men) it was 84, whereas among the 224 men aged 40–64 (all X-ray categories) without this syndrome the percentage breathless was 38. Similarly, the percentage placed in exercise tolerance classes B + C was 84 for the whole "en bloc" group, 89 for the marked cases alone, and 45 for the men without the syndrome; and the percentage placed in exercise tolerance class C alone was 46 for the whole "en bloc" group, 72 for the marked cases alone, and 13 for the men without the syndrome.

(4) About two-thirds of the "en bloc" cases had abnormal X-ray pictures, and the syndrome was found somewhat more frequently among men showing consolidation than among those whose films were normal. Of the 45 cases, the films were classed as normal

\* Defined on p. 49, footnote.



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in 17, reticulation in 7, consolidation (mainly major consolidation) in 16, and local gross fibrosis of uncertain cause (indefinite category) in 5. The incidences of the syndrome, rated upon the 269 men of the colliery population aged 40-64 grouped in the different X-ray categories, were: normal, 13 per cent.; reticulation, 12 per cent.; consolidation, 24 per cent.

Although emphysema must probably be fairly advanced to be accompanied by the "en bloc" syndrome, the latter is perhaps the least equivocal clinical evidence of the presence of this condition, since other physical signs may sometimes be obscured in the presence of the underlying consolidation changes.

Certain negative clinical findings at colliery A.3 may be briefly mentioned. There was, at the time of examination, no particular association between cardiac enlargement—judged clinically or by the cardio-thoracic ratio on the X-ray—and the abnormal pulmonary changes. Nor were cyanosis, fever or severe wasting common features. The question of wasting is particularly interesting, and the weights of the men in the main X-ray categories are compared for the age-groups 20-39 and 40-64 in the following tabulation:—

Age-group.	X-ray category.	Total men.	Mean weight.	S.D.
20-39..	Normal .. .. .	139	141.7	19.4
	Reticulation .. .. .	59	142.4	21.6
	Nodulation .. .. .	26	140.3	18.4
	Major consolidation .. .. .	15	133.2	15.7
	All consolidation .. .. .	41	137.7	17.8
40-64..	Normal .. .. .	130	144.4	25.1
	Reticulation .. .. .	57	138.1	19.9
	Nodulation .. .. .	24	142.9	21.6
	Major consolidation .. .. .	43	138.3	22.3
	All consolidation .. .. .	67	139.9	22.2

On statistical comparison there is a suggestion that the mean weight of the major consolidation group is less than that of the others, though the mean weight neither of this nor of any of the other abnormal X-ray groups tabulated differs from the normals by as much as twice the standard error of the difference.

The above remarks on negative findings apply to disabled men on compensation, some of whom have since died, as well as to men still at work; the tabulated comparisons of weight also include these compensation cases. It should, however, be emphasised that all men were examined at the clinic and none was seen at the time of death.

(v) *Clinical modes of death*

Opinion as to the common *clinical* modes of death in cases of pneumokoniosis among anthracite coalminers was sought from a number of doctors practising in Carmarthenshire, many of whose patients had been included in the investigation. Each doctor was asked to state for such cases the frequency of the following modes of death: (a) cardiac failure; (b) tuberculosis; (c) pneumonia, broncho-pneumonia or bronchitis. He was asked also to give the frequency of the following symptoms and signs in the terminal stages: (a) cough; (b) dyspnoea\*; (c) cyanosis†; (d) oedema of extremities and/or ascites‡; (e) fever; (f) severe wasting.

According to the majority view of seven doctors who gave opinions, cardiac failure and non-tuberculous respiratory affections are common clinical causes of death, while clinical tuberculosis sometimes occupies this rôle. As to terminal

\* i.e., difficult or troubled breathing.

† Bluish discolouration of skin, lips, etc., due to diminished oxygenation of the blood.

‡ i.e., dropsy of legs or arms, and/or fluid in the abdominal cavity

symptoms and signs, the majority view was that cough, dyspnoea, cyanosis and severe wasting are common, oedema and ascites occur sometimes, and fever rarely. Chest pain of various kinds was also mentioned as a terminal symptom.

The most interesting points about this information from local doctors are : (1) the comparative infrequency of clinically recognisable tuberculosis ; (2) the frequency of cardiac failure as a terminal feature, although gross cardiac symptoms or signs were not significantly associated with pneumokoniosis in similar cases at the time of their examination in the present inquiry ; and (3) the opinion that severe wasting is common terminally, although it again was not often noticed in the present inquiry, nor was much loss of weight apparent from statistical comparisons between men in the different X-ray categories at the time of examination (p. 118).

#### (vi) *Sputum examination*

Examination for tubercle bacilli was made (by Dr. A. F. S. Sladden) upon a smear from the sputum concentrate and, if the latter was negative, by culture as well as by guinea-pig inoculation. As stated on p. 35, sputum outfits were given to all men of colliery A.3 registered population who had expectoration, and to a number of others. Seventy-five men gave a history of productive continual cough, and 53 (71 per cent.) of these returned the sputum outfits. Forty-seven of the 75 men had abnormal X-ray films, and 40 (85 per cent.) of these returned the outfits. In addition to the above 53 men, sputum was examined from 27 others—with non-productive continual cough or with no continual cough, making a total of 80 sputa examined from this colliery. All of these 80 examinations were negative for tubercle bacilli.

#### (vii) *Tuberculin test*

In view of the connection between tuberculosis and pneumokoniosis in certain industries, it seemed of interest to determine whether there was any relation between the frequency and degree of tuberculin sensitivity and the various X-ray appearances found among coalminers. The number of men tested had to be limited, and it was thought preferable to take all of a narrow age-group suitably placed in the span of adult life, rather than a sample of widely varying ages, even though the latter might be more representative of the population as a whole. Accordingly, Mantoux tests were made upon 151 men, comprising all but six of the age-group 30-39 of the registered population of colliery A.3. The dosage was 0.1 cc. of 1:10,000 standard strength tuberculin, followed, if there was no reaction, by the same amount of 1:100 dilution (see also p. 35). The results are given in Table XXXVI (p. 131).

This table shows that the percentages positive to 0.1 cc. of 1:10,000 tuberculin were 55.6 for the men with normal X-ray films, 56.8 for those showing reticulation, 52.0 for those classed as nodulation, 53.4 for major consolidation (and 52.5 for all consolidation). The corresponding percentages negative to this dilution were 31.9, 32.4, 36.0, 33.3 (and 35.0) respectively, the remaining reactions being doubtful. These percentages differ little from one another, and they form no regular order in relation to the X-ray changes ; moreover, none of the figures for abnormal categories shows a statistically significant difference from the normal figures.

Taking the 1:100 dilution, the percentages positive were 95.8 for the normals, 89.2 for the men with reticulation, 96.0 for nodulation, 100.0 for major consolidation (and 97.5 for all consolidation). The corresponding percentages negative to this dilution were 4.2, 8.1, 4.0, nil (and 2.5), the remaining few reactions being doubtful. The remarks made for the weaker dilution apply also to these figures.

There is, therefore, no evidence of any definite hyper- or hyposensitiveness to tuberculin among men with the abnormal X-ray appearances either of reticulation or of consolidation.

It may be noted that for the whole series the percentage positive to the stronger dilution was as high as 94.7. This may be compared with the similar

percentages positive at 1 : 100 dilution found by Cummins and Evans (1933) among 445 clinically non-tuberculous adult males in a Welsh mental hospital (97 per cent.), and by Hart (1932) among 134 clinically non-tuberculous adults of both sexes from the London hospital class (93 per cent.). On the evidence of these indirect comparisons, Welsh miners would appear, therefore, to have as high an incidence of tuberculin sensitivity as the general adult population.

Some information of a more direct nature, about the Mantoux test in miners, is available from the Donetz investigation, 1930-1935 (Moshkovsky, 1941 ; and see pp. 150 and 157). The tests, at 1 : 5,000 dilution, of 336 bituminous coalminers of various ages and lengths of employment were compared, age by age, with those of 203 wives of miners. The percentages positive were 85 for all the miners and 93 for all the wives of miners, indicating, even at this relatively low concentration of tuberculin, a high incidence of sensitivity in both groups (the slight difference in total incidence in the two groups was evident also for each age-subdivision). Further, the percentage of positive reactors among the younger miners (20-29 years of age) differed little from the percentage among those with long experience (aged 40 and over), indicating that most of the miners on recruitment were already tuberculin-sensitive. It may be mentioned that some of the long-period workers in this Russian series showed "anthracosis", but these also gave positive reactions to the tuberculin ; and, in Moshkovsky's view, this disposes of the claims by Ikert and others that in anthracosis a negative skin reaction is characteristic, as an indication of developing positive "anergy" owing to a favourable effect of the pneumokoniosis on tuberculosis. The present South Wales findings support the view of the Russian investigators.

The two previous subsections and the present one contain rather negative evidence regarding tuberculosis in relation to the changes attributable to dust in coalmines. From the classification of X-ray appearances described in Chapter 5 it will be clear that the procedure adopted in this inquiry was to be chary of attaching specific names, such as silicosis or tuberculosis, to the X-ray films, and to classify rather according to the form of the changes shown upon them. Consequently, no evidence derivable from the radiological examinations of the men at the colliery A.3 is here presented as shedding light on the relationship of tuberculosis to pneumokoniosis in South Wales. Examinations of post-mortem material, which form the subject of the accompanying report by Dr. T. H. Belt, offer a better opportunity for obtaining information upon this relationship. At least, however, it is probably safe to infer that sputum-positive or *clinically obvious* tuberculosis is not a common association of pneumokoniosis in anthracite miners. Even this limited inference should be taken to apply to anthracite colliers, rather than to anthracite miners in general, for there were very few men at colliery A.3 who had done much hard-heading work and there is little doubt, from other published studies, that in a group of hard-heading men a significant incidence of clinically recognisable tuberculosis would have been found.

It may be mentioned that attempts were made to analyse such presumptive evidence of tuberculosis as appeared from the past and family histories of the men at colliery A.3 showing various X-ray changes, but the data proved inadequate.

#### (viii) Lung volume determinations

Determinations of the lung volume and its subdivisions were made by Dr. J. McMichael upon a selection of 180 men from colliery A.3, using the method described by Herral and McMichael (1939). The observations upon a sample of 66 men (included in the above total), who were normal clinically and radiologically, have been described by Aslett, Hart and McMichael, (1939), and the full results for the men with abnormal X-ray changes (including a number upon compensation) will also be given elsewhere (McMichael, Hart and Aslett, 1942). It may be stated briefly that a reduction both in average total lung volume and in average vital capacity was found among the men with X-ray

abnormalities attributable to dust, as compared with the normal controls. These differences were slight for reticulation and more marked for consolidation, and were evident mainly at the older ages. It should be noted that these findings apply to averages of *groups*. Unfortunately, the scatter of the values within the groups is too great in relation to the mean values to permit lung volume determination to be of much use in the *individual* case except when the deviations from normal are large, under which conditions the disability can probably be detected adequately by other methods. These observations do, however, provide information upon the pathological physiology of the lung changes.

**B. RESPIRATORY DISABILITY IN RELATION TO X-RAY APPEARANCE AMONG THE COLLIERS AT THE FURTHER 15 COLLIERIES**

No extensive clinical examination was made at the further 15 mines investigated, and the data are limited to brief histories of any respiratory illnesses or symptoms, taken by non-medical investigators when obtaining the working histories from the selected colliers (see p. 39). No exercise tolerance tests were made.

From these respiratory histories the men could be grouped according to whether they were recorded as suffering from breathlessness on exertion, or not. The same emphasis cannot be laid upon the results as upon those from colliery A.3, but they may be regarded as supplementary.

The incidences of breathlessness observed among the selected colliers at these 15 collieries in the three chief X-ray categories (indefinite category omitted) were as follows, for two age-groups:—

<i>Age-group.</i>	<i>X-ray category.</i>	<i>Total men.</i>	<i>Per cent. breathless.</i>
20-39 ..	Normal .. .. .	590	12.9
	Reticulation .. .. .	263	20.5
	Consolidation .. .. .	125	26.4
40-64 ..	Normal .. .. .	166	27.7
	Reticulation .. .. .	106	36.8
	Consolidation .. .. .	54	42.6

It will be seen that there is some progressive increase in incidence of breathlessness with increasing X-ray abnormality, corresponding to the findings at A.3, though in the present case the incidence for reticulation was appreciably higher than for normal in the younger as well as in the older age-group.

To obtain a comparative single incidence figure (all ages) for each X-ray category, and at the same time standardise for differences in age-distribution in the different categories, a similar procedure to that used in Table XXXII was followed. The expected total number with breathlessness was calculated for each X-ray category on the basis of the percentages breathless in five-year age-periods (from ages 15 to 64), among the men in the normal X-ray category. The results, which agree with the observed percentage-incidences given above, were as follows:—

<i>X-ray category.</i>	<i>Number observed.</i>	<i>Number expected.</i>	<i>Observed per cent. of expected.</i>
Normal (base) ..	131	131.0	100
Reticulation ..	94	73.7	128
Consolidation ..	56	38.4	146

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It will be remembered (Chapter 8) that some long-term surface screens workers were also examined at these mines, as well as some from colliery A.3. The figures for breathlessness in this small group are of interest :—

<i>X-ray category.</i>	<i>Total men.</i>	<i>Number breathless.</i>
Normal .. ..	36	9
Reticulation .. ..	8	4
Consolidation .. ..	3	3

The numbers involved are small, but they show clearly the same trends as before, viz., a greater proportion of breathlessness among screens workers with X-ray abnormalities than among those with normal X-rays.

C. RESPIRATORY DISABILITY IN RELATION TO X-RAY APPEARANCE AMONG THE COALTRIMMERS AT THE FOUR PORTS

Data upon the incidence of breathlessness on exertion, similar to those just given for the colliers at the further 15 mines, were also obtained from the trimmers examined at the four coal ports (see p. 41). In addition, sputum examinations were made in a selection of these men. As before, the data as to breathlessness were obtained by non-medical investigators when taking the industrial histories. The groups studied from both points of view included 16 men who, on account of chest trouble, were no longer in regular work, and were therefore not included in the analyses of Chapter 9.

(i) *Respiratory disability*

The observed incidences of breathlessness on exertion—including an extra category, “severe breathlessness” (breathless on any exertion)—among these selected coaltrimmers were as follows :—

<i>Age-group.</i>	<i>X-ray category.</i>	<i>Total men.</i>	<i>Per cent. breathless.</i>	<i>Per cent. with severe breathlessness.</i>
30-44..	Normal .. ..	55	27·3	0·0
	Reticulation .. ..	7	(42·9)	(0·0)
	Consolidation .. ..	0	(0·0)	(0·0)
45-74..	Normal .. ..	247	36·8	10·1
	Reticulation .. ..	127	44·1	15·7
	Consolidation .. ..	48	50·0	20·8

(The age-groups studied differ from those for the miners, since the trimmers were an older population.)

X-ray abnormalities were too few in the younger age-group to allow comparisons, but in the older group there was a progressive increase in incidence of breathlessness with increasing X-ray abnormality (more evident in the figures for severe breathlessness).

Comparison was also made between the observed numbers breathless at all ages and those expected on the basis of the incidence-rates amongst the

trimmers with normal X-rays, the figures being calculated in a similar way to those for the colliers (see p. 121). The results were as follows :—

<i>Breathlessness (ages 30-74).</i>						
<i>X-ray category.</i>	<i>Number observed.</i>		<i>Number expected.</i>		<i>Observed per cent. of expected.</i>	
	<i>All.</i>	<i>Severe.</i>	<i>All.</i>	<i>Severe.</i>	<i>All.</i>	<i>Severe.</i>
Normal (base) .. .. .	106	25	106·0	25·0	100	100
Reticulation .. .. .	59	20	50·7	14·2	116	141
Consolidation .. .. .	24	10	17·8	5·1	135	196

These figures show the same progressive increase of breathlessness, particularly of severe breathlessness, as the observed percentage-incidences given above.

The findings regarding respiratory disability among the coaltrimmers are, therefore, in general agreement with those for the coalminers given in Sections (A) and (B).

(ii) *Sputum examination*

Examination for tubercle bacilli was made (by Dr. Sladden) upon a simple smear from the sputum. As stated on p. 41, sputum outfits were given mainly to trimmers whose X-rays suggested focal changes, independently of the presence or absence of expectoration. The results yielded three positive cases; the X-ray findings in one (one of the 16 men no longer in work) had been classed as multiple fluffy shadows (category *f*) of consolidation, and those in the two others (one being at work and the other idle) as local gross fibrosis of uncertain cause (indefinite category *g*).

SUMMARY OF CHAPTER 10

(1) The results of clinical examinations of miners and trimmers have been considered in relation to X-ray appearances. These examinations were extensive at anthracite colliery A.3, while limited data were collected at the further 15 mines and at the four ports. The chief clinical manifestation studied is respiratory disability.

(2) The average stature of the population at colliery A.3, based on a sample of the men who were clinically and radiologically normal, was smaller than would be expected in population groups in many other parts of Great Britain, this difference probably being racial. There was no evidence that mining Welshmen differed significantly in height from non-mining Welshmen from the same locality.

Using the anthropometric data collected at colliery A.3, a slight association between a physical type and pneumokoniosis was found, but this association was considered insufficient for practical application in identifying the pneumokoniosis-prone miner.

(3) At colliery A.3, respiratory disability was assessed independently upon three bases: (a) presence or absence of chronic breathlessness on exertion, judged from the medical history; (b) the exercise tolerance, judged from a simple exercise test; and (c) various types of cough. The chief results were as follows :—

In the wide age-group 15-79, the proportion of men with respiratory disability, as indicated by breathlessness or by impaired exercise tolerance, increased progressively in the succeeding X-ray categories—normal, reticulation, nodulation, and major consolidation (i.e. coalescent nodulation, massive shadows and multiple fluffy shadows). Division by age showed a higher incidence of

disability, both at 20-39 and at 40-64 years, in the composite category consolidation (i.e. nodulation+major consolidation) than among the normals, the differences being statistically significant. For reticulation, the excess of disability over the normal incidence was very small at ages 20-39, but definite at ages 40-64, though not as great as for consolidation. In this older age-group the differences in incidence between reticulation and normal on the one hand, and between reticulation and all consolidation on the other, were twice their standard errors, and therefore more than was likely to be due to chance, thus indicating that reticulation is distinguishable, in its associated frequency of disability, both from consolidation and from normals.

The proportion of men showing respiratory disability, as indicated by various classifications of cough, in the abnormal X-ray categories showed (except with the most advanced X-ray changes) no definite excess in the age-group 20-39 over the incidence among the normals. In the age-group 40-64, a progressive increase in incidence of disability was found, similar to that for breathlessness and impaired exercise tolerance.

(4) The most important conclusion from these findings is that, as regards associated frequency and degree of respiratory disability, reticulation occupies an intermediate position between normal and consolidation, not much below the nodulation component of the latter composite category but considerably below its more advanced component, major consolidation. Like consolidation, reticulation on the X-ray film appears, therefore, to indicate a pulmonary condition which may cause respiratory disability, though such disability is less frequent and occurs mainly in the second half of life. As a corollary, a fairly considerable proportion of the men showing reticulation will have no detectable disability at the time of examination, as is also the case with nodulation.

(5) There was no evidence that, at least during the chronic stages, the pulmonary changes attributable to dust in anthracite coalminers (at colliery A.3) were associated with a rise in blood pressure—certainly not with a progressive rise in pressure.

(6) Physical signs were not found to be reliable evidence of the presence of pneumokoniosis by the X-ray standard, much less for distinguishing the different X-ray categories. Physical signs are, however, useful for indicating associated pulmonary conditions, such as emphysema or tuberculosis. The usual clinical signs of emphysema are sometimes disturbed by the underlying consolidation changes, and the syndrome of the "en bloc" chest is suggested as the best unequivocal clinical evidence of gross emphysema in such cases.

At the time of examination there was no particular association between cardiac enlargement and the pulmonary changes, nor was wasting a marked feature. In the view of a number of local doctors, however, cardiac failure and severe wasting were common terminal features.

(7) In the opinion of the majority of these local doctors, clinical tuberculosis was a less frequent mode of death in coalminers suffering from pneumokoniosis than either cardiac failure or non-tuberculous respiratory affections.

(8) Sputum examinations for tubercle were made in the majority of men at colliery A.3 who had expectoration. All the tests were negative.

(9) From tuberculin tests made upon almost the whole of the age-group 30-39 at colliery A.3, there was no evidence of any definite hyper- or hypo-sensitiveness to tuberculin among the men in either of the abnormal X-ray categories, reticulation and consolidation. The percentage positive to O.T. 1:100 dilution in the whole series was as high as 95.

(10) From (7) to (9), above, bearing in mind that no attempt was made to diagnose tuberculosis as a complication of pneumokoniosis from the X-ray appearances, it would be unwise to draw any inference except that *clinically obvious* tuberculosis is not commonly associated with pneumokoniosis in anthracite miners. Even this limited inference should be restricted to colliers

and not applied to anthracite miners in general. The only satisfactory information upon the association of pneumokoniosis with tuberculosis must be derived from post-mortem material; this, in fact, supports the belief in such an association (see Dr. Belt's report, p. 219).

(11) Lung volume determinations (to be published elsewhere), made by Dr. J. McMichael upon a selection of the population at A.3, showed, on the average, a reduction in total lung volume and in vital capacity for the men with abnormal X-ray appearances attributable to dust, as compared with normal controls. These differences were slight for reticulation and more pronounced for consolidation, and were evident mainly at the older ages. These findings provide information upon the pathological physiology of the pulmonary conditions, though the wide scatter of the individual values about their means prevents lung volume determinations being of much use for detecting deviations from normal in the individual case.

(12) In the colliers at the further 15 collieries investigated, respiratory disability was assessed only upon the presence or absence of chronic breathlessness on exertion, judged from a very brief medical history. The proportion of men with breathlessness was found to show a progressive increase from the radiographically normal to consolidation, with reticulation occupying an intermediate position. These results should be regarded as supplementary to those given by the more complete examinations at colliery A.3, with which it will be seen that they agree.

(13) Results for a small group of workers on or about the surface screening plants of the collieries investigated suggest that breathlessness was more frequent in men with abnormal X-ray appearances attributable to dust than in men with normal X-ray pictures.

(14) For coaltrimmers at the four coal ports, respiratory disability was assessed from brief medical histories, but figures for those with severe breathlessness, as well as for the total breathless, were obtained. The incidence of breathlessness on exertion, particularly of severe breathlessness, showed a progressive increase with increasing X-ray abnormality, in agreement with the findings among the miners.



TABLE XXXII

The incidence of breathlessness on exertion among men at colliery A.3 (colliery registered population, total 560 men) showing different X-ray appearances. (Based on the medical histories)

X-ray category. (1)	AGE-GROUPS.														
	20 - 29					40 - 64					15 - 79				
	Total men.	Breathlessness present.				Total men.	Breathlessness present.				Total men.	Breathlessness present.			
	Number observed. (2)	Number observed. (3)	Number expected.* (4)	Observed percentage-incidence. (5)	Observed per cent. of expected. (6)	Number observed. (2)	Number observed. (3)	Number expected.* (4)	Observed percentage-incidence. (5)	Observed per cent. of expected. (6)	Number observed. (2)	Number observed. (3)	Number expected.* (4)	Observed percentage-incidence. (5)	Observed per cent. of expected. (6)
(a) Normal .. ..	139	11	11.0	7.9	100	131	35	35.0	26.7	100	307	48	48.0	15.6	100
(a') Normal: underground workmen only.	111	10		9.0		78	25		28.2		208	38		15.9	
(b) Reticulation ..	59	6	5.6	10.2	107	57	25	16.1	43.9	155	121	32	22.0	26.4	145
(c) Nodulation ..	26	7	3.8	26.9	184	24	9	6.1	87.5	148	52	17	10.0	32.7	170
(d-f) Major consolidation	15	5	2.3	(33.3)	217	43	36	10.9	83.7	330	61	43	13.4	70.6	321
(c-f) All consolidation	41	12	6.2	29.3	194	67	45	17.1	67.2	263	113	60	23.4	53.1	256
(g-h) Indefinite ..	2	2	0.3	(100.0)	(667)	14	12	4.4	(85.7)	273	19	15	4.7	(78.9)	319
All X-ray categories	241	31	23.1	12.9	134	269	117	72.5	43.5	161	560	155	98.1	27.7	158
Differences/standard error of difference between :-															
(a) and (b) .. .. .					0.5					2.3					2.4
(a) and (c) .. .. .					2.1					1.0					2.6
(a) and (c-f) .. .. .					2.9					5.9					7.3
(b) and (c-f) .. .. .					2.4					2.7					4.3

\* Expected for men subject to the incidences of the normal X-ray category but with age-distribution similar to that of the men in the X-ray category under consideration. The expected number breathless of a given X-ray category in a particular age-group was obtained by applying the percentages breathless for the different 5-year age-periods of the age-group among the men in the normal X-ray category (a) to the populations (total men) for the same age-periods in the given X-ray category.

Notes.

- Column (1). Category (a') is limited to the underground working population, i.e. to men engaged in underground occupations at the time of examination. It thus excludes silicosis compensation cases and surface workers.
- Categories (d-f) comprise (d) coalescent nodulation, (e) massive shadows and (f) multiple fluffy shadows.
- (2). Total number of men, both breathless and not breathless.
- (3). Number classed as breathless.
- (4). Calculated expected number of breathless, i.e. number that would have been observed had the men in the given X-ray category been subject to the incidences at different 5-year age-periods of the men in the normal category.
- (5). Column (3) expressed as percentage of column (2). The figures are bracketed where column (2) is less than 20. The percentage breathless, age-group 15-79, among the 19 men in categories (e) and (f) is 90.
- (6). Column (3) expressed as percentage of column (4). The figures are bracketed where column (3) is less than 5.

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TABLE XXXIII

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The incidence of impaired exercise tolerance among men at colliery A.3  
(colliery registered population, total 560 men) showing different  
X-ray appearances. (Based on the exercise test)

AGES 20-39	All classes.	Exercise tolerance classes B + C.				Exercise tolerance class C.				
	X-ray category. (1)	Number observed. (2)	Number observed. (3)	Number expected. (4) *	Observed percentage incidence. (5)	Observed per cent. of expected. (6)	Number observed. (7)	Number expected. (8) *	Observed percentage incidence. (9)	Observed per cent. of expected. (10)
(a) Normal .. .. .	138	10	10.0	7.2	100	1	1.0	0.7	(100)	
(a') Normal : underground workers only.	111	9		8.1				0.9		
(b) Reticulation .. .. .	58	5	4.8	8.6	104	0	0.6	0.0	(—)	
(c) Nodulation .. .. .	25	5	2.7	20.0	185	1	0.5	4.0	(200)	
(d-f) Major consolidation .. .. .	15	5	1.7	(33.3)	294	1	0.4	(6.7)	(250)	
(c-f) All consolidation .. .. .	40	10	4.4	25.0	227	2	0.9	5.0	(222)	
(g-h) Indefinite .. .. .	1	1	0.1	(100.0)	(1,000)	0	0.0	(0.0)	(—)	
All X-ray categories .. .. .	237	26	19.3	11.0	135	3	2.5	1.3	(120)	
Difference/standard error of difference between :—										
(a) and (b) .. .. .				0.3				—		
(a) and (c) .. .. .				1.5				0.8		
(a) and (c-f) .. .. .				2.5				1.2		
(b) and (c-f) .. .. .				2.1				1.6		

AGES 40-64	All classes.	Exercise tolerance classes B + C.				Exercise tolerance class C.				
	X-ray category. (1)	Number observed. (2)	Number observed. (3)	Number expected. (4) *	Observed percentage incidence. (5)	Observed per cent. of expected. (6)	Number observed. (7)	Number expected. (8) *	Observed percentage incidence. (9)	Observed per cent. of expected. (10)
(a) Normal .. .. .	122	46	46.0	37.7	100	11	11.0	9.0	100	
(a') Normal : underground workers only	76	34		43.6		7		9.0		
(b) Reticulation .. .. .	52	28	21.1	53.9	133	8	5.4	15.4	148	
(c) Nodulation .. .. .	23	14	7.6	60.9	184	4	1.6	17.4	(250)	
(d-f) Major consolidation .. .. .	43	32	16.1	74.4	199	19	3.6	44.2	528	
(c-f) All consolidation .. .. .	66	46	23.8	69.7	193	23	5.2	34.8	442	
(g-h) Indefinite .. .. .	14	11	7.0	(78.6)	157	6	2.0	(42.9)	300	
All X-ray categories .. .. .	254	131	97.8	51.6	134	48	23.6	18.9	203	
Difference/standard error of difference between :—										
(a) and (b) .. .. .				2.0				1.1		
(a) and (c) .. .. .				2.1				1.0		
(a) and (c-f) .. .. .				4.5				4.0		
(b) and (c-f) .. .. .				1.8				2.6		

AGES 15-79	All classes.	Exercise tolerance classes B + C.				Exercise tolerance class C.				All classes.	
	X-ray category. (1)	Number observed. (2)	Number observed. (3)	Number expected. (4) *	Observed percentage incidence. (5)	Observed per cent. of expected. (6)	Number observed. (7)	Number expected. (8) *	Observed percentage incidence. (9)	Observed per cent. of expected. (10)	Number not listed. (11)
(a) Normal .. .. .	293	67	67.0	22.8	100	13	13.0	4.4	100	14	
(a') Normal : underground workers only.	207	49		23.7		8		3.9		1	
(b) Reticulation .. .. .	114	35	28.6	30.7	122	10	6.4	8.8	156	7	
(c) Nodulation .. .. .	49	19	11.3	38.8	168	5	2.1	10.2	238	3	
(d-f) Major consolidation .. .. .	60	39	19.2	65.0	203	21	4.1	35.0	512	1	
(c-f) All consolidation .. .. .	109	58	30.5	53.2	190	26	6.3	23.8	413	4	
(g-h) Indefinite .. .. .	17	13	8.7	(76.6)	149	7	2.1	(41.2)	333	2	
All X-ray categories .. .. .	533	173	134.8	32.5	128	56	27.7	10.5	202	27	
Difference/standard error of difference between :—											
(a) and (b) .. .. .				1.6				1.5			
(a) and (c) .. .. .				2.2				1.3			
(a) and (c-f) .. .. .				5.7				4.6			
(b) and (c-f) .. .. .				3.6				3.1			

\* Expected for men subject to the incidences of the normal X-ray category but with age-distribution similar to that of the men in the X-ray category under consideration. For example, the expected number in exercise tolerance classes B + C of a given X-ray category in a particular age-group was obtained by applying the percentages in these classes for the different 5-year age-periods of the age-group among the men in the normal X-ray category (a) to the populations (all exercise tolerance classes) for the same age-periods in the given X-ray category.

(For Notes to Table XXXIII, see next page.)

## PULMONARY DISEASE IN WELSH COALMINERS

*Notes to Table XXXIII.*

- Column (1). Category (a) is limited to the underground working population, i.e. to men engaged in underground occupations at the time of examination. It thus excludes silicosis compensation cases and surface workers. Categories (d-f) comprise (d) coalescent nodulation, (e) massive shadows and (f) multiple fluffy shadows.
- (2). Total number of men tested, i.e. exercise tolerance classes A (normal), B (abnormal) and C (abnormal).
- (3). Number classed as B (abnormal) or C (abnormal).
- (4). Calculated expected number in classes B + C, i.e. number that would have been observed had the men in the given X-ray category been subject to the incidences at different 5-year age-periods of men in the normal category.
- (5). Column (3) expressed as percentage of column (2). The figures are bracketed where column (2) is less than 20. The percentage in classes B + C, age-group 15-79, among the 18 men tested in categories (e) and (f) is 72.
- (6). Column (3) expressed as percentage of column (4). The figures are bracketed where column (3) is less than 5.
- (7). Number classed as C only.
- (8). Calculated expected number in class C, i.e. number that would have been observed had the men in the given X-ray category been subject to the incidences at different 5-year age-periods of men in the normal category.
- (9). Column (7) expressed as percentage of column (2). Figures are bracketed where column (2) is less than 20.
- (10). Column (7) expressed as percentage of column (8). Figures are bracketed where column (7) is less than 5.
- (11). Total number of men not tested, mainly on account of mechanical limitation from injury or arthritis. This number accounts for the difference between the totals in this table and those in Table XXXII.

TABLE XXXIV

The incidence of cough among men at colliery A.3 with different X-ray appearances

X-ray category. (1)	AGE-GROUPS.											
	20-39				40-64				15-79			
	Percentage with cough.				Percentage with cough.				Percentage with cough.			
	Total men observed. (2)	All coughs. (3)	Continual cough and chest colds. (4)	Chronic bronchitis. (5)	Total men observed. (2)	All coughs. (3)	Continual cough and chest colds. (4)	Chronic bronchitis. (5)	Total men observed. (2)	All coughs. (3)	Continual cough and chest colds. (4)	Chronic bronchitis. (5)
(a) Normal .. .. .	139	18.7	4.3	4.3	131	24.4	1.5	11.5	307	21.8	2.9	8.1
(a') Normal: underground workers only.	111	20.7	4.5	4.5	78	26.9	2.6	12.8	208	24.0	3.4	8.7
(b) Reticulation .. .. .	59	20.3	3.4	5.1	57	31.6	7.0	14.0	121	24.8	5.0	9.1
(c) Nodulation .. .. .	26	19.2	3.8	3.8	24	37.5	12.5	20.8	52	28.8	7.7	11.5
(d-f) Major consolidation .. .. .	15	(40.0)	(13.3)	(20.0)	43	72.1	16.3	51.2	61	60.7	14.8	41.0
(e-f) All consolidation .. .. .	41	26.8	7.3	9.8	67	59.7	14.9	40.3	113	46.0	11.5	27.4
(g-h) Indefinite .. .. .	2	(100.0)	(0.0)	(50.0)	14	(64.3)	(21.4)	(42.9)	19	(63.2)	(15.8)	(42.1)
All X-ray categories .. .. .	241	21.2	4.6	5.8	269	36.8	7.1	20.8	560	28.8	5.5	13.4

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Notes.

- General. Percentages are bracketed where column (2) is less than 20.
- Column (1). See Table XXXII, notes, column (1).
- (2). Total number of men, with or without cough. On these totals the percentages in columns (3) to (5) are based.
- (3). Men with continual cough, or with frequent "chest colds", or with both. Continual cough is defined as a cough, apart from chest colds, which had been present for three or more months. Chest colds were regarded as frequent if they occurred three or more times a year. (This column includes men in columns (4) and (5).)
- (4). Men of column (3) who had both continual cough and frequent chest colds.
- (5). Men of column (3) who were regarded as having chronic bronchitis.

TABLE XXXV

The blood pressures of men at colliery A.3 (colliery registered population, total 560 men) with different X-ray appearances

X-ray category. (1)	AGE-GROUPS.															
	20-39					40-49					50-79					
	Total men observed. (2)	Blood pressure.				Total men observed. (2)	Blood pressure.				Total men observed. (2)	Blood pressure.				Total men not tested. (7)
		Mean. (Mm.)		Class. (Per cent.)			Mean. (Mm.)		Class. (Per cent.)			Mean. (Mm.)		Class. (Per cent.)		
Systolic. (3)		Diastolic. (4)	b + c (5)	c (6)	Systolic. (3)		Diastolic. (4)	b + c (5)	c (6)	Systolic. (3)		Diastolic. (4)	b + c (5)	c (6)		
(a) Normal .. .. .	139	129.6	77.6	7.2	1.4	129	145.3	86.2	37.2	20.9	305	137.7	81.6	23.3	12.1	2 (1)
(b) Reticulation .. .. .	69	129.4	80.8	16.9	3.4	57	143.0	89.1	35.1	17.6	121	137.9	83.6	28.1	13.2	0 (2)
(c) Nodulation .. .. .	26	134.2	79.1	15.4	7.7	24	144.2	85.7	19.7	12.8	52	140.9	82.6	19.2	11.6	0 (4)
(d-f) Major consolidation .. .. .	15	(132.3)	(79.6)	(6.7)	(0.0)	43	137.9	84.4	25.6	16.3	61	137.6	83.6	23.0	13.1	0 (5)
(g-f) All consolidation .. .. .	41	133.5	79.3	12.2	4.9	67	140.1	84.8	22.4	14.9	113	139.1	83.1	21.2	12.4	0 (4)
(g-h) Indefinite .. .. .	2	(120.0)	(80.0)	(0.0)	(0.0)	13	(140.2)	(86.5)	(23.1)	(15.4)	19	(140.7)	(86.1)	(22.2)	(16.7)*	1 (6)
All X-ray categories .. .. .	241	130.1	78.6	10.4	2.5	266	143.3	85.8	32.3	18.4	557	138.1	82.4	23.9	12.6	3 (7)

Notes.

- General. Means in columns (3) and (4) and percentages in columns (5) and (6) are bracketed where totals in column (2) are less than 20.
- Column (2). Total number of men tested, i.e. blood pressure classes a (normal), b (abnormal) and c (abnormal). On these totals the percentages in columns (5) and (6) are based.
- (3). Mean systolic blood pressure in mm. of mercury.
- (4). Mean diastolic blood pressure in mm. of mercury.
- (5). Percentage of men in blood pressure classes b + c.
- (6). Percentage of men in class c only.
- (7). Total number of men not tested, through inadvertence. This number accounts for the difference between the totals in this table and those in Table XXXII. The figures in brackets are the numbers on whom no diastolic pressures were obtained; they were used for columns (3) and are included in totals of columns (2).

TABLE XXXVI

Results of intracutaneous tuberculin tests upon 151 of the 157 members of colliery A.3 registered population who were aged 30-39, grouped according to their X-ray categories

<i>X-ray category.</i> (1)	<i>Dilution.</i> (2)	<i>Number of cases in series.</i> (3)	<i>Number of cases tested.</i> (4)	<i>Number negative of cases tested.</i> (5)	<i>Number doubtful of cases tested.</i> (6)	<i>Percentage negative of series.</i> (7)	<i>Percentage doubtful of series.</i> (8)	<i>Percentage positive of series.</i> (9)
(a) Normal .. ..	1 : 10,000	72	72	23	9	31.9	12.5	55.6
	1 : 100	72	32	3	0	4.2	0.0	95.8
(b) Reticulation .. ..	1 : 10,000	37	37	12	4	32.4	10.8	56.8
	1 : 100	37	16	3	1	8.1	2.7	89.2
(c) Nodulation .. ..	1 : 10,000	25	25	9	3	36.0	12.0	52.0
	1 : 100	25	12	1	0	4.0	0.0	96.0
(d-f) Major consolidation ..	1 : 10,000	15	15	5	2	(33.3)	(13.3)	(53.4)
	1 : 100	15	7	0	0	(0.0)	(0.0)	(100.0)
(c-f) All consolidation .. ..	1 : 10,000	40	40	14	5	35.0	12.5	52.5
	1 : 100	40	19	1	0	2.5	0.0	97.5
(g-h) Indefinite .. ..	1 : 10,000	2	2	2	0	(100.0)	(0.0)	(0.0)
	1 : 100	2	2	0	0	(0.0)	(0.0)	(100.0)
All X-ray categories .. ..	1 : 10,000	151	151	51	18	33.8	11.9	54.3
	1 : 100	151	69	7	1	4.6	0.7	94.7

Notes.

- General. Percentages in columns (7)-(9) are bracketed where totals in column (3) are less than 20.  
 Column (4). Figures for 1 : 10,000 comprise all the cases in the series. Figures for 1 : 100 consist of all the cases negative or doubtful to 1 : 10,000.  
 Note that all cases doubtful to 1 : 10,000 were positive to 1 : 100.  
 (7). Figures of column (5) expressed as percentage of those of column (3).  
 (8). Figures of column (6) expressed as percentage of those of column (3).  
 (9). One hundred less figures of columns (7) and (8).

## CHAPTER 11

**X-ray Abnormalities attributable to Dust in relation to certain Processes and Methods used in Mining Coal**

To throw light upon the causation of the pulmonary conditions described in this report, and especially on their high incidence in the anthracite area, various environmental examinations have been carried out as part of the field survey. These have been directed particularly to the environment of workers at the coal-face in collieries selected from the present series of 16, so that they may be integrated with corresponding medical findings.

The many possible factors upon which the environmental work has a bearing will be discussed by the investigators in their respective reports, which are to be published as a separate volume in this series. Upon one such group of factors, however, some information is already available from the data collected in the present, medical part of the field survey, namely, the processes and methods used in mining. The medical findings for individual men in relation to their industrial histories make it possible to *exclude* certain of these processes as *essential* factors in the production of the large amount of chronic pulmonary disease in colliers. In using the term "essential factor", it is recognised that the fundamental cause of the pneumokoniosis is a time-dosage of dust, or of certain constituents of dust. Theoretically, a number of mining processes or methods might contribute to the production of the harmful dust, or to its action upon the lungs; and one or more of these might thereby be important in causing a high incidence of the disease in one mine, and another or others in causing a high incidence in another mine, according to the different mining conditions. But, taking the anthracite coalfield *as a whole*, one or other particular process might be an *essential* factor in the sense that, by its modification or elimination, the generally high incidence in this area would be abolished or very materially reduced; such essential or major responsibility has, indeed, been variously attributed to different mining processes. It is in this sense that the term "essential factor" is used in the present context.

The procedure followed in this chapter is, in the main, negative and crude. It is negative, since it consists in finding either an adequate group of the men examined that has not been exposed to a particular process or method of working but, nevertheless, shows an unsatisfactorily high incidence of pulmonary abnormalities, or alternatively, a group that has been so exposed but shows a low incidence of such abnormalities: the given process or method is then inferred not to be an essential factor, though it may still be contributory. The procedure is also crude, since the actual chemical or physical effect produced by the given process upon the environment of the worker cannot be taken into consideration in this way. Some such data will, however, be provided in the environmental reports, e.g. those upon ventilation and dust concentrations by Dr. Bedford and Dr. Warner.

In the following discussion the incidence of X-ray abnormalities, rather than the incidence of certified silicosis, is taken as the measure of the incidence of pulmonary abnormalities attributable to dust, the arbitrary scale of division into incidence classes, described in Chapter 7, being used. It may be recalled that this scale was based upon consolidation, and not upon all X-ray abnormalities. On the evidence presented in that chapter—particularly the parallelism of reticulation and consolidation incidences from one mine to another, no special consideration of reticulation was thought to be necessary in the present discussion.

The processes and methods involving the collier that can be studied are (i) system of work; (ii) ripping work; (iii) blasting; (iv) stone-dusting

(v) spake trains. Each of these has been variously suggested as mainly responsible for the present position; hence the justification for considering each separately.

(i) *System of work.* (See Table VI, p. 44, column (14))

Three systems of work used for getting the coal in the South Wales coalfield can be eliminated with confidence as essential factors in producing the high incidence of pulmonary abnormalities in many anthracite mines; these systems are (a) intensive machine-cutting and conveyor-mining, (b) the pillar and stall system, and (c) the longwall stall system. Indeed, no one system in this area can be regarded as exclusively responsible for the present findings.

(a) While intensive machine-mining is generally on the increase in the British coalfields, it was being used, at the time of this inquiry, in only one Welsh anthracite mine, viz., in the Yard seam at colliery A.8. In this seam the period which had elapsed since intensive mining was introduced had been too short to determine its importance. But since chronic pulmonary disease occurs elsewhere in the anthracite area, intensive mining cannot be an essential causative factor. Intensive machine-mining might, however, become a potentially serious factor in the future, by increasing the concentration of air-borne dust.

(b) The pillar and stall method (narrow work) had been prominent in the medium incidence anthracite mines A.7 and A.8. Moreover, for a few years from 1924 (when the Stanlyd seam was opened) the greater part of the coal at the high incidence mine A.3 had been got by this system, though more recently longwall working had accounted for most of the output. At this mine nearly every collier of more than short experience had thus passed through a period of narrow work (amounting on the average to roughly one-fourth of the total period employed as a collier, and to two-fifths of that spent in the Stanlyd seam). Since at A.3 an increase in incidence of X-ray abnormalities was related to an increasing period of work both in narrow places and in longwall stalls, the two systems could not be separated in their effect, short though the period of narrow work had been. However, at collieries A.1 and A.6, anthracite collieries with incidences of X-ray abnormalities as high as in A.3 and higher than in A.7 and A.8, the system of work had been longwall—either with stalls or with conveyors—throughout the lives of these collieries (about 40 years); this shows that narrow work cannot be one of the major factors in the anthracite problem. It may well be a contributory factor by creating more dust than the longwall system—a point that will be discussed by Bedford and Warner in their report.

(c) The third system of work that can be excluded as having essential significance is the longwall stall system itself, since this system was, or had been, important not only in all the eight anthracite mines, but also in seven of the eight steam and bituminous coal mines, of the series. Furthermore, it had been the most important or only system, as judged from the histories of the selected colliers examined, in three of the anthracite collieries, including two with high incidences of X-ray abnormalities (A.1 and A.3), on the one hand, and in seven of the non-anthracite collieries, including three classed as of low incidence (S.4, B.2 and B.3); on the other. Within the anthracite area itself also there are, on the one hand, the two high incidence mines already mentioned, where longwall stalls had been the most important system, and, on the other hand, the low incidence mine A.5, where the only systems of work had been longwall stalls and the modified form of double stalls (intermediate between longwall and pillar and stall working), as well as the low incidence mine A.2, where the most important system had been another longwall method named longwall top-hole.

(ii) *Ripping work.* (See Table VI, column (15))

In concluding Chapter 6 it was pointed out that at A.3, as at most anthracite collieries where the coal is got on the longwall stall system, it is the practice for the collier, with his assistant, to be responsible for the ripping of the "cliff" roof at the stall roadhead of his working place. Systematically he gets down the rippings, bores the shot-holes when—as is frequent—blasting is required, and clears and packs the debris into the waste (gob) behind him. These operations of face-ripping, including the actual blasting, take place on the coal-getting shift and occupy, generally speaking, about one-fifth of his time (see also Chap. 3). Under these conditions, the collier is a part-time ripper as well as a coal-getter, and it is difficult, therefore, from the results at colliery A.3 alone, to assign the high risk incurred by colliers in such a mine mainly either to their coal-getting proper or to their face-ripping work. Some information appears, however, to be supplied by the data from certain other mines in the present series.



(a) In the medium incidence anthracite mine A.8, the Nine Feet seam had always been worked on the pillar and stall system, and the seam had been sufficiently thick to make face-ripping of roof or floor for height unnecessary, both in the stalls and in the coal headings. The only regular contact of the collier with rippings was that he packed the gob with rubbish brought from the other main seam. A group of 67 home-colliers whose working lives had been predominantly in the Nine Feet seam showed no striking difference in incidence of X-ray abnormalities from a group of 33 men whose work had been mainly confined to the Yard seam, or from all the 151 home-colliers examined at this mine. Similar results were obtained at A.7, another medium incidence anthracite colliery, where two of the seams (Nine and Eighteen Feet) required no face-ripping, on account of their thickness. In this case, 57 home-colliers who had worked in either or both of these seams showed, if anything, a somewhat higher incidence of X-ray abnormalities than those (24) whose work had been mainly in the third seam, and than all the 115 home-colliers examined at this colliery.

The above evidence is rather inconclusive because, although the colliers did not carry out the whole ripping process, they did, as stated, handle a certain amount of rippings from elsewhere and it is not possible here to decide how far this might have constituted a risk.

(b) At the high incidence anthracite mine A.1, it had been the practice for about the past 15 years for special men to bore the holes, for the colliers, in the hard clift roof at the face. For the past five years, moreover, boring and firing had been done mainly on the afternoon and night shifts (when little coal was being got), leaving the colliers to clear and pack on the next coal shift. The increasing use during the past 10 years of face-conveyors had also reduced the contact of the colliers with face-rippings. In fact, 26 of a group of 68 home-colliers examined, and five of 20 whose X-ray films showed consolidation, had either only packed rippings shot down on the back shifts, or, through being on conveyor faces, had not handled any at all.

(c) At A.6, another high incidence anthracite mine, conveyor-working had been the most important system, as judged by the histories of the home-colliers examined. On the conveyor faces the only systematic face-ripping was in the clift roof of the widely-spaced conveyor roads, and this was done, not by the colliers, but by other workmen on the back shift. Moreover, the rubbish from these rippings, together with the clod at the top of the seam brought down by the colliers along the working face, was packed into the gob by special men, also working on the back shift. Since, however, the selection of colliers for examination at this colliery was confined to those of over 20 years experience, there being an inadequate number of 10-20 years employment in this occupation, it was not possible to isolate men who had worked entirely on conveyor faces and not in stall work.

(d) At the medium incidence steam coal mine S.3, there was a sub-group of 19 of the home-colliers who had done very little ripping of the clift roof. These men had mainly ripped top coal (in the thick Nine Feet seam) or had worked in places where the clift roof was ripped by special workmen. The incidence of X-ray abnormalities in this small group was no lower than that expected on the basis of the incidences for all the 95 colliers examined at this mine.

(e) In addition to the above cases of colliers who had not done much ripping work but yet showed an unsatisfactorily high incidence of pulmonary abnormalities, there are the converse examples of colliers at the three non-anthracite mines of low incidence (S.4, B.2 and B.3), and at two more of low-medium incidence (S.5 and B.1). The home-colliers at these mines had mainly carried out their own face-ripping, as in most anthracite seams also worked on the longwall stall system. Comparison between ripping in anthracite and non-anthracite mines is, however, complicated by certain regional differences, three of which may be mentioned (see also p. 37). First, there is a greater proportion of thick seams in the steam and bituminous coal mines of the present series than in the anthracite mines—the thinner non-anthracite seams being largely mechanised and, therefore, unsuitable for this investigation; this factor would tend to reduce the thickness of face-rippings needing to be taken, except where only part of the section of the seam was mined. Secondly, blasting, which would be expected to raise the level of dustiness at the coalface, has been used extensively as an aid to face-ripping in the anthracite area generally, but less frequently for this purpose in the steam coal collieries—at least in the present series—and only rarely in the bituminous coal collieries investigated; moreover, it has been the practice in non-anthracite mines for any blasting to be done upon a back shift. Thirdly, the previous point might conceivably be a reflection of a regional difference in the hardness of the clift roofs overlying the seams, and consequently in the ease of ripping, although we do not yet know of any proof of such a difference.

While the foregoing results are, therefore, inconclusive, they suggest, when taken together, that the process of ripping is not an essential factor in the production of the pulmonary abnormalities found in South Wales colliers. The working face between the haulage roads would itself seem able to provide

a major risk through the dust produced during the actual process of coal-getting. Such a tentative inference, however, is not incompatible with ripping being a contributory factor of considerable importance. More information upon these questions is provided in the environmental reports.

(iii) *Blasting.* (See Table VI, columns (14) and (15))

It has been suggested that blasting, either by raising the level of dustiness at the coalface or by producing nitrous fumes in excessive concentration, might play a part in the aetiology of pulmonary disease in the South Wales coalfield. Colour is lent to this suggestion by the contrast in the amount of shot-firing between the anthracite and non-anthracite areas. In the anthracite mines, blasting has been systematically and extensively used as an aid both to coal-getting and to ripping at the face, and, generally speaking, the shots are fired as occasion arises, and therefore mainly on the coal-getting shifts. In the steam and bituminous coal mines, it is not the practice to blast the coal, and, on the whole, blasting is also less frequently employed for ripping roof or floor (in some seams in the bituminous mines blasting, even for this purpose, is quite rare); moreover, it is the practice to fire on a back shift or between shifts, when the colliers are not present.

It may be objected that, although shot-firing in the coal is even more intense at anthracite mines A.2 and A.5 than generally in anthracite mines, yet these two collieries showed a low incidence of pulmonary abnormalities among their colliers. This contrary evidence can, however, be countered by pointing out that the underground workings in both these mines are distinctly damp (see Table XXV, p. 95), and this factor may reduce the concentration of nitrous fumes and dust (see later report by Mr. Ivon Graham and Dr. Runnicles). (Differences in ventilation also have to be considered in judging the relation of nitrous fumes concentration to the intensity of shot-firing.)

Although, however, when the anthracite and other mines are considered together, there appears to be some degree of correlation between blasting and the incidence of pulmonary abnormalities, there are sufficient exceptions to show that blasting could be no more than a subsidiary factor in the present problem. This evidence is as follows.

(a) In the Nine Feet seam of the medium incidence anthracite mine A.8, blasting had not been the practice in the coal and, since ripping had not been required in this seam, there had been no systematic firing in the roof or floor at the coalface. Nevertheless, as stated above on p. 134, the 67 home-colliers, 90 per cent. or more of whose employment as collier at colliery A.8 had been spent in the Nine Feet seam, showed a medium incidence of X-ray abnormalities (results not tabulated). Similar results were obtained with the smaller number of home-colliers at the medium incidence anthracite mine A.7 (29 out of the 115 total) who had worked predominantly in the Nine Feet seam in that mine, where again shot-firing had not been the practice.

(b) At the high incidence anthracite colliery A.1, all blasting, both in coal and for ripping, had, for the previous five years, been confined to a back shift, when very few men were at work. This change, however, was too recent to have provided information upon the influence of shot-firing. At anthracite colliery A.6, on the other hand, shot-firing had been entirely transferred from the coal shift to a back shift about 10 years before this inquiry, and had been mainly so for about another five years previously. Yet the incidence of X-ray abnormalities among the home-colliers from this mine was among the highest of the present series.

(c) At steam coal collieries S.1 and S.3, as at the other non-anthracite collieries, blasting had not been done in the coal, and shot-firing in rippings had been carried out upon the back shifts; the colliers, therefore, were not exposed. Nevertheless, the 54 home-colliers examined at S.1, and the 95 examined at S.3, showed medium incidences of X-ray abnormalities on the scale adopted here.

Although the numbers in the groups are not large, these observations suggest that, even when there is no systematic shot-firing at the coalface, a substantial incidence of pulmonary abnormalities can yet occur. This suggestion is supported by the finding that coaltrimming, in which the direct influence of blasting

is of course entirely excluded, may also lead to an important amount of lung changes similar in character to those found among colliers. It may be inferred, therefore, that blasting, whether by its effect upon dustiness or by its production of nitrous fumes, is not an essential, nor even a major, factor in the distribution of pneumokoniosis in South Wales. Blasting may well, however, be a contributory factor; indeed, if dust from the mined products of the coalface is important, anything that increases the average concentration of the dust would be expected to increase the hazard, quite apart from any possible action of nitrous fumes.

(iv) *Stone-dusting.* (See Table VI, column (16))

Since stone-dusting has not been practised in the anthracite mines (see p. 99), it can obviously be dismissed as a factor in their incidence of pulmonary disease. There remain the possibilities: (a) that stone-dusting is a harmful factor in the non-anthracite mines, or, alternatively, (b) that it inhibits the action of pneumokoniosis-producing dust, is to that extent beneficial, and might so account for the low incidence of pulmonary abnormalities in many non-anthracite mines.

Under (a), no harmful effect has been attributed to limestone dust, and attention may be confined to the dust from local shales. In Chapter 8 it was shown that at two bituminous mines of the series, B.1 and B.2, where shale had been used for stone-dusting for 20 or more years, neither the colliers at the face nor the hauliers on the underground roadways showed evidence of any considerable hazard due to inhalation of this added dust. It was, however, emphasised that these results could not necessarily be applied to non-anthracite mines in general, since conceivably the dust from shales obtained in certain classes of steam coal mines might have a different action. The general tendency for limestone to replace shale for dusting purposes in the steam coal mines is noteworthy.

Under (b), the available evidence does not suggest that the inhalation of stone-dust in the non-anthracite mines of South Wales is beneficial and in this way accounts for their generally lower incidence of pulmonary abnormalities—unless this protective function is to be attributed to limestone as well as to shale dust. For while collieries B.1 and B.2, which had employed shale for stone-dusting for 20 years or more, showed low-medium and low incidences of X-ray abnormalities, so also did collieries S.5 and B.3, where shale dust had never been used, the stone-dusts having been limestone, and fuller's earth and limestone, respectively. If shale is protective, the protection cannot be of a high order or must be limited to certain classes of mine, for collieries S.1 and S.3 also had employed shales for stone-dusting for 20 years, yet their incidences of X-ray abnormalities were classed as medium. As regards limestone dust, the present medical data offer no information as to possible protective action.

(v) *Spake trains*

As stated in Chapter 2, South Wales anthracite is chiefly mined from slants, whereas in the steam and bituminous areas of the coalfield the very productive seams in the lower part of the measures have been reached by vertical shafts. Along the majority of the anthracite slants of any considerable depth, the men are transported mechanically from the surface to the bottom of the main slant, and in the reverse direction; frequently also they are similarly conveyed between the bottom of the main slant and the entrance to one or more of the working districts. Formerly empty trams (tubs) were often the means of transport, but latterly there has been a tendency to substitute open carriages, with transverse seats, these being known as "spake" trains or spakes.

At the time of the inquiry there were spakes from and to the surface at collieries A.1, A.2, A.3, A.4, A.5 and A.7. At colliery A.8 the men were taken down from the surface in trams, but at the end of the shift they walked out along the main slant; subsidiary spakes conveyed them to and fro between the main slant and the districts. At colliery A.6 there was a short shaft instead of a slant; though here, too, there was a spake operating below ground.

An interesting possibility, worthy of investigation, has been suggested by T. David Jones (1936) and by Haldane, Haynes, Shaw and Graham (1939). The suggestion is that if the man's body, when hot and perspiring after work, is subjected to rapid cooling, as may result from riding in spakes against the

draught of the cold intake air, he will acquire a predisposition to bronchitis. This bronchitis, it is further suggested, might interfere with the normal process of dust elimination, and facilitate the accumulation of dust in the damaged lung.

It is not possible to reach definite conclusions on this matter from the data available, and it is difficult to see how satisfactory evidence could be obtained, since, in general, anthracite mines have slants and non-anthracite mines have shafts. The following facts are, however, noteworthy.

(a) Low incidence anthracite collieries A.2 and A.5, as well as high incidence collieries A.1 and A.3, employed spakes from the surface (the journey in the spake train at colliery A.5 was believed to be the longest in South Wales). It was, however, indicated in Chapter 7 that in the anthracite area low incidence mines are, in general, shallower than those of high incidence, so that the differences in temperature between the surface and the lower end of their slants would be smaller, whatever the length of the travel. The temperatures at the coalface at collieries A.1 and A.3 were, in fact, considerably higher than those at collieries A.2 and A.5, and the chilling effect of the spake journeys was likely to be distinctly greater; further, the incidence of X-ray abnormalities in the whole present series of anthracite mines was correlated with depth and consequently with temperature at the face; there appears to be some correlation also between incidence and the degree of chilling experienced during the period of transit to the surface. Yet, in spite of these facts, it is difficult to believe that the very great contrast in incidence of X-ray abnormalities between collieries A.1 and A.3 and collieries A.2 and A.5 could be due only, or indeed mainly, to the difference in temperature changes and degree of chilling during the ride to the surface.

(b) At colliery A.6, with a high incidence of pulmonary changes, there was no slant from the surface, the men being raised or lowered in cages through a vertical shaft. Against this may, however, be set the facts that this shaft was short (about 150 yards), and that spakes ran over a distance of some 1,000 yards between the pit bottom and the underground working districts; it is conceivable, therefore, that chilling might occur on these spake journeys. Equally equivocal is the case of colliery A.8, of medium incidence, where the men were transported from the surface to the bottom of the main slant by trams but walked out on the return journey to the surface; for here again (as already mentioned) there were secondary spakes further in-by which transported most of the men in both directions, and the temperature changes were substantial and the resultant chilling probably severe.

(c) As shown in Chapter 7, the incidence of X-ray abnormalities decreases steadily from anthracite to bituminous mines, a medium incidence being shown at some of the steam coal as well as at some of the lower rank anthracite mines. If spakes were an important factor in these abnormalities, one might expect an abrupt change on proceeding eastwards as the spake area was left. This is probably the strongest evidence on the spake factor available from this inquiry, for in these intermediate-rank mines we have a significant incidence of X-ray changes despite the absence of spakes.

(d) If travel in spakes promoted bronchitis, one would expect an excessive incidence of this affection not only among coalface workers, in whom most of the pulmonary X-ray abnormalities were actually found, but also to some extent among underground workers on the haulage roadways, in whom the incidence of X-ray changes was comparatively small (although, admittedly, the latter are subjected to less extreme changes in temperature, as between place of work and the surface, than are colliers). The following groups at colliery A.3 were compared: (1) 91 selected home-colliers (71 aged less than 40 years and 20 aged 40 or over); (2) 40 selected hauliers (21 under 40 and 19 aged 40 or more); and (3) 57 selected surface workers employed elsewhere than on the screens (29 under 40 and 28 aged 40 or more). The incidences of various X-ray abnormalities in these three occupational groups have already been given in Tables XV, XVI and XXI, respectively. Their incidences of "all coughs" and of "chronic bronchitis" were now compared (all X-ray categories taken together), the definition of these terms used in Table XXXIV (p. 129) being followed. The comparison showed no statistically significant differences between the incidences, both of "all coughs" and of "chronic bronchitis", in the three occupational groups at ages under 40 years. At ages 40 and over, the percentage of colliers with "all coughs" and with "chronic bronchitis" exceeded the corresponding percentages among the hauliers by more than twice the standard errors of these differences; on the other hand, the differences between the hauliers and the surface workers were statistically insignificant. If, as might be expected on clinical grounds, there is any tendency for haulage hands, even the older ones, to suffer an excess of bronchitis or coughs as compared with the surface workers, it is not apparent in the small groups included in this comparison. Chilling experienced by these men on the spake journeys does not appear to have injured them to any considerable extent. In other words, if spake-chilling is to explain the excess of coughs and bronchitis among the colliers as compared with the hauliers, the difference apparently must lie in

the warmer working places from which the former come at the end of the shift. It seems, however, much more likely that the real explanation of these bronchial affections among the colliers is that they are the accompaniment, not the precursor, of the pneumokoniotic changes prevalent in this occupation.

Although much of the evidence here adduced is inconclusive, it leaves no doubt that spake travel can produce severe chilling in men coming from warm working places; and any protection given against this effect—such as the protective clothing suggested by Jones—is highly desirable. But the facts give no clear support to the suggestion that the use of spakes plays any major part in the causation of the particular pulmonary abnormalities found so frequently among the colliers, though it may be a contributory factor. Such abnormalities occur at certain steam collieries that have no spakes, while, on the other hand, at colliery A.3, where even the hauliers were subjected to a fair degree of chilling, these latter suffered no significant excess of coughs or bronchitis, nor had they any considerable incidence of X-ray abnormalities.

These conclusions are supported by evidence from the Pennsylvania coalfield. According to our information, the anthracite mines of this coalfield used for an investigation into anthraco-silicosis made by the U.S. Public Health Service (Bloomfield *et al.*, 1935) employ mainly vertical shafts through which to transport their underground workers to and from the surface; only a minority travel along slants. None the less, there was, at these collieries, a serious incidence of chronic pulmonary disease similar in type to that found in South Wales.

#### SUMMARY OF CHAPTER 11

(1) An examination has been made of the parts played in the uneven distribution of pulmonary abnormality in the South Wales coalfield by the conditions associated with certain of the processes and methods used in mining. The processes and methods examined were: the various systems of work (pillar and stall, longwall stall, etc.), ripping work, blasting, stone-dusting and the use of "spake" trains.

(2) The evidence suggests that none of these processes or methods of mining can be regarded as an essential or indispensable factor, or even the main factor, in the production and maintenance of the high incidence of chronic pulmonary disease among the colliers in certain South Wales mines. Some of them, however, may well be important contributory factors, by their effect upon the quantity and quality of the dust inhaled, or by their effect upon the miner himself.

**PART III. GENERAL REVIEW OF PAST AND PRESENT INQUIRIES**

**CHAPTER 12**

**Review of Previous Published Work upon Pneumokoniosis in Coalminers and Coaltrimmers**

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**A. PULMONARY DISEASE IN COALMINERS**

While it is not possible here to make an exhaustive survey of the literature, it may be useful to summarise the stages by which knowledge has accumulated upon this complicated subject. In doing so, the references will be kept mainly within the scope of this medical report. Thus morbid anatomy will be discussed only briefly, since it is the subject of Dr. Belt's accompanying report (p. 203); while causation, except in reference to methods of working, will here be considered only in general terms. Another restriction made is that the discussion of present-day literature will be confined to that especially applicable to the problem in South Wales.

The following review is arbitrarily divided into three phases, the periods being approximate.

(i) *Earlier work (1800-1875)*

The first phase in the development of knowledge upon the medical aspects of pulmonary disease in coalminers occupied the major part of the last century, and consisted in the accumulation of evidence that men in this industry suffered excessively from chest trouble, and that their lungs might present some peculiar features.

Thackrah (1831), in his book upon occupational ill-health, recognised that colliers were subject to asthma; it should be stated that, as Greenhow (1862) later pointed out, the term asthma was used by operatives to designate any form of pulmonary disease attended by dyspnoea, arising from their occupation. Thomson (1836) described a number of fatal pulmonary cases from Scottish mines and, in addition, obtained the views of local doctors as to symptomatology. The chief symptoms were dyspnoea, and cough with sputum, the sputum being at first mucoid but later often a characteristic "black spit"; the progress

was slower, emaciation less severe, and hectic fever and purulent sputum less frequent, than in ordinary tubercular consumption. Cox (1857), writing on diseases of colliers in South Lancashire, divided their pulmonary complaints into (a) asthma (dyspnoea), which was so common as to be called by contemporary popular writers "the scourge of the mine," (b) bronchitis, almost always present with the asthma, (c) black spit, and (d) tuberculous consumption.

Meanwhile, descriptions of morbid anatomy were appearing. According to Cummins and Sladden (1930), Pearson (1813) was the first to describe coaly pigmentation of the lung, which he noted in city-dwellers. Laennec (1829) discussed the presence of black pulmonary matter in the lungs of the general population, which was so common as hardly to be considered morbid. But Thomson (1836), in the paper already referred to, collected nine autopsy reports on Scottish coalminers whose deaths were thought to have been caused by lung disease, and another six where the disease had been comparatively latent in life. In the first group the lungs were infiltrated with black matter and there were large areas of friable, dense consolidation, sometimes with excavation; in some cases there were also focal black areas or nodules. In the second group the "black lung" was mostly softer and appeared to be in an earlier stage. In 1838, according to Cummins and Sladden (1930), Stratton designated this black lung of coalminers as "anthracosis," distinguishing it from the almost universal pigmentation of town-dwellers (see above), to which, however, this term has since been also applied. Cox (1857) considered that dust in the lung might have set up inflammatory changes resulting in the indurated areas of the later stages of black lung; and Greenhow (1869), in his description of solid masses, accompanied by excavation, in cases of collier's phthisis or black lung, suggested that the process was a chronic bronchitis excited by the dust, and leading to an interstitial pneumonia. (For further early literature on tissue changes, see Klotz (1914), Willis (1921), Cummins and Sladden (1930), and Cooke (1932).)

From this account it seems probable that, during the first half of the last century, lung disease was prevalent among British coalminers, though it was not clear whether there was a single medico-pathological entity or a group of entities, or how far the changes were related to the ordinary respiratory diseases. As to the immediate cause, however, there was a fair measure of agreement, for while some of the earlier workers had suggested that impure air or explosives were the cause of pulmonary disease in coalminers, the view most consistently put forward, even from the earliest writings, was that the lung changes were due to dust, either from the coal seam or from the stone in the adjacent strata.

The early publications so far quoted refer to the English or Scottish coalfields, and little or no special attention seems to have been paid to Wales, possibly because anthracite mining had not yet been developed on a large scale. There was, however, some evidence that even at that time Wales provided a focal problem.

The first definite mention of this seems to have been made by Sir John Simon in his Public Health Report of 1861; he drew attention to mortality statistics suggesting a relative freedom from chest trouble in the Northumberland and Durham coalfields as compared with Wales, which he attributed to differences in ventilation. In the same report, Greenhow (1862) described the results of a special inquiry into these matters, following upon some rather indefinite statistical results obtained by him a few years previously (Greenhow, 1858). On the evidence of local doctors, he concluded that there was a great prevalence of chronic chest affections—particularly asthma and bronchitis—among coalminers in the areas of Wolverhampton (Staffordshire), Merthyr Tydfil (Glamorganshire) and Abergavenny (Monmouthshire), opinions differing as to whether the diseases were due to dust or to ventilation, climate, temperature or moisture conditions. It is important to note that the two Welsh areas were east of the present anthracite field. Greenhow himself examined 53 men from Merthyr and Abergavenny, half of whom he considered to be suffering from bronchial irritation due to their work, many of these having been diagnosed by their doctors as having miner's asthma. He stated that the disease of colliers in this part of Wales was a chronic bronchitis analogous to that of Cornish miners and of lead miners, but with emphysema more frequent, and pneumonia, followed by breaking down of lung tissue, less common. He noted the chronic nature of the complaint, and recorded that dyspnoea often preceded cough, and that congestive cardiac failure was a frequent terminal feature, though none of the 53 men showed signs of this at the time of examination.

#### (ii) *Middle phase (1875-1920)*

Towards the end of the last century the view appeared to be developing that the problem of excessive pulmonary disease in coalminers had to a considerable extent been solved.

Thus Arlidge (1892), in his text-book, acknowledged the high incidence in the past, but noted the widespread belief that the serious lesions of the lungs associated with the calling of coal-getters belonged to past history or, at the most, were very uncommon. He attributed this position to better ventilation, shorter hours of work, and greater attention to hygiene in the mines. Twenty years later, Sir T. Oliver (1909), in Allbutt and Rolleston's *System of Medicine*, also wrote of the high incidence of pulmonary trouble among coalminers in the past, but continued: "So much have the conditions of labour in mines improved that, apart from explosions, coalmining is now a healthy occupation. . . . Coalminers' phthisis or anthracosis is in this country on the decline." And in his *Milroy Lectures on the Hygienic Aspects of Coalmining*, Shufflebotham (1914), a Workmen's Compensation medical expert in Staffordshire, stated that prior to the Coalmines Regulation Act, 1911, which among other things required improved ventilation and control of shot-firing, one of the principal diseases from which coalminers suffered had been fibrosis of the lungs or miners' phthisis, as described by Greenhow, but that at the present time in Great Britain fibrosis of the lungs among miners could be said to be practically non-existent; and he quoted, in support, certain evidence given by English physicians before the Departmental Committee on Industrial Diseases in 1906 and 1907. According to Shufflebotham, however, infiltration of the lung with coal dust was still widespread, though it did not seem to entail disablement; Shufflebotham called this infiltration "anthracosis", using the term differently from the earlier writers. Views similar to those of Shufflebotham were expressed as recently as 1922 by Mavrogordato in the following words: "It is well known that colliers do not now develop miners' phthisis and that they are very well placed with regard to respiratory diseases in general. . . . The collier was not always free from chest trouble; 'asthma' was as well established as silicosis; colliers' asthma was a by-word, and old-established pathological museums have specimens of colliers' lungs showing fibrosis."

The attitude of complacency at that time was probably in part justified, and in part founded upon insufficient information. All the work published on lung disease in British coalminers had referred to the English or Scottish fields, or, as in one case mentioned above, to the eastern part of South Wales. It is very possible that in these areas the incidence of lung trouble, or at least of the more serious lesions, had decreased considerably during the latter part of the last century. But from western Wales, where the anthracite mines were now (1880-1900) being rapidly developed, no information had so far been forthcoming, and the mortality rates for the comparatively small numbers of men employed were diluted by the figures for the whole country. Subsequent revelation of the great prevalence of serious chronic pulmonary disease, including pulmonary fibrosis, in this part of Wales shows that the views expressed by Arlidge, Oliver, Shufflebotham and Mavrogordato—though reasonable at the time—were to prove either too inclusive or too optimistic. We need only quote the dramatic words of the Medical Officer of Health to one of the principal anthracite urban districts, written 20 years after Shufflebotham's lectures, to show that the anthracite position had either become more serious with the rise of this industry or had never yet become satisfactory: "Silicosis has caused a heavy toll in the anthracite district, including your area. . . . The miner of your area to-day is terror-stricken by the thought of developing silicosis" (Harper, 1937). And, more recently still, a working anthracite miner himself writes of "our greatest fear, silicosis, and its black twin, anthracosis" (Coombes, 1941).

With the increasing prevalence of the view that the changes in coalminers' lungs described by the earlier writers could be considered as past history, there appeared accounts of respiratory affections among coalminers which were divorced from the morbid anatomy formerly defined.

Thus Collis (1915), in his valuable review of the industrial pneumokonioses, made before the widespread use of radiography of the chest, stated that bronchitis was the chief of the pneumokonioses. He noted the prevalence of deaths ascribable to dust returned both under this heading and as pneumonia in certain coal-fields, particularly in South Wales (anthracite not being, however, specially distinguished), but he did not give prominence to the peculiar consolidation appearances of coalminers' phthisis; indeed the incidence of "dust-phthisis" was considered by him to be low in this industry.

Dr. J. S. Haldane went further in the same direction, and since his papers have attracted much attention, they will be discussed in some detail.



Haldane, before he wrote on this subject, had performed the outstanding service of associating the excessive death-rate from "miners' phthisis" and other lung diseases among Cornish tin-miners with the inhalation of stone-dust by the rock-drillers (Haldane, Martin & Thomas, 1904); and in 1909 he had brought to the notice of the Royal Commission on Health and Safety in Coalmines the possible danger of similar rock work in coalmines. Haldane (1916, 1918), as Director of the Doncaster Coal Owners' Research Laboratory, proceeded to discuss the continued higher death-rate, noticeable from the occupational mortality statistics of the Registrar-General, among the older age-groups of coalminers in England and Wales as a whole. This he narrowed down to a relative excess returned under the heading of bronchitis. He suggested that this relative excess might be due to physical exertion and consequent overbreathing, and that the much greater amount of bronchitis some decades previously had been due to worse ventilation, which caused accumulation of CO<sub>2</sub> and increased respiration. Haldane adduced evidence from which he argued that (apart from the driving of roads through siliceous rock) the present relative excess among coalminers was not due to dust-inhalation, stating that "there is no real statistical evidence of harm resulting from the inhalation of coal-dust or shale-dust in the quantities ordinarily breathed by miners, and a strong presumption that the dust they breathe protects them from serious dangers". In his second paper he recapitulates: "Coal-mining in Great Britain is on the whole a very dusty occupation; but...there is no evidence in the mortality returns for either young or old colliers that dust-inhalation has hitherto caused appreciable danger to life in British coalmining."

A number of criticisms can be made of Haldane's thesis as originally stated. (1) Bronchitis is a crude heading, and it is now well recognised that many cases that would to-day be diagnosed and certified at death by the practitioner as silicosis or pneumoconiosis were formerly (before X-rays were so widely used and before 1929, when compensation first became payable to coalminers) returned as bronchitis; and there has been a gradual, though by no means complete, change from the heading of bronchitis to that of chronic interstitial pneumonia (which latter contains all the occupational lung diseases returned as such). (2) Overbreathing due to increased CO<sub>2</sub> or to physical exertion might result not only in overstretching the lungs, but also in increased inhalation of dust. (3) The position in South Wales, particularly in the anthracite area, was not at that time studied; physical exertion is not likely to be greater in this area, than in the lower-incidence, English coalfields.

Since Haldane maintained his general viewpoint fairly consistently, it will be convenient to follow his papers through till the last one, published a few years after his death. In a paper published in 1931 he slightly modified his original thesis, so as to meet the statistics of the Registrar-General's two most recent Decennial Supplements, those for 1911 and 1921, and the new facts that had come to light about pulmonary disease in the anthracite mines. In this paper he stated that "...it seems practically certain that excessive inhalation of coal-dust or shale-dust must cause bronchitis". However he still held, though criticised by Collis in discussion, that the mortality from bronchitis among older miners was connected with muscular exertion and that even if no dust-inhalation accompanied coalmining, the mortality from bronchitis would probably still be almost as high; he further affirmed that, apart from very exceptional conditions (hard-heading work), there was no evidence that coalminers suffered excessively from silicosis or, apparently, from any respiratory disease other than ordinary bronchitis. But he did suggest now that in a lung already injured by bronchitis or emphysema, or by ordinary phthisis, the capacity for dust-elimination was necessarily impaired, so that local accumulations of dust might occur. The latter, according to him, seemed to produce a scattered development of fibrous tissue, giving an X-ray appearance similar to silicosis (Welsh National Memorial Association, 1931), this being most prevalent in the anthracite area of South Wales.

In the discussion on Fisher's (1935) paper, Haldane (1935) still opposed the view that the lung lesions which by now had become well recognised among clinicians and pathologists in South Wales were primarily the result of dust inhalation; he maintained that, while undoubted silicosis did occur among miners working in highly siliceous rock, the large number of other cases officially diagnosed as silicosis, particularly from the Welsh anthracite mines, were "primarily cases of either bronchitis or ordinary phthisis, the collections of dust with such extra fibrosis as is found on post-mortem or X-ray examination being due to paralysis by bronchitis of the normal process of dust elimination". These remarks were contested, in the same discussion, by Kettle, who held that there was no evidence that chronic bronchitis interfered with elimination of dust inhaled into the lungs; and also by Cummins, who considered that it was not the bronchitic state of the anthracite miner that was the cause of the dust accumulation in the lungs, but that the lung injury was caused in the first instance by the inhalation of siliceous dust, which set up nodular fibrosis, and that this in turn interfered with the elimination of dust and so might aggravate bronchitis. Cummins also made the important point that bronchitis was often a label of convenience, obscuring a case of silico-anthraxosis or pneumoconiosis; deductions from mortality statistics of "bronchitis", without post-mortems, might therefore be partly fallacious (see also Cummins, 1936).

In his last paper (Haldane, Haynes, Shaw and Graham, 1939) Haldane's original thesis was still further modified. In order to account for the observation that the X-ray focal changes among Welsh colliers working at the face, as opposed to hard-heading workers, were particularly prevalent in the anthracite mines, the suggestion of T. David Jones (1936), that the spake trains frequently used on anthracite slants (see Chapter 11) might conduce to bronchitis through chilling, was accepted. (For further reference to Haldane's work, see later, p. 155.)

(iii) *Recent work (since 1920)*

It is now necessary to return to the period following Haldane's earlier (1916, 1918) papers, when, as Cummins and Sladden (1930) put it, coal dust had come to be considered by many as harmless and possibly beneficial, while "anthracosis" or coalminer's lung disease tended to be relegated to the limbo of departed pathological problems connected with the faulty mining conditions of the past. The third arbitrary phase in the history of the subject may be considered to have commenced about this time, coinciding with and largely due to the increasing use and understanding of radiography as applied to the chest. This third phase has consisted in the gathering of evidence which has focussed attention upon coal-mining as still providing a respiratory hazard, and upon anthracite mining as the present major source of pulmonary trouble in this industry. The evidence has been obtained from (a) clinical and radiological studies, (b) compensation statistics, (c) mortality statistics, and (d) autopsies.

(a) *Clinical and radiological studies.* The clinical and radiological investigations have been made mainly in Great Britain, the United States and the Soviet Union, in all of which countries anthracite is extensively mined. In addition, there have been similar types of investigation in other countries, upon non-anthracite miners.

(1) *Great Britain.*—The steps which, in this country, rapidly dispelled the view that coalminer's pulmonary fibrosis was a condition of the past, and placed South Wales in the limelight, are well described by Fisher (1935), H.M. Medical Inspector of Mines. In 1925, attention was drawn by X-ray examinations to serious lung disease among hard-heading workers in the Somerset coalmines (see Fisher), and in 1926 Tattersall reported similar cases among hard-heading men in South Wales. The few fatal cases of men in this occupation in these two series, and from other sources, that came to post-mortem were considered to show silicosis or some of the characters of that condition (Cummins, 1927; Middleton, 1930; Jordan, 1930; Fisher, 1935).

In 1929-30 an X-ray investigation was carried out by the staff of the Welsh National Memorial Association (1931) into long-term colliers at the face, both anthracite and non-anthracite, who had not done hard-heading work; these colliers were in employment at the time of examination. A total of 130 colliers from three South Wales areas were examined, and 12 agricultural workers were used as controls. Marked alterations on the X-ray, including mottling and sometimes diffuse shadows, which were comparable in many respects to those regarded as characteristic of silicosis, were found in many cases. The incidence increased with length of employment, and was higher among the colliers in anthracite than among those in steam or bituminous coal, though, since the men were not selected statistically, the comparison is rough. It was found that the X-ray changes might be compatible at first with ability to work, but they were considered to represent a definite impairment of lung structure and to involve an increasing respiratory disability, manifested, for example, by shortness of breath.

This field-study made by the Welsh National Memorial Association, perhaps the first to attempt a systematic comparison between anthracite and non-anthracite colliers, was followed by a number of other clinical and radiological investigations, which supported the Association's findings and provided much additional information.

In South Wales, Enid Williams (1933) examined 100 miners—half anthracite and half non-anthracite—of the older age-groups, who had retired from active mining; they were taken at random from the insurance panel lists of local doctors. Although X-rays could be obtained only in a few cases, and reliance had to be placed mainly upon clinical examination, some interesting results were reported. Though their physique was good, the great majority of the men was found to have chest symptoms (mainly dyspnoea, cough and sputum); these cases were distributed fairly generally throughout the different occupations, and included colliers as well as rock workers. A year later, Harper (1934) pointed out the very serious frequency of X-ray abnormalities of silicotic type in the men X-rayed by him systematically under a colliery workmen's contributory scheme in the centre of the anthracite area. Similar X-ray changes were described by him (1935) among 30 men who had been employed for varying periods at or near the surface screens of anthracite collieries, and who had not worked underground. Amor and Evans (1934) described radiographic stages in the development of pneumokoniosis in South Wales coalminers, basing their classification on that of Pancoast and Pendergrass (see below); while T. David Jones (1936), after inquiry from local doctors in the anthracite area, differentiated between the classical silicosis of hard-heading workers which ran a rapid course, and the more common cases among colliers which were difficult to diagnose without X-ray examination; many of these cases were formerly probably called bronchitis, since the chief cause of absenteeism in the area used to be that complaint (D. Farr Davies). Cummins (1936) made a similar distinction in his pathological-radiological classification of the pneumokonioses of South Wales, in which he used the term silico-anthraxis for the characteristic condition found among colliers at the face. Sen (1937) examined 100 definite pneumokoniosis cases diagnosed by X-ray, half being rock workers and half colliers, and found that many had severe degrees of respiratory disability. Peterson, Peterson and Startup (1939) measured the vital capacity in 36 coalminers incapacitated through dyspnoea, and found that the degree of dyspnoea was correlated with the reduction in vital capacity per unit area of the body surface.

As a contrast to these findings in South Wales, an inquiry in a Scottish bituminous area by Hall (1937) may be mentioned. He examined, by X-rays and clinically, 64 miner-patients with chest affections, and diagnosed half as pneumokoniosis (of the generally accepted type); but here, although the patients were consecutively examined, they were mostly rock-drillers or rippers, whereas in South Wales, and particularly in the anthracite area, colliers as well as rock workers were prominent among those who suffered from chest affections. Hall's findings are consistent with there being a low incidence of pneumokoniosis among colliers in this Scottish area.

(2) *United States*.—In the United States, Pancoast and Pendergrass (1926) presented a valuable monograph upon the radiological aspects of pneumokoniosis, which included a study of 85 definite cases among anthracite coalminers who had attended their clinic in Philadelphia.

The X-ray appearances were described in the three stages used for the authors' classification of pneumokoniosis in general (this following closely the classification introduced earlier by Lanza and Childs (1917)), and a considerable proportion was assigned to the second or third stages. The authors remarked that the nodules on the X-ray in these cases were not quite so dense or sharply defined as those seen in workers in certain other industries, e.g. metal grinders. No estimate of the incidence of these pneumokoniosis cases in the anthracite mines was possible from the nature of the data collected; and unfortunately the individual occupations were not given in this monograph, though it was stated that "coalbreakers" (? colliers, ? surface workers) suffered less than drillers or diggers. Pancoast and Pendergrass also examined radiographs of 500 bituminous coalminers, but in comparatively few of these found any very advanced pneumokoniosis; again, drillers were the most affected. In a later review (1931), these authors gave it as their impression that the occurrence of pneumokoniosis is somewhat earlier, the progress a little more rapid, and the terminal "diffuse fibrosis" changes more frequently found, in anthracite than in bituminous mines.

More recently there has been the opportunity in the United States to carry out investigations of a more systematic nature. Brundage and Frasier (1933) found that the sickness rates for respiratory complaints among employees in two Pennsylvania anthracite mines were somewhat higher than the rates for a West Virginia bituminous mine. This preliminary study was followed by the extensive medical-statistical and environmental field-investigation at three anthracite mines in Pennsylvania, carried out in 1933 by the Office of Industrial Hygiene

and Sanitation of the U.S. Public Health Service, under the direction of Dr. R. R. Sayers (Bloomfield *et al.*, 1935; summarised by Dreessen and Jones, 1936, and also, with a somewhat different arrangement, by Sayers, 1938a). This important report (which will be referred to as the Pennsylvania report) has assisted in the planning of our South Wales investigation. Its results will be given in some detail, special emphasis being laid upon those aspects which bear particularly upon the present inquiry. Additional points of comparison will be raised in the next chapter. It should be stated that certain of the interpretations and comments in the following review are our own.

The Pennsylvania investigation was based upon 2,711 men, comprising practically the entire personnel of three representative anthracite collieries in different parts of this coalfield, supplemented by 135 disabled ex-miners. Industrial and medical histories were taken, and clinical and X-ray examinations made. Investigations of the working environment (atmospheric dust, temperature, humidity and ventilation) were also made at the three selected mines. The atmospheric dust concentration (in particles per cu. ft. of air) was measured, by the impinger method, during a number of the common operations of each occupation, and, on the basis of time studies, weighted averages were calculated to represent the exposure (in particles per cu. ft.) in that occupation, or in each of certain subdivisions of work within that occupation (e.g. in the case of colliers, the different systems of mining). From these dust exposures (particles per cu. ft.), together with the number of years subjected to each of them (obtained from the industrial history), the number of particle-years per cu. ft. of air was calculated for each employee, to express the total dust exposure during his whole mining life. Finally, this figure, divided by the total years of employment, gave the weighted average dust concentration (again particles per cu. ft.) to which the man had been exposed during his period of service.

The anthracite coalfield of Pennsylvania is the only important source of anthracite in the United States. The three mines selected differ in geological formation and in methods of mining. In the area containing Mine 1, the coal measures are flat except at the outcrops; in that containing Mine 2, the seams are steeply pitched, with many faults; and in the area containing Mine 3, the seams are of intermediate type. While some seams of this coalfield are only 2 ft. thick, the bulk of the coal is obtained from seams varying from 5 to 40 ft., and in some cases as much as 100 ft. thick; the thickest seams being in the area containing Mine 2. On this statement, the seams would appear to be in general much thicker than those in South Wales, but since it is also stated that the thicker seams are often split by intrusions of rock into two or more separate seams, the difference may not be real.

The great majority of the output in the Pennsylvania anthracite field is brought to the surface through vertical shafts, an exceptional method in the South Wales anthracite mines, where slants are usual. The two principal systems of work in this field are chamber and pillar mining (equivalent to the pillar and stall system of South Wales), which is the method represented by Mine 1, and chute or pitch mining (similar to the tophole system of South Wales), which is represented in Mine 2. Longwall mining (presumably longwall stall and longwall conveyor systems) is relatively unimportant in this coalfield and is, therefore, not represented in the study. The comparative frequency of the various systems of mining in Pennsylvania is thus in strong contrast to that in the South Wales anthracite area, where the longwall stall system is the commonest method of mining, while pillar and stall and tophole systems are much less important.

The coal is hand-cut at the three selected mines, and hand-loaded at two of them; in Mine 3, as in some other mines of this field, mechanised loading of the coal is employed. Systematic use is made of explosives in getting the coal, the collier drilling the holes, firing the shots, and handling the coal afterwards. In addition, the collier drills, blasts and clears the rock encountered in the seam. In the chamber and pillar mining of Mine 1, colliers are stated often to have to take out top and bottom rock; in the pitch mining of Mine 2, little rock work is necessary on the part of the colliers at the face; and Mine 3 is intermediate in this respect. It is not clear to us whether this rock work at the face corresponds to the face-ripping in South Wales, particularly since in Wales ripping is not the practice in the pillar and stall system of work.

The coal in Mine 1 is described as dry, and in the other two mines as wet. The relative humidity at the working face was measured, and the range over the three mines was found to be 89 to 97 per cent., averaging 92 per cent. These figures correspond to some of the less dry mines of the South Wales anthracite series. The depth or head-cover of the workings in the Pennsylvania mines is not given.

The major chronic pulmonary disease in these anthracite mines is termed anthracosilicosis in the Pennsylvania report. "The term anthracosilicosis.....is a descriptive title for the form of pneumokoniosis commonly called miners' asthma." The men were classified either as negative, or as showing anthracosilicosis, stage 1, 2 or 3; the presence of super-added or complicating pulmonary infection, and whether this was suggestive of tuberculosis, was recorded; and a clinical estimate of the degree of disability (physical

impairment sufficient to reduce capacity for strenuous work) was made, chiefly upon the basis of an exercise tolerance test. The classification of anthraco-silicosis (without infection) into three stages is stated to follow a general classification for pneumokoniosis presented by two committees of the American Public Health Association (1933). On reference to this classification, stages 1, 2 and 3 are stated by these committees to correspond respectively to the ante-primary, primary and secondary stages of the South African terminology. This would imply that they are based upon clinical disability (stage 1, disability nil or slight; stage 2, disability definite though moderate; stage 3, disability marked and permanent) as well as upon X-ray appearance (stage 1, "generalised arborisation" with more or less small discrete mottling (nodulation); stage 2, generalised medium-sized mottling; stage 3, mottling more intense and nodules larger and conglomerate)—see also Irvine and Steuart (1930) and Irvine (1938).\*

Of the 2,711 employed workers examined from the three anthracite mines, 2,095 (77 per cent.) were diagnosed as "essentially negative" and 616 (23 per cent.) as anthraco-silicosis; 510 (19 per cent.) in stage 1, 82 (3 per cent.) in stage 2, and 24 (1 per cent.) in stage 3. The incidence of colds and bronchitis, of cough, and of the symptom of dyspnoea, increased progressively from the negative group, through stages 1 and 2, to the group of stage 3 anthraco-silicosis. The frequency and degree of estimated disability showed a similar progressive increase, and this excess was found for all age-groups above 35 (the numbers below this age were too small to justify any conclusion). For example, 9 per cent. of the men (all ages together) not having anthraco-silicosis showed some degree of disability (slight, moderate or marked), as compared with 56 per cent. in stage 1, 96 per cent. in stage 2, and 100 per cent. in stage 3. The corresponding percentages with moderate or marked disability were 1, 10, 67 and 92, respectively. Of the total 616 classed as anthraco-silicosis, 63 per cent. showed some degree of disability, this being moderate or marked in 27 per cent. As a rule, the lung changes shown on the X-ray film corresponded with the amount of disability, though there were marked individual variations from this general association.

The validity of these strong correlations between clinical disability and stage of anthraco-silicosis depends upon the criteria used for classification into these stages. If indeed the criteria used by the Pennsylvania investigators had been combined clinical and radiographic, as reference to the source of their classification suggests (see above and also their pp. 3, 55, 58), then much of their correlations between symptoms and disability and the stages of anthraco-silicosis would be necessarily biased. Since, however, it appears that the X-ray was the main determinant of the stage, then such correlations are valid. Even so, the stages of the Pennsylvania classification are not properly comparable with the X-ray categories used in the present investigation. (The radiographic interpretation of the Pennsylvania report in relation to the South Wales classification is discussed in Chapter 13.)

The criteria of diagnosis of tuberculosis, and its incidence, in the Pennsylvania inquiry are referred to briefly on a later page of the present chapter. It was considered by the investigators that pulmonary infection played an important part in aggravating disability due to anthraco-silicosis.

On the basis of the average concentration and free silica content of the atmospheric dusts examined, and taken as representative of the exposure in different occupations, the 2,711 men were placed in the following chief occupational groups:—

<i>Group.</i>	<i>Nature of exposure.</i>	<i>Definition.</i>	<i>Main occupations included.†</i>	<i>Number of men.</i>
A	Dust of low free silica content.	All employees, except those in non-mining occupations underground and except those who had worked in rock dust for more than 2 or 3 years.	Colliers, assistant colliers, special coal-loaders, and employees in surface breaker-house.	1,435
B	Dust of low free silica content.	Those of group A most of whose working life had been spent in the one occupation of mining anthracite coal and who had done little rock work.	Colliers and assistant colliers (sub-grouping of A).	426
C	Dust of medium free silica content.	Workers in non-mining occupations underground, excluding rock workers.	Men on haulage roads (chiefly repairers and hauliers).	602

† The approximate English equivalents to the occupations are given.

\* From a personal communication from the American investigators, we are given to understand that the classification into stages for the Pennsylvania survey was, in fact, based largely upon the X-ray findings.

<i>Group.</i>	<i>Nature of exposure.</i>	<i>Definition.</i>	<i>Main occupations included.†</i>	<i>Number of men.</i>
D	Dust of high free silica content.	Men who had been employed in rock work for more than 2 or 3 years during their total working life to date.	Hard-heading and other rock workers.	151
Special groups.	.. .. .	.. .. .	.. .. .	162
Control group.	Little dust exposure.	.. .. .	.. .. .	361
Total Men (excluding group B) .. .. .				2,711

† The approximate English equivalents to the occupations are given.

Since the numbers of men in these groups add up to the total number of employees, there must have been many in each group (with the exception of the purposely restricted sub-group B) who had had a mixed occupational history, although finally classified under one particular occupational heading.

Taking all the occupational groups together, the general incidence of anthraco-silicosis was found to be much the same in Mines 2 and 3, but the incidence in Mine 1 was somewhat higher than in either of these. This excess was attributed to a corresponding excess in average particle-years of exposure of the employee population. Possible factors in raising the dust concentration in Mine 1, as compared with Mine 2, are that the dustier chamber and pillar system was employed in the former and the less dusty pitch system at the latter, and that the coal in Mine 1 was drier than that in Mine 2.

Combining the figures for the three mines, and considering the occupation groups A, B, C and D separately, the incidence and severity of anthraco-silicosis were found to have increased with period of service for each of these groups, the increase being most rapid among the rock workers. Under 15 years service, there were very few cases except among the rock workers, whereas, after 25 or more years service, the majority of the men in the collier groups (A and B), and practically all of those classed as rock workers (Group D), had developed the disease.

When the figures for each occupational group and for each period of service were further subdivided according to the various average dust concentrations to which the men had been exposed during their periods of service, it was shown that even after 25 or more years of employment the incidence was low for colliers, provided that the average dust concentration of exposure had been small; but with higher concentrations of dust, while there were still only a few cases among the colliers in the under-15-years period-group, an important incidence was evident at 15-24 years and this had become considerable by 25 or more years. (The numbers were too small to draw conclusions from a similar analysis of rock workers.)

When the incidences of anthraco-silicosis for a given occupational group and a given period of service were compared for these different dust concentrations, it was shown that, for equal periods of service, there was, in the case of the collier groups A and B, a definite increase in incidence and severity of disease with an increase in average dust concentration of exposure over the period in question. In the case of the roadway group C, no evidence of any such relationship can be inferred from the figures presented, owing to the small numbers of men in the different subdivisions; and among the rock workers D there is, for the same reason, no more than a slight suggestion of an increase in incidence with an increasing amount of dust. It should be pointed out in connection with comparisons between the men who had been exposed to different dust concentrations even though they were in the same occupation group, that the two main factors in producing these differences in dust exposure appear to have been: (1) that, except in group B, many of the men must have had other occupations (and consequently other dust concentrations) besides that under which they were now grouped, and (2) that men in certain of the occupations must have differed as to the nature of work within those occupations, e.g. colliers as to the system of coal-getting (chamber and pillar, chute or pitch) or as to the method of coal-loading (manual or mechanical). Both the above factors are taken into account in the investigators' method of estimating the weighted average dust exposure of each employee during his working life. In other words, the numbers of men in a given occupation group and in a given length-of-employment group that have been exposed to different dust concentrations are determined mainly by the relative proportions of the period in question which have been spent (1) in different occupations, where there has been more than one, or (2) in different subdivisions of work in a particular occupation.

On the basis of the relation between incidence, and dust concentration and length of service, threshold values of dust concentration were estimated for each occupation, and possible safe limits for the usual length of working life were suggested. These estimates would seem to be reasonable for the colliers, but for the other occupation groups they are based on very small numbers.

The effects, for each occupation group, of different periods of service with dust concentration kept constant, and of different dust exposures for equal periods of service, have just been discussed. The Pennsylvania figures also permit of comparisons of the incidences of disease as between the different occupation groups. Owing to the small numbers of men in the various subdivisions, however, no clear results would seem to be obtainable from such comparisons, beyond some evidence that rock workers incurred a greater, and roadway workers a smaller, risk than the colliers.

The Pennsylvania investigation was the first to entail a systematic combined medical and environmental inquiry, capable of statistical treatment, into the incidence of chronic pulmonary disease among anthracite miners. In the view of the present authors, the most notable results are as follows: (1) A serious incidence of disabling pulmonary disease of characteristic type, attributable to dust, is shown among U.S. anthracite miners. (2) The frequency and degree of disability are shown to increase with the extent and severity of the disease (subject to the above *caveat* on statistical validity). (3) The incidence of pulmonary disease is shown to be considerable among colliers at the face, as well as among rock workers. (4) Period of service, and average concentration of dust exposure during that period, are shown to be two important factors in the production of the disease. Thus, if the concentration of dust is sufficiently small, the incidence of disease produced is low even after a prolonged period, while, whatever the concentration of the dust, a significant period elapses before any important amount of the disease is evident. Again, men in a given occupation who experience a great exposure to dust (e.g. colliers engaged in chamber and pillar mining) are more likely to contract disease, and to do so sooner, than men in the same occupation under a somewhat smaller exposure (e.g. colliers on the pitch mining system). (5) There is also a suggestion that the free silica content of the dust is a factor, but the evidence on this point is much less clear. In particular, while the somewhat lower incidence of the disease among the colliers than among the rock workers could be explained by the smaller free silica content of the dust inhaled by the former, the fact that the difference in free silica is very large but the total concentrations of the dusts in these two occupations are not very different, makes it difficult to explain why the incidence among the colliers is not very much lower than it is—unless the operation of some other factor in the dust besides its free silica (e.g. the coal itself) be postulated.

Although not stated in this form in the Pennsylvania report, the general conclusions as to causation would appear to be that anthracite colliers have a serious incidence of pulmonary disease because they are exposed to dust of which, while the percentage content of free silica is low, the total concentration is high; and that the reason why some anthracite colliers develop the disease before, or with greater frequency than, others is that they have been exposed to dust either for longer periods, or at higher average concentrations (produced, for example, by a dustier system of mining), or both, than have their fellow-workers.

In the Pennsylvania report the time-risks of anthracite-silicosis among colliers in each of the three selected anthracite mines are not compared with one another; only the general incidences without reference to periods of service are given. Further, it was not possible within the scope of that inquiry to ascertain in a comparable manner the differences in incidence between colliers in these anthracite mines of Pennsylvania, on the one hand, and colliers in the bituminous mines that are found elsewhere in the U.S.A., on the other, and to see how far such differences could be accounted for by quantitative differences in the dusts. This brings us directly to the causative aspects of the South Wales problem. Here the situation is in some respects rather simpler than in Pennsylvania, for we have a coalfield in which at one end seams are being mined of which the coal is anthracite, and at the other end similarly-placed and often equivalent seams are worked of which the coal is bituminous; and a continuously changing rank of coal extends between these two geographical extremes. And in Wales the problem is why, as shown in the present medical report,

the incidence of pulmonary disease among colliers is generally high at the anthracite end of the coalfield, and comparatively low at the bituminous end, and intermediate about the centre; and also why there is a number of important low-incidence mines within the anthracite area itself. Consequently, unlike the Pennsylvania inquiry, one of the most important features of the Welsh survey is the comparison of incidences between representative mines. In this connection two points should be emphasised. One is that it has been found necessary in the Welsh inquiry, in order to sketch an "incidence-map" of the coalfield, to compare the time-risks, for equivalent periods of service, of selected colliers from each mine examined who have done little other work apart from this occupation and whose work as collier has been mainly confined to the colliery in question; such an arrangement has been practicable on account of the comparatively small amount of migration in certain areas. The other point to be emphasised is that whereas, in the Pennsylvania inquiry, mines with different systems of mining (and consequently different concentrations of dust at the face) were purposely selected, so as to produce variations in dust concentration, in the present field-survey the differential factor of system of mining has been so far as possible reduced, and similar working environments of the coalface workers aimed at, in choosing suitable mines for study.

The lack of an investigation in the bituminous coalmining industry of the United States, comparable with that upon Pennsylvania anthracite miners, has now been met by a separate but similar field-study at three bituminous mines in the State of Utah, made by the Division of Industrial Hygiene of the National Institute of Health, U.S. Public Health Service, in co-operation with the Utah State Board of Health (Flinn *et al.*, 1941)\*.

In all, 535 men (80 per cent. of those available) were examined from these three mines, but 28 were rejected as unsuitable on account of working histories, leaving 507; the working environment was also studied, as in Pennsylvania. Some seams of this coalfield are only 4 ft. thick, but the bulk of the coal is obtained from seams varying from 8 to 30 ft. The output is brought to the surface along slants, in contrast to most of the South Wales *bituminous* mines, which have vertical shafts; the system of work is chamber and pillar (pillar and stall) mining, which is seldom found in the Welsh bituminous mines. At two of the mines selected the coal is machine-cut and mechanically loaded, but at the third it is loaded by hand. Systematic use is made of explosives in winning the coal, and this blasting is carried out on all shifts, in contrast to conditions in Welsh bituminous mines, where blasting is uncommon and is confined to a back shift. The relative humidity ranged from 72 to 96 per cent. at the three mines and averaged 85 per cent. (an average found also at the coalface in the Welsh bituminous mine B.3). Watering of the coal at the face is carried out to some extent, a practice not at present in general use in South Wales.

The men were classed as non-affected, borderline cases, and anthraco-silicosis stage 1, 2 or 3, the diagnosis and stage-differentiation being definitely stated to depend on the clinical as well as on the X-ray findings; we are therefore unable to decide how far these stages correspond to those used in the Pennsylvania inquiry, but in any case, like the latter, they cannot be directly compared with the present South Wales X-ray categories (see also Chapter 13). Of the 507 workers, 16 (3.2 per cent.) were diagnosed as anthraco-silicosis, 15 (3.0 per cent.) in stage 1, 1 (0.2 per cent.) in stage 2, and none in stage 3; in addition, 26 (5.2 per cent.) were diagnosed as borderline cases. Assuming the stages to be comparable, a contrast with the Pennsylvania anthracite miners is thus evident, the latter having shown 23 per cent. with anthraco-silicosis, 19 per cent. being in stage 1, 3 per cent. in stage 2, and 1 per cent. in stage 3. The 16 Utah cases were all underground workers (giving an incidence of 4.6 per cent. rated upon total underground workers), 13 of them being face-workers (colliers, firemen, etc.) and three being transportation workers. No hard-heading men were examined. (In the English and Scottish bituminous mines, rock workers appear to account for the majority of the cases of pneumokoniosis.)

The main points of immediate interest in this study are that the incidence of pulmonary abnormality attributable to dust is much less in the Utah bituminous mines than in the Pennsylvania anthracite mines. The investigators explain this difference by the important finding that the dust exposures were considerably

\* The following review of certain aspects of this inquiry is based upon the report in manuscript, sent us through the courtesy of Dr. W. C. Dreesen, National Institute of Health.



lower, both in dust concentration and in free silica content. How far this difference is inherent in these mines, and how far it was due to the watering at the face at present in use in the bituminous mines examined, is not clear, but the remarkable effect of the generous use of water upon dust counts is evident from the controlled experiments quoted in the report.

Another, more limited, recent field-study of bituminous miners in the United States is based upon 774 workers in the Southern Appalachian Region (Clarke & Moffet, 1941). Chest X-rays showed "presilicotic changes" in 2 per cent. and varying degrees of "silicotic nodulation" in 1 per cent., these changes being mainly among the men on coal work. The incidences agree with the Utah study in showing a contrast to those for Pennsylvania anthracite miners.

(3) *Soviet Union*.—In the U.S.S.R. an extensive field-study of pulmonary diseases was made in 1930-35 at one anthracite and two bituminous coalmines in the Donetz Basin; it was carried out by a team under the Ukrainian Central Tuberculosis Institute and the Donetz Institute for Industrial Hygiene and Occupational Diseases. The home and working environment of the men, as well as their medical condition, was investigated. The main results of the medical examinations in this study (which will be referred to as the Donetz investigation) are assembled in a monograph by Moshkovsky (1941); those concerning pneumokoniosis, and relevant to the present problem, will now be summarised (for findings on tuberculosis see p. 157).\*

The clinical material comprised 298 underground workers at the Khrustalny colliery (anthracite); 1,329 at the Vetka colliery (bituminous coal); 987 at the Gorlovka colliery (bituminous coal); these totals included men transferred to surface work, and also a number who were no longer working in the coalmines. Other surface workers, and some of the miners' wives and children, served as controls. Clinical and X-ray examinations were made on these groups. The chief X-ray method was fluoroscopy (see p. 33, footnote), which was done on all the subjects, but this was supplemented by radiography (i.e. a film) on a large scale, especially among long-term workers; a film was also taken in every case where fluoroscopy gave rise to the least suspicion. The investigators were satisfied, after careful consideration, that this procedure made the figures represent with sufficient accuracy the actual extent of pneumokoniosis in the groups examined. (The working and home environment of these miners is described in another publication, by the Donetz Institute for Industrial Hygiene and Occupational Diseases, which we have not seen.)

Pneumokoniosis, as found in these men, was classified in three stages, based on the extent and intensity of the process as judged from the X-ray picture; the classification was apparently a modified form of that accepted by the 1930 International Conference on Silicosis (see p. 163). It is pointed out that the diagnosis of stage I had not the same precision as that of stages II and III, which expressed well-defined changes. In addition to the classification based on the X-ray picture, the clinical characteristics were recorded in each individual case.

The figures for all underground workers together at each mine were first grouped according to length of employment and stage of the disease. In the Khrustalny (anthracite) colliery, pneumokoniosis was found in 11.1 per cent. of the 298 men; 5.7 per cent. in stage I, 2.3 per cent. in stage II and 3.0 per cent. in stage III. In the Vetka (bituminous) colliery, the incidence of pneumokoniosis was lower, it being found in 3.3 per cent. of the 1,329 men; 2.3 per cent. in stage I, 0.9 per cent. in stage II and 0.1 per cent. in stage III. In the Gorlovka (bituminous) colliery, the disease was also comparatively rare, being found in 2.3 per cent. of the 987 men; 1.5 per cent. in stage I, 0.5 per cent. in stage II and 0.3 per cent. in stage III. In each of the three mines, the frequency and degree of the abnormalities increased with the length of employment; stages II and III were practically confined to men of more than 15 or 20 years service. Comparing one mine with another by periods of service, there was little difference in the younger employment groups; in men of more than 20 years service, however, an excess was evident, both in the frequency and in the degree of pneumokoniosis, in the anthracite mine over the two bituminous mines. Thus, the percentage affected in this employment-group was 27.1 (14.0 in stages II and III together) in the former, and 13.5-11.0 (6.7-4.4 in stages II and III together) in the two latter.

When the miners in the Vetka colliery were compared by occupation, those on coal work showed, on the average, a rather higher incidence of pneumokoniosis than those on

\* We are indebted to the U.S.S.R. Commissariat for Public Health for transmitting, despite the war, this and other recent material upon lung diseases among miners, and upon methods for their prevention. (The material was received while this report was in proof.)

general underground work; apart from this, there was no striking occupational difference—a finding explained partly by the frequency of mixed occupational histories, and partly by differences in length-of-employment distribution in the groups compared. The group composed of miners transferred to the surface from underground work actually showed a somewhat higher incidence than those working underground at the time, due, it was considered, to the tendency of relatively unfit men to move, or to be moved, to surface work; at the other two mines, also, a proportion of the pneumokoniosis cases found was among men who had been transferred to surface work or had left the mine altogether. Removal of these cases reduced, for each of the three mines, the incidence rated upon men working underground at the time of examination; this reduction happened to be differentially in favour of the anthracite mine investigated, so that the recorded excess in the incidence of pneumokoniosis among anthracite miners over that among bituminous miners was also reduced. However, it was pointed out that the contrast in the degree and intensity of the changes found (judged from the stage-classification) remained definite.

Moshkovsky considers that pneumokoniosis amongst bituminous coalminers has a comparatively benign course, and generally has little effect upon the working capacity of the patient. Miners in anthracite mines show more serious forms of pneumokoniosis, which limit their working capacity. This limitation is mainly determined by emphysema and myocardial damage.

The main point of present interest in this Donetz investigation is the contrast—albeit a small one—in incidence of pneumokoniosis between the anthracite and bituminous miners examined from the same region; though the incidence was not great at any of the mines selected. After reviewing the many variable factors in the Don collieries that might affect the recorded amount of pneumokoniosis at a particular mine—such as the method of mining, the geological and hygienic features and concentration of dusts in a mine, the length of employment of the men, and the departure from the mine of the unfit—the investigators conclude that the contrast in incidence is substantially genuine, and that pneumokoniosis, as an occupational disease, is particularly important in connection with anthracite mines; such mines, therefore, require radical measures for the reduction of dust. One of the causes of the difference between the two classes of mine is thought to be the physical properties of anthracite dust, and the production of a more noxious effect on the lung by the latter than by dust from bituminous coal; the work of several Russian authors (Belliaev & Shavinin, 1931; Stoyanovsky *et al.*, 1936; Ravvin & Eniakov, 1940) is quoted in support of this suggestion.

It is of interest to mention some of the methods for preventing pneumokoniosis in coalminers to which the Soviet authorities attach importance. In addition to efforts towards reduction of mine-dust, there are measures directed to the individual protection of miners especially exposed to risk. These include planned selection of new entrants to the industry; preliminary and periodical medical examination, with transfer of the affected, when necessary, to more suitable jobs; special insurance grants, and pensions at an earlier age than usual; annual holidays of one month, and the provision by the colliery administration of an extra pint of milk daily; breathing exercises and physical culture; and prophylactic treatment at spas and sanatoria.

(4) *Other countries.*—Reports from other countries, upon the X-ray examinations of non-anthracite miners, have given very varied incidences of pneumokoniosis. Critical appraisal of these reports is not possible, since most of them lack sufficient information as to conditions of mining and as to the nature of individual occupations.

In *Australia*, in 1930, Moore and Badham (1931) examined 477 non-anthracite miners of New South Wales, and found that 26 per cent. showed radiographic changes indicating pulmonary fibrosis. The cases included some with advanced lesions. Attempts to differentiate incidences referable to different mines were hampered by the fact that only a small number of employees at each pit was examined, and many of these had very mixed mining histories (see also Badham, 1939b).

In *Southern Rhodesia* a Government Commission in 1938 investigated employees of the Wankie coalmines. Clinical and X-ray examinations were made of 116 of the 3,100 native employees, forming a sample of those most liable to be exposed to colliery dust.

In five cases the X-rays showed an abnormal increase in striation and in one case symmetrical massive shadows. These changes were attributed mainly to other causes, and the Commission concluded that coalmining at Wankie was not productive of silicosis (Southern Rhodesia, 1938).

Oddo (1899), in *France*, was perhaps the earliest worker anywhere to correlate an X-ray picture of a pneumokoniosis with the post-mortem findings. He described a case showing an ovoid opacity of the chest, radiographically, which at autopsy was revealed as an "anthracotic" cavity. More recent studies at coalmines in various parts of France by Leclercq (1933) and Magnin (1935) are quoted by Middleton (1938a).

In *Germany*, the X-ray examinations of 1,500 Ruhr coalminers were reported by Boehme (1925a). This total included colliers as well as stone-cutters. Out of 71 colliers of over 10 years service, 23 were classed as showing definite pneumokoniosis, though mostly of slight type. Other findings were that the period of service was an important factor, and that the disease was more severe and frequent in the stone-cutters than in the colliers. In a later communication by Boehme (1930b), radiological changes were reported in 75 out of 223 colliers. The positive cases included 28 showing fine mottling, beyond which stage—corresponding to a small nodular dust fibrosis at autopsy—the disease was stated hardly ever to proceed. Boehme (1930a) also quotes a number of more recent investigations among rock-drillers in coalmines in the Ruhr and elsewhere in Germany.

Edling (1926), in *Sweden*, was one of the first writers to describe a classification of stages in the X-ray development of pneumokoniosis in coalminers; he based his description upon a study of 46 miners from the Höganäs district. Most of these men were in regular work. X-ray examination showed mottled or massive shadows (stages 2 and 3 of his classification) in 32 of the 46 miners, the majority of those affected having worked for long periods underground. It is presumed, although not explicitly stated, that Edling's subjects were colliers.

In *Belgium*, in 1935, an investigation was made of 900 men who had been exclusively rock workers, and also of 100 pure colliers, from various coalfields, all of them being in regular work. Among workers of over 10 years' service, normal X-ray findings were the exception. A considerable number showed extensive or highly-developed fibrosis on the X-ray, or even nodular and pseudo-tumoural forms. The proportion of affected subjects was as high among the colliers as among the rock workers, an unexpected result (Langelez, 1938). Similar findings were reported by Courtois (1938).

(b) *Compensation statistics.* Under the Various Industries (Silicosis) Scheme, 1928, which came into force in February, 1929, compensation became payable in Great Britain to coalminers employed in drilling and blasting in siliceous rock (i.e. mainly hard-heading men) if certified (by a special Medical Board from June, 1931), as disabled through silicosis or silicosis accompanied by tuberculosis; the scheme was soon (1934) extended to include all colliery workers underground. For compensation to be payable, the pneumokoniosis had to reach certain X-ray or post-mortem standards (see Chapter 13; for the history of compensation legislation regarding coalminers, see also Harrington & Davenport, 1937, and Middleton, 1938a).

This compensation legislation meant that, for purposes of diagnosis and the issue of certificates, a large number of X-rays was taken and autopsies held of British coalminers. The result was to bring the whole South Wales problem sharply into focus. The compensation figures mounted rapidly, mainly of course on account of the fresh diagnosis of already existing cases, and so the rate of increase was largely artificial. It soon became clear (Fisher, 1935; Middleton, 1936) that the great majority of the cases was being supplied by South Wales, with uneven distribution to the disadvantage of the west (anthracite). Many of the cases were of men who had not drilled in rock, and many came from anthracite mines, where stone-dusting has not been the practice though much ripping is done; whereas outside South Wales most of the men certified had been rock-drillers. This inequality of distribution of certified silicosis, both geographically and occupationally, was well brought out in the statistics given by T. David Jones (1936, 1938).

Using the Medical Board's figures, Jones showed that the greater part of the certificates issued for silicosis in Great Britain to date was in respect of South Wales; that the majority of the Welsh cases came from the Swansea Division, which includes the anthracite area; and that most of the cases from the Swansea Division were from its anthracite collieries. He showed also that, of the persons

affected in South Wales, many more were colliers than hard-heading workers, though the incidence-rate was much higher among the latter; and, further, that the proportion of certified cases that had worked intensively in rock was greater outside than inside the anthracite area. In connection with the excess in the anthracite mines, Jones referred to the greater use of explosives in anthracite mines than in the steam and bituminous coal, and to the common use of spake trains on the anthracite slants. The incidence of certified silicosis was higher in those anthracite mines where spakes were employed. It was suggested that exposure on these trains might promote bronchitis and so impair elimination of dust from the lungs. (The arrangement of Tables III and V (pp. 8 and 9) of the present report was suggested by Jones's tables.)

An important sequel to Jones's statistical studies was supplied by Cox (1938), who pointed out a parallelism between the incidences of cases certified as silicosis from various South Wales collieries and the different ranks of the coals mined by the men, which ranged from high-rank anthracite to bituminous coal. This parallelism is in general supported by the distribution of the incidences of X-ray abnormalities among colliers at the 16 collieries investigated in the present inquiry. Cox's data were obtained by personal investigation of working histories.

(c) *Mortality statistics.* The selective localisation of chronic pulmonary disease in the anthracite part of the coalfields of England and Wales, shown by these compensation statistics, was also being demonstrated by means of the occupational mortality statistics of the Registrar-General's Decennial Supplements. The figures in the 1921 Supplement indicated that there was a greater respiratory mortality among colliers in South Wales than in other parts of the country; this excess was more pronounced in the western part of Wales than in either Glamorgan or Monmouthshire, and more so in Glamorgan than in Monmouthshire (see discussion by Collis, 1931). The excess respiratory mortality was mainly confined to the older ages (45 and upwards). Discussing the data in the most recent Supplement (1931), which covered the years 1930-32 and embodied a number of improvements, Stocks (1938) explained how the mortality figures for the wives of men in various occupations, included for the first time, could be used as controls to see whether the variations in occupational mortality noted for males were in fact due to occupational effects or to variations in general environment affecting their wives also. In the 1931 Supplement itself (Registrar-General, 1931), this method of control was used for coalminers for the country as a whole, with the following result: "these comparisons (with corresponding wives) suggest that the only important causes from which the mortality of male hewers and getters (colliers) was enhanced as a result of their occupation, as distinct from their home environment and selection, were septic infections, bronchitis to a slight extent, chronic interstitial pneumonia (including deaths returned as silicosis), suicide and accident." Analysis of the regional distribution of the mortality from respiratory diseases of male hewers and getters, and also of other underground workers (irrespective of the mortality of the wives), showed an excess for anthracite as against other South Wales mines; while an analysis of the age-distribution of the excess respiratory mortality of coalminers for the whole country indicated that this was now (1930-32) present at the younger ages and not, as ten years previously, mainly confined to the older groups. (The table on p. 86 of the 1931 Supplement suggested the presentation of Table II (p. 7) of the present inquiry.)

There have been a few studies in the United States upon occupational mortality statistics, which have also incriminated anthracite mining as the biggest source of respiratory disease in the coalmining industry. Owing to limitations of the data available it has been necessary to use the percentage of deaths due to a given cause (proportionate mortality), instead of death-rates as in this country. In a careful study Brundage (1933) found that both anthracite miners (from Pennsylvania) and bituminous miners (from Indiana, Missouri and Wyoming)

showed an excess mortality from respiratory disease as a whole over other males of the same ages in the same regions, the excess being greater for the anthracite workers at every age. Similar evidence of the higher respiratory risk suffered by anthracite over bituminous miners was presented by Lanza and Vane (1939), using statistics for the period 1925-36.

(d) *Autopsies.* During the past two decades, side by side with the accumulating clinical, radiological and statistical evidence of the prevalence of pulmonary disease among anthracite miners, there has been development of knowledge of the pathological changes in the lungs of these and other coalminers, and of the relation of these changes to coal and silica, and to silicosis.

Perhaps the most thorough investigation has been that of Cummins and Sladden (1930), based upon autopsies of South Wales coalminers, of whom some had worked in hard headings but others had been mainly ordinary colliers at the face; the men were chiefly from anthracite mines. These authors demonstrated that the changes were a pathological entity, which might disable and kill. They concluded that the conditions comprised a combination of silicotic fibrosis and accumulation of coal dust, the silicotic factor damaging the lung and setting up fibrosis, and preventing elimination of the coal dust. Cummins and Sladden used the term anthracosis in this paper, but later referred to this pneumokoniosis as a silico-anthracosis (Cummins, 1935); this is equivalent to the anthracosilicosis of the U.S. workers, who reserve the term anthracosis for the condition commonly found among ordinary city-dwellers.

Many subsequent workers have also presented evidence of a relationship between the changes found in coalminers' lungs and those of silicosis.

Among this post-mortem work we may mention that of Policard (1930), in France, who considered that the pathological changes in the lungs of French coalminers were also allied to or phases of silicosis; Cooke (1932), who seems to have been the first to apply the term silico-anthracosis, and who described some of the stages in the histological development of the disease; Sladden (1933), who found silica in important quantities in the lungs of South Wales miners; Stewart (1933), who, with Fowweather, found a similar excess for English bituminous miners; Gardner (1934), who ascribed the variability of the lung changes in part to the relative proportions of coal and silica; Miller (1935), whose findings in connection with the Pennsylvania inquiry into anthracosilicosis among anthracite miners agreed with those of Cummins and Sladden; and Cooke (1938), who contrasted the silico-anthracosis found mainly in anthracite miners working in silica and coal dust with the classical type of silicosis in coalminers engaged in drilling sandstone rock, there being gradations between the two types.

Other authors have emphasised the differences, rather than the similarities, between the changes in coalminers' lungs and those in silicosis.

Prominent among these workers are Badham and Taylor (1933, 1936) and Badham (1939a), who stressed the points of anatomical difference from classical silicosis in their series of lungs from coalminers (non-anthracite) in Australia, many of which showed advanced fibrotic changes. They attributed the differences to the injurious factor being carbon or silicates, and not free silica, and they suggested that dust from the coal seam itself—without the surrounding rock strata—was to blame, supporting this by evidence of fibrosis in colliery surface screens workers. These authors considered that the pulmonary fibrosis in the Australian coalminers was more frequently accompanied by emphysema than ordinary silicosis, that this emphysema was more often secondary to the fibrosis than to bronchitis, and that it was usually the incapacitating element. Badham and Taylor's findings in non-anthracite miners may be compared, firstly, with the investigation of miners in the Högånäs district of Sweden by Edling (1926), who stated that, even with advanced changes on the X-ray, the coal dust in the lungs was not associated with any pathological increase in fibrous tissue; and, secondly, with the study by Gardner (1933) of eight autopsies in American bituminous coalminers. In the latter study, the lungs were reported as usually soft, and the reaction to the dust as usually minimal, though foci of emphysema were found. The presence of silica was demonstrated in addition to the coal. As a result of further pathological and chemical work, Badham and Taylor (1939) have modified their previous view upon the fibrosis in coalminers' lungs, and now attribute the difference from classical silicosis to the action of free silica inactivated by other dusts, or modified in its action by so-called inert dusts. They leave open the question of how far this type of reaction may be due to the minimal amount of free silica found with the inert dust.

Relevant also to the problem are the recent experiments of Ravvin and Eniakov. These authors investigated the aetiology of the small foci of fibrosis characterising the condition often termed occupational anthracosis (the term here being used differently from its use by the U.S. workers, see above).

In a summary of their work (1940), they report that they exposed rabbits to anthracite and bituminous coal dusts, using practically ashless dusts (mineral impurities 0.25-0.69 per cent.) and concentrations not exceeding 2,000 particles per c.cm. The pathological lung picture with both these practically pure coal dusts was similar to that obtained after exposure to coal dusts with mineral admixtures; it included dust-cell accumulations, up to the beginnings of formations similar to "pseudo-tubercles" (Mavrogordato), and appeared to be an early reaction of the lung tissue to coal dust. Ravvin and Eniakov conclude that the basic factor in determining the lung changes in "occupational anthracosis" in coalminers is the coal dust as such, and not its mineral admixtures. Such a conclusion would perhaps be consistent with the determinant being the *whole* dust from the coal (which, of course, includes a small amount of inherent mineral matter), but not primarily the adventitious mineral matter from the adjacent strata (which may be mixed with the coal in the dust in very varying degree). Ravvin and Eniakov note two further points of interest in their experiments: first, that the lung reaction to the anthracite dust was sharper than to the bituminous coal dust—a difference which agrees with the observation from field-studies, that anthracite mining is more associated with pneumokoniosis than bituminous coalmining; second, that an increase in external temperature of the animals led to a greater retention of dust in the lungs and a sharper cellular reaction, suggesting that the temperature of the mining environment may also influence the development of pneumokoniosis.

Finally, in connection with the relation of the pneumokoniosis of coalminers to silica and silicosis, as studied by post-mortem examination, the work of W. R. Jones (1933) must be mentioned. Jones examined the mineral residues from a series of pneumokoniotic lungs, many of them from South Wales miners, and put forward his hypothesis that sericite was an important factor in the cause of silicosis. Although, in the form put forward, Jones's hypothesis has not been generally accepted, the possible importance of sericite or other types of mica cannot be discounted. In this connection, pneumokoniosis in significant amount and degree has been recently reported in a group of men exposed to dust from mica which is stated to contain almost no free silica (Dreessen *et al.*, 1940).

#### (iv) *Tuberculosis in coalminers*

In this review of literature the question of the association of tuberculosis with pneumokoniosis in coalminers has been deferred to the end.

(a) *Earlier work.* From the earliest interest in this subject it was noted (e.g. by Greenhow, 1862) that pulmonary affections among men in the coalmining industry tended to be less toxic and less rapidly progressive than those among workers in other dusty trades. Even allowing for a certain amount of confusion in terminology between miners' phthisis (dust-phthisis or pneumokoniosis) and tuberculous phthisis (respiratory tuberculosis), mortality statistics, so far as they went, appeared to indicate that coalmining in general carried no special liability to tuberculosis, in spite of a relative excess of non-tuberculous respiratory disease (e.g. Tatham, 1902; Haldane, 1916, 1918). Haldane (1931, 1935) argued that the lesions which were being increasingly described in Welsh miners could not, therefore, be silicosis, and he and some other authors suggested that coal dust might even be protective against tuberculosis (Wainwright and Nichols, 1905; Haldane, 1916, 1918), a view with which Kettle (1930) did not agree. Haythorn (1913) made the interesting suggestion that smoke or soot might assist in the healing of the tuberculous type of inflammation, but might promote the action of more acute inflammatory processes such as acute pneumonia.

Even in the earlier writings, however, doubt was expressed as to whether tuberculosis was not a possible factor in coalminer's pulmonary fibrosis, at least at some stage. Thus Arlidge (1892), after discussing the association between tuberculosis and this condition, left open what was evidently a controversial question, while Oliver (1909) considered that dust and the tuberculous process were both connected with its aetiology.

(b) *More recent work.* From the evidence, derived from experimental work and from gold mining experience in South Africa, that a simple quartz silicosis unaccompanied by tuberculosis was a pathological entity which might at some point become complicated by tuberculous infection, it seemed possible that in coalminers the pneumokoniosis might also be similarly complicated, though in a modified and less toxic form, owing to the mixed nature of the dust. This suggestion—that tuberculosis occurred among coalminers more frequently than had been supposed, though it might often be difficult to recognise—has been, in the main, supported by autopsies and clinical studies, as well as by recent compensation figures and mortality statistics.

(1) *Autopsies.*—Cummins and Sladden (1930) held that great caution was necessary to exclude tuberculosis as an element of the histological picture in "anthracotic" (anthracosilicotic) lungs; and Cummins (1931, 1934, 1935, 1936) considered that tuberculosis not infrequently complicated South Wales coalminers' pneumokoniosis. As a result of experiments in his laboratory (Cummins and Weatherall, 1931, 1933; Cummins and Williams, 1938), Cummins suggested that the coal itself was capable of adsorbing the tuberculin of the tubercle bacillus, so that the presence of tuberculosis became difficult to recognise during life, and, without a post-mortem, might be returned at death simply as silicosis or as bronchitis. With this difficulty in mind, Charr, Cohen and Bettag (1938) compared the post-mortem records of 541 anthracite miners and 730 non-miners in a county of Pennsylvania. They considered that among the miners 28 per cent. showed, and 21 per cent. had died from, pulmonary tuberculosis; for the non-miners the corresponding percentages were 10 and 9; the more marked the anthracosilicosis the more evident, though the more chronic, was the tuberculosis. Unfortunately, these authors do not state what proportion of their miners were colliers and what proportion rock-drillers; nor do they subdivide the incidence of tuberculosis in the mining group, so as to show separately its incidence with and without associated anthracosilicosis. This series of anthracite miners may be compared with a group of 113 bituminous miners, included among a much larger series of autopsies made in Pittsburgh (Schnurer *et al.*, 1935), some of whose lungs showed excessive fibrosis. Only four cases of active tuberculosis were found in this group, though completely healed lesions were detected in a further 39.

Some authors have gone so far as to suggest that tuberculous infection is *necessarily* present in the pathogenesis of pneumokoniosis. After reviewing these suggestions, Moshkovsky (1941), on the basis of material from the Donetz coalfields, concludes that, while tuberculosis may develop on the background of a koniotic process or in close relation with it (konio-tuberculosis, as it is termed), pneumokoniosis is basically an independent disease-unit.

(2) *Clinical studies.*—Boehme (1925b) found a significant amount of tuberculosis in a series of Ruhr coalminers. Tattersall (1926), in South Wales, observed clinically recognisable tuberculosis as a frequent terminal feature of pneumokoniosis in his cases of hard-heading men; this observation was confirmed by experienced practitioners in the area (see Jones, 1936), who held that this feature distinguished pneumokoniosis in such classes of miner from the much more frequent type of disease among colliers. In Wales also, Enid Williams (1933), in her study of 100 old and retired miners, found tubercle bacilli in the sputum of six men, but four of these were colliers (though a short period of rock-drilling had been done by certain of them); all the sputum-positive cases had only slight constitutional symptoms and in four the disease had not previously been suspected. In another South Wales inquiry, Sen (1937) examined 100 definite cases of pneumokoniosis, half being rock workers and half colliers, and found 12 positive sputa, these being equally distributed among the two occupations.

Similar data are available from the United States. Sokoloff (1936) examined 418 anthracite miners institutionalised through disabling pulmonary disease, and found positive sputa in the remarkably high number of 203, though it is not clear what proportion of these had been primarily rock-drillers, and what proportion colliers at the face. The Pennsylvania inquiry, 1933, also revealed a high percentage. Out of 2,711 working anthracite miners clinically and radiographically examined, 6 per cent. were diagnosed as having clinical tuberculosis (as compared with less than 1 per cent. in a control group); in 2 per cent. the disease was considered to be present alone (a frequency approximately equal to that for the whole country) and in 4.5 per cent. to be accompanying anthracosilicosis, giving an incidence of 20 per cent. when based on the total anthracosilicosis cases. The prevalence of tuberculosis was greater among the rock workers than among the colliers. No sputum tests were made on these employees, and the diagnosis of tuberculosis was therefore provisional. Moreover, the criteria of superadded infection (including asymmetry, irregularity of outline, and loss of definition, of the X-ray shadows) would probably not find general acceptance in this country.

These Pennsylvania anthracite data may be compared with those of the recent study on Utah bituminous mines (Flinn *et al.*, 1941), in which the incidence of anthracosilicosis was

found to be low. The incidence of clinical tuberculosis was 2·5 per cent. (similar to that in studies of the general population, but contrasting with 6 per cent. among the anthracite miners). When rated upon miners without anthraco-silicosis, the incidence was again 2·5 per cent. (compared with 2 per cent. for the anthracite miners), and when rated upon total anthraco-silicosis cases it was one case (minimal and healed) in the 16 (in contrast to the 20 per cent. found for the anthracite miners). Tuberculosis was therefore considered not to present a serious hazard among these bituminous miners. Similar conclusions were drawn by Clarke and Moffet (1941), who noted that the incidence of healed and active adult-type tuberculous changes in a group of bituminous miners in the Southern Appalachian region did not differ appreciably from that in a control group examined.

Evidence of a comparatively low incidence of tuberculosis among bituminous coalminers was obtained also in the course of the Donetz investigation, 1930-35, in the Soviet Union (see p. 150; Moshkovsky, 1941). Among 1,315 of the 1,329 underground workers examined at the Vetka (bituminous coal) colliery (in which the incidence of pneumokoniosis was low), clinical tuberculosis was found in 1·6 per cent.; this incidence was lower than those in the two control groups, viz., 123 men who were primarily surface workers (3·5 per cent.), and 546 wives of miners (2·5 per cent.). Restricting the cases to open tuberculosis, and rating them upon the 1,161 miners who were actually working underground at the time of the investigation, the other 154 being men who had been transferred to surface work, the percentage-incidence was reduced to 0·17 per cent. Similarly, among the 987 underground workers examined at the Gorlovka (bituminous coal) colliery (also low-incidence as regards pneumokoniosis), clinical tuberculosis was found in 1·4 per cent.; for open cases, based upon the number actually working underground (934 men), the incidence was only 0·1 per cent. (The results of tuberculin tests upon these Don miners were referred to on p. 120). Reviewing the many hypotheses put forward to explain the relatively low tuberculosis morbidity recorded among bituminous mineworkers, the Soviet investigators do not agree with the view, frequently expressed, that coal dust, or the fibrosis set up by it, has a protective effect against lung tuberculosis; they consider that the general social and hygienic conditions in the life of the miner, and natural occupational selection, are two factors of special importance. Natural occupational selection and rejection act in virtue of the tendency of men who take up underground mining work to be above the average in physical fitness, and the tendency of relatively unfit men either not to engage in such work or to leave it soon (and in many cases so to escape inclusion in the morbidity figures of the coal industry); support is given to the existence of these tendencies by the data collected. In many of the Don collieries, place of residence is excluded as a factor in the natural occupational selection, since the men come mainly from remote parts of the Union; the basic "lever" in the selection is, it is believed, the physical strain *plus* the special working conditions associated with underground mining. These natural selective tendencies will, of course, be enhanced where preliminary and periodical medical examinations are made of the miners.

Little clinical work has been done on the natural history of tuberculosis in coalminers apart from pneumokoniosis. The studies of Glyn Jones (1938) upon bituminous miners and non-miners in South Wales suggest that even if the incidence of tuberculosis is low among the former, the type and course of the disease in those who do develop it—apart from pneumokoniosis—is very similar to the condition as found in the non-mining population. This was also the conclusion drawn in the Donetz investigation.

(3) *Compensation figures.*—The experience of the Medical Board for Silicosis is valuable in the present question. From 1932 to 1939, 173 deaths in the coalmining industry (mainly from South Wales), coming to the notice of the Board in connection with compensation claims, were certified as silicosis accompanied by tuberculosis, as compared with 261 certified simply as silicosis. The tuberculous cases included colliers as well as rock workers, though the proportions are not stated (Sutherland, 1940). According to Glyn Jones (1938) and Davies (1940), cases such as these, unless the sputum is positive, afford considerable difficulty in diagnosis of the tuberculous complication during life.

From these compensation figures, together with the autopsy and clinical studies mentioned above, the view emerges that rock workers in coalmines who suffer from pneumokoniosis are specially liable to develop clinical tuberculosis in addition; and that colliers with pneumokoniosis also have a tendency to develop this complicating infection, though often in a modified form so that it may not be easy to recognise clinically and may even be difficult to determine at autopsy. There is still no clear evidence that, apart from pneumokoniosis, coalminers have any special liability to tuberculosis; indeed they may even prove to have a reduced liability (see below).

(4) *Mortality statistics.*—Meanwhile, on the statistical side, Collis (1922, 1926), after pointing out that an apparently low incidence of tuberculosis among coalminers, *on the average*, was still shown by current mortality statistics, threw doubt on the latter's general applicability, suggesting that they might obscure a raised incidence at certain ages or



among certain classes of miner. Point was lent to this argument by the clinically obvious tuberculosis among hard-heading workers in Wales, which the mortality statistics had failed to reveal. Furthermore, the mortality figures in the 1921 Decennial Supplement indicated (Collis, 1931) that, while colliers as a whole had a low mortality from respiratory tuberculosis, differences became manifest when areas were taken separately; colliers in the western part of Wales showed an excess over those in Glamorgan and Monmouthshire and had a rate no lower, and possibly even slightly higher, than the standard population. A clearer picture is given by the figures in the 1931 Supplement (Registrar-General, 1931). Using the mortality of wives as a control, the sub-standard respiratory tuberculosis mortality of coalminers in general is shown to be probably real, i.e. the result of occupational environment (or occupational selection) and not merely due to general environment affecting wives as well as husbands. When anthracite and other miners, both in South Wales and in England, are considered separately, as in Table II (p. 7) of the present inquiry (a modified form of the table on p. 86 of the Supplement), the Standardised Mortality Ratio for respiratory tuberculosis among anthracite miners (103) is greater than among non-anthracite (79), the former being the same as, or slightly higher than the standard (100), and the latter having the usual low figure.

The separate mortality from respiratory tuberculosis of anthracite miners has been the subject of recent study also in the United States, though the occupational statistical data are more limited. In the report upon proportional mortality, already mentioned, Brundage (1933) found the percentage of deaths due to tuberculosis among bituminous miners to have the usual low figure, but the figure for the anthracite miners was approximately equal to, if not slightly greater than, that for the control population. Using more recent statistics (1925-36), Lanza and Vane (1939) found a similar excess of respiratory tuberculosis mortality among anthracite miners over bituminous miners, with a similar relation of each to the figures for the standard population.

These recent statistics, both for this country and for the United States, confirm, therefore, the long-held view of a low respiratory tuberculosis mortality for miners in general, and also for bituminous miners in particular, but indicate that this older view must be modified for anthracite miners. It is important, however, to recognise the possibility that there may be a dual effect upon the development of tuberculosis, such effect being due (*a*) to the occupational environment (or occupational selection) as such, and (*b*) to the presence of a pneumokoniosis that has itself already developed as a result of the occupation.

Hypothetically, certain classes of coalmining might increase the liability both to pneumokoniosis and to tuberculosis, with the two conditions invariably co-existent, as some workers hold; but an alternative hypothesis for examination is that the occupational environment, e.g. the coal, protects from tuberculosis unless pneumokoniosis occurs, in which case subsequent development of the infection is favoured. On the first hypothesis, the statistics in Table II (p. 7) could be explained by the production of a greater risk of tuberculosis, as well as of pneumokoniosis, by an anthracite mining environment as such (e.g. dust) than by a bituminous mining environment. On the second hypothesis, while the actual anthracite mining (dust, etc.) is responsible for the greater risk of pneumokoniosis, it is not the factor directly causing the excess risk of tuberculosis; the Standardised Mortality Ratio of 103 being consistent with a low tuberculosis mortality due to the dust *plus* a high tuberculosis mortality due to the frequent presence of pneumokoniosis resulting from the dust, giving a resultant mortality in this case of about standard and, therefore, greater than that for the bituminous miners.

With the English bituminous miners in Table II we are on surer ground, since the incidence of certified pneumokoniosis is low and—if it be permissible to extrapolate the results from high to low rank of coals across the South Wales coalfield obtained in the present investigation—so also is the incidence of X-ray abnormalities. The influence of mining environment (dust, etc.) is, therefore, present without the large amount of pneumokoniosis of the anthracite miners. Consequently, the low Standardised Mortality Ratio for respiratory tuberculosis for these miners (79) can probably be correctly ascribed to the occupation *per se*.

The preceding argument, it is suggested, is not academic. Much more research work upon the association of tuberculosis with coalmining is clearly required, and it would be desirable if in such work the effects of (*a*) dust and (*b*)

non-tuberculous pneumokoniosis upon the development and spread of this infection could, so far as possible, be studied separately. The parts played by natural occupational selection, and by the general social conditions under which the miners live, on which factors the Soviet investigators have laid great stress, also merit close attention.

From the preceding account of the more recent literature upon pneumokoniosis in coalminers it may be seen that attention has become focussed upon anthracite mining, both in Wales and in other countries where this class of coal is mined. Whatever may have been the position in the earlier days of this branch of the coalmining industry, at the present time it is the chief source of the considerable amount of disabling pulmonary disease that is recognised in the British coalfields. Non-anthracite areas contribute to some extent, however, though there is lack of uniformity in the reports from various countries as to the amount of the pneumokoniosis present in non-anthracite mines. The pulmonary disease in anthracite miners, or at least a large part of it, appears to be a fairly distinctive pathological entity, accompanied by definite X-ray changes. It is found not only in rock workers (e.g. hard-heading men) but also in considerable amount among colliers working at the face, though the latter may breathe, in addition to dust from the coal seam itself, stone dust produced by ripping of the overlying or underlying strata. The relation of this pulmonary condition to classical silicosis caused by quartz in fairly pure state, on the one hand, and to tuberculosis, on the other, is left in uncertainty; so also are the parts played by silica or silicates, and by coal.

#### B. PULMONARY DISEASE IN COALTRIMMERS

Very little work has been published upon pulmonary affections among coaltrimmers. The first mention we have found is that by Oliver (1902), who stated in his book on Dangerous Trades that "phthisis and pulmonary diseases carry off a large percentage of coal hewers and trimmers"; he did not, however, attribute this predilection to the inhalation of dust.

Credit for first drawing attention to the possible occurrence of pneumokoniosis in coaltrimmers goes to Collis and Gilchrist, who published an important statistical and medical paper from Cardiff in 1928, at the time when pneumokoniosis was just being recognised as comparatively widespread among coalminers in South Wales. These authors gave the clinical and X-ray records of 11 long-term coaltrimmers from Cardiff docks, where the coal handled was mainly Welsh steam coal; the group consisted of those trimmers who had attended a tuberculosis clinic during the previous three years. Since all had come suspected of having tuberculosis, all had chest symptoms, but in only one was the sputum positive for tubercle. The X-ray pictures of none of these men were normal, the majority showing generalised mottling, and a few cases dense or massive shadows. The authors concluded that, after many years of work, coaltrimmers exhibited X-ray signs in their lungs similar to those usually accepted as characteristic of silicosis.

Collis and Gilchrist supported their thesis with mortality figures, namely (a) proportional mortalities based on the death certificates of members of Cardiff, Barry and Penarth Coaltrimmers Union, and (b) the occupational mortalities of coal hewers in the Registrar-General's Decennial Supplement for 1911, and of coal-boat loaders and dischargers in the 1921 Supplement. From these figures they concluded that coaltrimmers suffered an excess mortality returned as bronchitis and pneumonia, but that there was no excess mortality from tuberculosis. They pointed out, however, that part of this excess of respiratory disease might be due to causes other than dust, such as exposure to unfavourable weather conditions.

Additional information upon mortalities is obtainable from the Registrar-General's 1931 Supplement (Registrar-General, 1931), by comparing the mortalities of coal-boat loaders and dischargers, and of stevedores and of other dock labourers, with those of the corresponding wives. There is an excess mortality from respiratory disease as a whole in each of these groups of males as compared with all males, but when compared with the corresponding wives the coal-boat loaders and dischargers alone maintain their excess mortality at all clearly. This suggests that the mortality from respiratory diseases of the men in this group is augmented by their occupation, perhaps to a greater extent than in the other two groups of dock workers.

In 1934 the Industrial Pulmonary Disease Committee of the Medical Research Council issued a report of a clinical and radiological investigation of coaltrimmers at Swansea docks, where the coal handled was mainly anthracite.

It was based upon clinical examinations by Drs. N. Keating and R. W. Thomas, members of the Medical Board for Silicosis, Cardiff, and upon radiological examinations by Drs. Howell M. Williams and R. G. Prosser Evans, of the Welsh National Memorial Association staff. The X-ray films were interpreted by members of the Committee. A total of 40 working trimmers was examined out of an employee population at these docks of about 250. Of these 40 men, 11 were recent recruits to the industry and had seen less than 5 years service, and the remainder had been trimmers for over 10 years (2) or over 20 years (27). Both sub-groups were probably fairly representative of short-term and long-term coaltrimmers, respectively, but with a slight bias towards the inclusion of men with some suspected chest trouble. From the 11 short-term workers examined, there were 9 films classed as negative and 2 with "evidence of fibrosis in the lungs not considered to be due to dust but to other causes, mainly antecedent disease". From the 29 long-term trimmers, there were 12 negative films and 12 films with fibrosis not considered to be due to dust (see above), and there were 5 men with chest conditions other than fibrosis and not due to dust (e.g. cardiac abnormalities).

The Committee concluded that no evidence had been shown of pulmonary fibrosis resulting from the inhalation of anthracite coal dust during the operation of trimming.

In 1936, Bathgate, working, like Gilchrist, in Cardiff, gave the details of 44 coaltrimmers examined in the course of his panel practice or sent to him from Gilchrist's tuberculosis clinic. Bathgate considered that 11 out of these 44 patients were unfit for work on account of their pulmonary condition, and agreed with Collis and Gilchrist as to the occurrence of gross X-ray changes in the lungs of men in this occupation.

In 1940, Gough, also working in Cardiff, published the first description of the post-mortem appearances in steam coal trimmers.

The autopsy findings and clinical histories of 12 Cardiff trimmers who had not been miners—comprising all of this category that had come to the author's notice in routine post-mortem work during the preceding ten years—were described. In 8 cases (all of which had been trimmers for more than 25 years) marked fibrosis was found, and in at least 5 of these pneumokoniosis was the main cause of death; in the remaining 4, lung fibrosis was slight though not entirely absent. The fibrosis present in the trimmers was discrete nodular, or conglomerate or massive; it was stated by Gough to be practically identical in appearance with the so-called anthraco-silicosis of colliers, and, like the latter, to differ in appearance from silicotic changes as seen in the gold-miner or in the hard-heading coalminer.

The finding of definite pneumokoniosis post-mortem in a high proportion of the Cardiff trimmers examined supports the clinical experience of Collis and Gilchrist, and of Bathgate; and Gough adduces the records of the Cardiff City Coroner as further evidence that pneumokoniosis is a not infrequent cause of death in this occupation at Cardiff. He draws the general conclusion that "inhalation of Welsh steam coal dust for many years leads to serious and sometimes fatal lung fibrosis".

From this account of the published work it is clear that there is an apparent sharp conflict of evidence between the report of serious pneumokoniosis in Cardiff (mainly steam coal) trimmers by Collis and Gilchrist, by Bathgate, and by Gough, and the more or less negative findings among Swansea (mainly anthracite) trimmers by the Industrial Pulmonary Diseases Committee of the

Medical Research Council. The fact that the various Cardiff series were composed of ill persons, while the Swansea series was of men at work, does not seem adequate to explain the difference in results.

The conflict of evidence has now been resolved as a result of the present comparisons between the X-ray appearances among statistically selected groups of trimmers of similar periods of service at four South Wales ports. This review will, therefore, be continued at the end of the discussion of the present investigation on trimmers (Chapter 13, p. 179).

## CHAPTER 13

### General Discussion

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It is shown in Chapter 1 that the incidence of certified silicosis in the anthracite mines of South Wales in recent years (1931-37) has been more than five times as high as in the rest of South Wales and nearly 100 times that for the coalmines in the rest of Great Britain. In some of these anthracite mines, however, the incidence of certified silicosis is comparatively low. These statistics epitomise the problem at issue, and the present investigation was instituted to define it

more exactly by means of a medical survey, and to attempt its solution by means of parallel studies of the underground environment of the men. Further, there was the prevalent local belief that other pulmonary conditions due to employment, but as yet unidentified, affected the working capacity of miners in South Wales. The identification and study of any such conditions constituted another reason for the present investigation.

In other words, the objects of the present inquiry may be summarised as follows: (a) to determine, more accurately than is possible by means of mortality or silicosis certification statistics, the character, distribution and incidence of chronic pulmonary disease in different parts of the South Wales coalfield and in different classes of mining occupation there; (b) to discover whether pulmonary conditions due to employment exist that do not come under the present definition of silicosis for purposes of compensation, and if so whether they cause disability; and (c) to elicit the causes of these various industrial pulmonary diseases, and especially of the high incidence of certified silicosis in the anthracite area. Although these objects clearly overlap, it will be convenient in the following discussion of the medical field survey to consider them separately in the order given, and to see how far they have been achieved, recognising that (c) is mainly the province of the environmental part of the investigation, which is to be published in a separate volume in this series.

#### A. CHARACTER, DISTRIBUTION AND INCIDENCE OF THE PULMONARY ABNORMALITIES

The character, incidence and distribution of the chronic pulmonary disease found in the medical survey are treated in this section from the radiological angle, because it is believed that the X-ray provides the best basis during life for defining the types, the extent and the degree of development of such affections, and for determining their ecology. The clinical aspects, including the vital subject of associated disability, are more conveniently considered in connection with object (b) and are discussed in Section (B). Morbid histology and its correlation with the X-ray changes are discussed by Dr. T. H. Belt in his pathological report (p. 203).

##### (i) *Nature and classification of the X-ray appearances*

The radiological characteristics of the pulmonary conditions found among Welsh miners in this investigation are best viewed against the background of previous descriptions and classifications.

(a) *Previous X-ray classifications.* During the past 25 years there has been a number of formal classifications of the X-ray appearances of the pneumoconioses. The most notable of these are (1) the terminology used by the Miners' Phthisis Medical Bureau for silicosis in the Rand gold mines of S. Africa; (2) the general classification for silicosis drawn up at a meeting in England in 1927; and (3) the general classification for silicosis recently formulated by the American Committee on the Prevention of Silicosis through Medical Control.

(1) The present South African practice is to classify the X-ray appearances found in non-silicotic and silicotic miners into eight types, ranging from those of the "normal thorax", through progressive grades of "increased striation" (the culmination of this type of change being alternatively termed "generalised arborisation"), to those which show successive stages of "mottling" up to the most advanced degree of this appearance; and there is, in addition, notation as to whether any of these types is accompanied by an infective element ("partly infective in type") or by larger diffuse opacities ("with diffuse opacity") (Miners' Phthisis Medical Bureau, 1939). There are also the well-known legal notification standards of the Rand mines, which, on a combined clinical and radiographical basis, divide silicosis into the ante-primary, primary and secondary stages; the X-ray distinctions are here implied rather than stated, being included in the definition "earliest detectable specific physical signs of silicosis" of the ante-primary stage, and in the description "definite and specific physical signs" of the primary and secondary stage (see Simson, Strachan and Irvine, 1930. Irvine and Steuart, 1930. Harrington and

Davenport, 1937; Irvine, 1938). An adaptation of these three stages by the Committee on Pneumokoniosis and the Committee on Standard Practices in Compensation of Occupational Diseases, of the American Public Health Association (1933), is relevant in that it was used for the Pennsylvania anthracite inquiry (see below); in this American classification of uncomplicated silicosis, designed for compensation use, the X-ray appearances corresponding to the three stages were stated to be, respectively, generalised arborisation with more or less small mottling, generalised medium-sized mottling, and more intense and larger mottling with conglomeration of nodules.

(2) The general classification of silicosis drawn up at a meeting convened at Stoke-on-Trent in 1927 on behalf of the Workmen's Compensation (Silicosis) Committee, and given by Sutherland and Bryson (1929), also divides the disease into three stages. The radiological appearances of the first stage are "not less than the presence of nodular shadows, together with an increase of hilum shadows, linear shadows and pulmonary reticulum"; of the second stage, "an increase in the area of the nodular shadows with a tendency to confluence of the individual nodules"; and of the third stage, "massive consolidation". A further subdivision of the radiological appearances of both the first and the second stages into three types is made, the subdivision of the first stage depending upon the extent of the nodulation in the lung fields, and that of the second stage upon the extent of the coalescence. The X-ray appearances of the three-stage classification of silicosis approved by the 1930 International Conference on Silicosis (Johannesburg) follows closely those of the Stoke-on-Trent classification just mentioned. The appearances of the first stage are "an increased density of linear shadows, and the presence of discrete shadows, indicative of nodulation"; of the second stage, "an increase in the number and size of the discrete shadows indicative of nodulation, with a tendency to their confluence"; of the third stage, "the above conditions are grossly accentuated, and indications of areas of massive fibrosis are usual" (International Labour Office, 1930).

(3) The general classification for silicosis of the American Committee on the Prevention of Silicosis through Medical Control describes three types of X-ray appearance for the normal lungs (healthy lungs, irregular exaggeration of linear markings, and increased root shadows), two types for simple silicosis (nodulation, and conglomerate shadows), and four modifications of these for silicosis with infection (localised discrete or string-like shadows, mottling, soft nodulation, and massive shadows) (Pancoast *et al.*, 1935; and see Sayers, 1938b, and U.S. Department of Labor, 1938).

The above classifications refer to classical silicosis, but they have usually been adapted or modified in connection with pulmonary disease in coalminers, though there is as yet no agreed formal classification for the latter. Confining ourselves to the chief studies that have included anthracite mines, we may consider the survey by the Welsh National Memorial Association in 1929-30, the Pennsylvania inquiry, 1933, in the United States, and the Donetz investigation, 1930-35, in the Soviet Union (see Chap. 12).

In the Welsh study the films were classified under three headings—arborisation, mottling and diffuse shadows—which terms are derived from the South African terminology; in addition, marks up to 10 were allotted to each film under each heading. The Pennsylvania investigators gave a scheme of X-ray interpretations that included linear, granular, nodular and conglomerate phases, which overlapped; and in their X-ray reports they used the following terminology—"usual fibrosis", "commencing generalised fibrosis", "generalised fibrosis 1+, 2+ and 3+". They did not, however, give the numbers of men placed under these headings, and the cases were finally classed according to three stages, which were based upon the American Public Health Association's 1933 general classification mentioned above, itself derived from the South African legal notification standards; in addition, the presence of pulmonary infection was noted (see Chap. 12, p. 146; Bloomfield *et al.*, 1935; Sayers, 1938b).† The X-ray classification used in the Donetz investigation, and in the Don coalfields generally, also comprises three stages, modified from those approved by the 1930 International Conference on Silicosis. The first stage is characterised by reticulation, on the background of which is scattered nodulation (it is not clear whether the presence of nodulation is an essential to the diagnosis of this stage); the second stage is marked by well-defined and widespread nodulation on the background of reticulation; the third stage by agglomerated or massive formations; intermediate stages are also sometimes used (see p. 150; Ziprinsky, 1940; Moshkovsky, 1941).

† In the recent Utah bituminous mine survey (of which we have been privileged to see a report in manuscript), this X-ray interpretation is more clearly defined, and the numbers under each heading (as well as the numbers classed in each anthracite-silicosis stage) are given. Further, it is here stated that films showing the granular and nodular X-ray phases are consistent with stage 1 or stage 2 silicosis, and coalescent nodules and conglomerate shadows with stage 2 or stage 3 (depending on history, signs, symptoms and disability), and that most of the remainder of the granular group are considered as borderline cases (see Flinn *et al.*, 1941).

It may be mentioned here that in the compensation procedure for silicosis in coalminers in Great Britain, no X-ray subdivisions are legally defined, beyond, of course, the requirement that the standard recognised as silicosis be reached.\*

While there are many variations, the above classifications agree broadly in describing discrete nodular shadows and conglomerate or coalescent shadows, all of which were frequent also among the films from the present inquiry. It is uncertain, however, whether and how far the various descriptions of linear shadows correspond to the present "reticulation." In view of the emphasis laid throughout this report upon reticulation as an X-ray category of which account must be taken, in addition to the better-appreciated discrete and conglomerate shadows, it is desirable now to consider in greater detail what previous mention there has been of this type of radiographic change.

(b) *Previous mention of reticular X-ray pattern.* Consideration of the literature of "reticulation" will be limited mainly to descriptions dealing with classical silicosis, as well as to previous coalmining studies. Even so, it is perhaps questionable whether the former are relevant to the present issue.

In the descriptions, published from the South African Miners' Phthisis Medical Bureau, of the various types of radiographic appearance met with in gold miners, the nearest equivalent to reticulation is the type termed formerly "commencing generalised fibrosis" and latterly "very well-marked increase in linear striation" or "generalised arborisation". In this type ("the leafless tree"), the hilar shadows are increased and there is a "very well-marked increase in the number and extent of the linear and dendritic markings radiating from the hilar areas, so that practically the whole of the lung fields up to their peripheral margins is now occupied by a fine 'generalised arborisation'". There is no definite indication of a significant degree of the specific "silicotic mottling". As with the present reticulation, the proportion of cases in the gold mines showing this type of change increases with exposure to dust, indicating an occupational influence, and practically all cases that develop definite nodular silicosis have passed through this stage; as with reticulation, too, some cases showing this striation do not progress further. However, unlike the Welsh miners with reticulation alone, about half of such cases show at autopsy a significant degree of silicotic nodulation. Moreover, although the South African abnormal increase in striation is stated also to have been seen in coalminers, it "may undoubtedly be due to causes other than pneumokoniosis", such as chronic cardiac failure or chronic bronchitis; on the other hand, the reticulation of South Wales has not been found in colliery workers unexposed to dust. (Irvine and Steuart, 1930; Irvine, 1938; Miners' Phthisis Medical Bureau, 1939.)

The experience of the South African Miners' Phthisis Medical Bureau had naturally a profound influence on the first International Conference on Silicosis, held at Johannesburg in 1930. Reporting on the discussions of this Conference, Middleton (1931) wrote that the presence of discrete shadows indicative of nodulation was held to be characteristic of silicosis; and although it was realised that before this stage was reached there might be X-ray appearances indicating increase of linear shadows, these might or might not indicate fibrosis and were not, therefore, considered characteristic.

In the United States, many authors have described "exaggeration of linear markings" in silicosis, but the tendency, as in South Africa, is to regard this appearance as not necessarily part of a pneumokoniotic process. Thus Gardner (1937) considers that linear exaggeration in films may occur as a preliminary to the stage of silicosis, but that it may also be caused by non-specific dust or by other conditions unassociated with dust. Sampson (1937, 1939) expands this view in the practical sphere. He considers that "first degree linear exaggeration", as used at Saranac Lake, is of no significance, and that films showing it should be reported as revealing no evidence of reaction attributable to inhaled dust. "Marked linear exaggeration" (apparently sometimes including a network appearance at the periphery) must be interpreted on the basis of probabilities. According to Sampson, it may be caused by prolonged exposure to various dusts, and with some it possibly precedes nodulation; but even this appearance may also occur in unexposed persons and in them be due to age, chronic infections, cardio-vascular disease or even faulty technique. Furthermore, Sampson states that, even in dusty occupations, this linear exaggeration shows no very clear relation to duration of exposure. It is, therefore, questionable whether the appearance described by him corresponds to reticulation in coalminers. The American Committee on Prevention of Silicosis through Medical Control (Pancoast *et al.*, 1935) goes further than the above workers in its formal classification of silicosis. Describing "irregular exaggeration of linear markings, with possibly some beading confined to the trunks"—the only possible equivalent to reticulation in their classification—they state that this comes

\* For discussion upon compensation aspects of pneumokoniosis in coalminers, see p. 189.

within the limit of normal variation, even when found in persons with a history of considerable exposure to silica, for "such changes are non-specific in character and they do not involve the parenchyma of the lungs. . . . They are not of diagnostic significance".

In Germany, Koehler (1935) mentions that a feature distinguishing the pneumokonioses from miliary tuberculosis is that "the foci in the pneumokonioses are connected up by strands, which leads to the koniotic lung a peculiar netlike appearance". The foci referred to, however, are nodular shadows and no mention is made of a pure reticulate appearance.

Turning to the coalmining industry, we should expect to find descriptions of X-ray appearances showing more definite correspondence with the reticulation of the present report. Edling (1926) describes a pre-stage of "anthracosis" in non-anthracite miners in Southern Sweden, in which "the vascular and bronchial ramifications radiating from the hilum are coarser and denser than normally, and can be followed right out to the periphery, where they will often form well-defined reticular markings". But since Edling likens this appearance to the picture of chronic bronchitis it is doubtful whether it is the same as reticulation.

In the Pennsylvania anthracite report (Bloomfield *et al.*, 1935), the linear phase, which is the first deviation from normal, is not regarded as significant, but the granular phase, which comes between the linear and the nodular phases, may well correspond to reticulation, though the very limited description of this appearance leaves the question in some doubt. During this phase the usual linear markings decrease but it is not stated whether the granular appearance persists after the full development of nodulation, as has been noted in South Wales.\*

The most definite equivalent of the present reticulation in other coalmining studies is to be found in recent Soviet publications. Thus, Ziprinsky (1940) discusses the stage defined radiographically as "primary dusting of the lungs", which is seen in miners of the Donetz coalfields. The X-ray picture is characterised by an increase in the density of the network of the lung structure, which is actually termed "reticulation", together with increased root shadows and sclerosis of the walls of small and large bronchi; nodulation is not visible. Although such peribronchial changes might not be of pneumokoniotic origin, they are regarded as such on account of their frequency. Great importance is attached to this pre-nodular stage of "primary dusting of the lungs", as being the point of onset of the pneumokoniotic process. For its identification in slight or equivocal cases, a technique, used by Soviet workers in other lung conditions, is being tested, with encouraging results. This is to radiograph the patient, inject a lymphagogue in the form of Witte's peptone, and take another X-ray film a number of hours later; markings that were questionable on the first film may be found to have greater density, or to be more clearly defined, on the second film.

In South Wales itself, the Welsh National Memorial Association (1931) used the heading "arborisation" in the classification of their colliers; but this change—even in marked degree—was, in fact, found more frequently among healthy agricultural workers used as controls, than among miners, so that its identity is in doubt. Cummins (1935), reviewing pneumokoniosis in South Wales, makes no mention of this type of linear X-ray appearance. Amor and Evans (1934) mention reticulation in connection with a first stage of pneumokoniosis in coalminers, but consider that this can be caused by conditions unassociated with dust; they regard films as characteristic only when the second, or stage of mottling has been reached. However, Harper (1934), working in the centre of the anthracite area, recognises a typical appearance of granular deposits "connected together by a fine network-like arrangement of fibrous tissue, giving koniotic lung a definite lacework-like appearance with numerous pseudo-cavities". This obviously is reticulation, though it is stated to be confined at first to the right lung field. T. W. Davies (1940) mentions X-ray appearances known under such names as "anthracosis" or "dust retention" as being seen continually by tuberculosis physicians working in the coal areas, and as being industrial in origin. His memorandum will be referred to again later, when we are discussing reticulation in relation to compensation.

In his X-ray atlas of silicosis (published while this report was in manuscript), Amor (1941), an industrial medical officer who has had much experience of the Welsh coalmining industry, describes linear and reticular changes as pre-nodular radiological stages in silicosis, representing pathological alteration in the lung. He differentiates two types of reticular appearances, a coarse type described as "arborisation" and an extremely fine type like fine veiling. The former, which is the commoner, progresses eventually to nodulation on the X-ray; the latter, which is relatively uncommon, tends to persist without nodulation. According to this author, linear changes are most definite in industries in which the silica content of the inhaled dust is high and the total quantity of dust considerable, while reticular

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\* From the Utah bituminous report the identity of the granular phase with reticulation seems unlikely, since it is stated to indicate "the formation of the minute nodules characteristic of silicosis" (Flinn *et al.*, 1941).



changes tend to be more marked among anthracite miners than in men subject to classical forms of silicosis. Among the plates of colliers are some with reticulation and nodulation together, the term "reticulo-nodular changes" being used to describe certain of them. While being apparently the first author to suggest that reticulation is more evident in coalmining than in other silicosis-producing industries, Amor regards both linear and reticular X-ray changes as non-specific, in the sense that with advancing age they are not uncommonly found in the normal town-dweller, as well as in the workman whose occupation exposes him to other dusts besides those associated with the production of silicosis.

Linear and reticulate appearances have been described recently by various American authors as the typical and practically sole feature of X-ray films from certain industries in which the dust has a low free silica content, such as gypsum and cement; nodular changes are infrequent or absent. The interpretation and significance of "this equivocal roentgenological finding" is still undecided (see Sayers, 1938b; Saranac Laboratory, 1939). In certain of the South Wales coalmines investigated there is a similar preponderance of reticulation, but here we have the contrast of other mines of the series in which nodulation, as well as an identical reticulation, is frequent.

While, therefore, considerable interest in the question of linear shadowing has been evident, and some of the appearances described have similarities to the reticulation of the present report, their concordance is by no means clear; and this uncertainty extends even to some of the descriptions based upon the Welsh coalmining industry itself. One of the chief discrepancies is that the linear shadows described by most other authors have usually been regarded as attributable to other causes as well as to dust, and to the dust that may be inhaled in ordinary urban life as well as to that breathed in dusty occupations; the present reticulation, on the other hand, is undoubtedly caused by inhaled dust, has not been found in colliery workers unexposed to dust, and does not seem to have been confused with any appearance occurring at all widely in the general male population of this area. It is considered, therefore, to be definitely occupational in origin. Secondly, most previous authors, if they recognise a reticulate change, do not stress it as an essential part of the pneumoconiotic process, whereas we hold that reticulation is as characteristic a feature of the pneumoconiosis of coalminers as the discrete and conglomerate shadows, and that it may even have as specific a causation. Thirdly, from most previous descriptions it is not clear whether the linear shadows persist when the nodular shadows have developed, as well as preceding the latter. This persistence is practically a constant finding in South Wales.

These considerations raise the question whether the slighter degrees of linear shadowing described in connection with ordinary silicosis are similar to the increased lung markings commonly found in the general population, while the well-marked degrees of linear shadowing, perhaps in the minority, are allied to or identical with the present reticulation of coalminers. At any rate, reticulation, whether it is different, or more well-defined, or merely more frequent, seems quite typical in appearance and can be distinguished from "increased lung markings" by the facts (1) that the latter are rectilinear rather than a fine network, and (2) that they radiate from the hila, fading towards the periphery of the fields, unlike reticulation, which is as well-marked peripherally as nearer the hila.

Although we can give no final opinion upon X-ray concordance, owing to insufficient familiarity with films derived from other dusty industries, we consider that an adequate case has been made to justify the use of the term reticulation without fear of redundancy of terminology, and to warrant stress being laid upon this as a radiographic entity—which has also an anatomical individuality (see Belt, p. 206). There is, indeed, no reason why such a change should not be a striking and frequent feature in certain dusty industries only, coalmining being one of these.

(c) *Present X-ray classification.* After reviewing the previous classifications, and in particular the accounts bearing upon linear and reticulate appearances,

it was decided that neither the classifications in general use for classical silicosis nor the terminology employed for pneumokoniosis in the Pennsylvania anthracite mines were, as they stood, entirely suitable for the films in the present inquiry. A somewhat different classification was therefore formulated and is given in Chapter 5. The following are some of the points of which account had to be taken in arriving at it: (1) the need to give due weight to the frequency of widespread well-marked fine reticulation, and to its place in the pneumokoniotic process, by introducing it as a primary part of the classification; (2) the less opaque and less well-defined appearance of the discrete nodulation shadows, as compared with the mottling or nodulation of classical silicosis; (3) the difficulty of recognising radiographically, with any degree of certainty, the presence of complicating infection such as tuberculosis; and (4) the need to provide separate categories for films showing reticulation alone, and for films showing the various forms of discrete and conglomerate shadows—nearly always with co-existing reticulation.

Finally, categories (*a*) normal, (*b*) reticulation, (*c*) nodulation, (*d*) coalescent nodulation, (*e*) massive shadows, (*f*) multiple fluffy shadows, and (*g*) and (*h*) indefinite, were adopted. Since it is convenient to class all the films showing discrete or conglomerate shadows under one composite heading, the term consolidation has been used for categories (*c-f*); moreover, it is frequently useful also to class together those categories of consolidation with more extensive changes, and (*d-f*) have therefore been termed major consolidation. The two main divisions of X-ray abnormality are thus reticulation and consolidation, while the groupings of reticulation, nodulation and major consolidation are also frequently used.

It should be stressed again that in almost all the films classed as nodulation and coalescent nodulation, and in the majority of those classed as massive shadows and multiple fluffy shadows, reticulation has been visible in addition; consequently, for practical purposes, the consolidation category refers really to consolidation *plus* reticulation, while the reticulation category refers to reticulation without any of the changes of consolidation.

In the above method of X-ray classification, form, rather than degree of change, is the determinant. Reticulation, nodulation and consolidation are used purely descriptively, although it happens that they correlate with a fairly well-defined pathology. No attempt has been made to diagnose the presence of complicating infection, such as tuberculosis, on the X-ray film. The groupings of abnormality into reticulation, nodulation and major consolidation receive support by the finding not only that they appear (in colliers) in this order, but also that they are associated, in the same order, with a progressive increase in incidence and severity of respiratory disability. The term "stage" is, however, avoided in the classification.

The present classification was originally arrived at on the basis of examination of the films at anthracite colliery A.3, but it has proved suitable for those derived from the other anthracite mines investigated, for those from the steam coal and bituminous mines, and also, allowing for minor differences, for those of the coaltrimmers at the ports. The classification is not necessarily applicable outside the coal industry, and even within the industry it must be held to apply mainly to workers in contact with coal and the coalface, and less properly to men who are primarily rock workers, whose X-ray shadows approach the types characteristic of classical silicosis.

A radiographic classification, rather than a combined clinical and radiographic classification, is employed as the primary basis for grouping the subjects examined in this inquiry. For we believe that in assessing a man exposed to a dust hazard, the X-ray should be used as the chief index of the anatomical presence and degree of progression of the pulmonary condition, and that the clinical

findings should be recorded *separately*, as indicating the disability and constitutional effect produced by the condition.

(ii) *Incidence of X-ray changes in different mining occupations*

The incidence of the various abnormal X-ray appearances among the different occupations in an anthracite colliery with a high incidence of certified silicosis (colliery A.3) has been analysed in Chapter 6.

The main X-ray abnormalities found at this colliery were reticulation and the changes grouped under the heading of consolidation; both were present in considerable quantity. Excluding the compensation cases and other men idle through illness, and considering only the 396 men in underground work at the time of the examinations, the incidence of X-ray abnormalities was nearly 50 per cent.; 26 per cent. were classed as reticulation and 19 per cent. as consolidation.

These figures are averages based upon all occupations and ages, including, of course, boys as well as men of long service. If the basis is restricted to certain occupational groups, the incidence becomes much higher. Among the underground workers who had been mainly engaged as colliers, and whose employment in this occupation had been chiefly at this colliery, 35 had been on the coal for twenty or more years; as many as 27 (77 per cent.) of this group showed abnormal appearances, the films being classed as consolidation in 17 (49 per cent.).

That these incidences of X-ray abnormalities are not exceptional is shown by the finding (Chapter 7) of similar figures for working colliers examined at two other anthracite collieries with high incidences of certified silicosis (collieries A.1 and A.6).

If the X-ray findings at colliery A.3 can be taken as typical for anthracite collieries in which the incidence of certified silicosis is high, then since 27 per cent. of all South Wales anthracite mines (employing 100 or more men underground) have high incidences of certified silicosis, and another 24 per cent. have medium incidences (on the arbitrary basis of Table IV, p. 8), it follows that the amount of pulmonary abnormality *by an X-ray standard* must be very considerable in this area.

Does this largely unrecognised pulmonary abnormality among *men still at work* matter? Apart from the question of the future progress of the lung changes, and of the subsequent development of disability in association with them, is there a serious amount of such disability *now*, while the men are still working? The relation of respiratory disability to the different individual categories of X-ray abnormality is fully discussed later, but it is convenient to consider this particular point of "latent" disability here.

The comparisons, in Chapter 10, between incidences of respiratory disability in the different X-ray categories are based upon the entire "registered" population of colliery A.3, including 37 men receiving silicosis compensation—practically all of whose films were in the composite category of consolidation; for the present purpose these, and other men idle through illness, must be excluded, and attention confined to the 396 men working underground at time of examination. When this has been done, the excess incidence of disability associated with the abnormal X-ray groups is reduced—as would be expected, since many of the more severely incapacitated men have left work. An excess is, however, still evident. Comparing the number of underground workers showing consolidation who gave a history of breathlessness on exertion or who showed impaired exercise tolerance, with the corresponding numbers that would have been expected amongst them had they been subject to the incidences of breathlessness and impaired exercise tolerance obtaining among the underground workers with normal radiographs, we have the following position:—

UNDERGROUND WORKERS ONLY (396 MEN)

(i) *Breathlessness :*

<i>X-ray category.</i>	<i>Total men.</i>	<i>Number observed.</i>	<i>Number expected.*</i>	<i>Observed per cent. of expected.†</i>
Normal (base) .. .. .	208	33	33.0	100
All consolidation .. .. .	74	26	15.3	170
Major consolidation .. .. .	33	16	7.5	210

(ii) *Impaired exercise tolerance :*

<i>X-ray category.</i>	<i>Total men.</i>	<i>Number observed.</i>		<i>Number expected.*</i>		<i>Observed per cent. of expected.†</i>	
		<i>Classes B+C.</i>	<i>Class C.</i>	<i>Classes B+C.</i>	<i>Class C.</i>	<i>Classes B+C.</i>	<i>Class C.</i>
Normal (base) .. .. .	207	49	8	49.0	8.0	100	100
All consolidation .. .. .	74	31	9	19.6	3.6	160	250
Major consolidation .. .. .	33	19	7	11.0	2.2	170	320

The evidence from this colliery is, therefore, that although many of the more severely disabled of the men with X-ray abnormalities have left work, there is a serious amount of disability among those who have remained. This disability may not suffice to prevent a man carrying out his accustomed work within a limited range of effort, but may become troublesome with some unaccustomed work, or upon extra exertion such as walking up an incline ; it is usually evident to an observer after a functional exercise test. A similar excess of disability among men with pulmonary abnormalities, though still in work, was noted by the Pennsylvania investigators (Bloomfield *et al.*, 1935). It should be stressed that in neither inquiry was a bias possible, since neither the subject nor the observer was aware of the X-ray findings at the time of the clinical examination.

The X-ray abnormalities found at colliery A.3 have been shown in Chapter 6 to be accounted for mainly by the colliers working at the face, and this applies to reticulation as well as to the changes grouped under the heading of consolidation. Occupations on the roadways, such as haulier and repairer, and the occupations of fireman-shotsman and hard-heading worker, have been responsible only to a minor extent for the X-ray changes. The evidence is that the actual work at the coalface—and not the *general* level of dustiness underground, or the wear and tear of a strenuous life—is the source of the X-ray abnormalities in the collier.

The strong similarity in the occupational distributions of reticulation and consolidation is of considerable importance, for it suggests a similarity in origin. (This suggestion receives support from other relationships, to be discussed later.)

The development of X-ray abnormalities in the collier is very closely related to duration of employment. By selecting men from the whole group in such a way that the influence of other occupations is removed, this development can be studied. There is an orderly progression in the changes. A certain time

\* Expected figures based on the incidences at 10-year age-periods in the normal X-ray group.

† Percentages to nearest 10.

is required for any abnormality to appear; reticulation, nodulation, coalescent nodulation, then appear in that order. Later, there is an apparent transfer of some of the reticulation to nodulation, and of the latter to coalescent nodulation; massive and multiple fluffy shadows also seem to be a late development. The longer the duration of service, the higher the incidence of total abnormality and the greater the proportion of consolidation, though the latter group shows an eventual reduction, due presumably to affected men falling out.

By the various methods of selecting men so as to isolate or concentrate the influence of the occupations desired, it has been possible to compare, for equivalent periods of service, the risks incurred at colliery A.3 in different occupations. It is only practicable to give these risks relative to those of colliers; even so, the occupational comparisons are in some cases based upon quite small numbers, and conclusions drawn from them can, therefore, be regarded only as suggestive. The main conclusions suggested are that, for similar lengths of service, both the haulier and the repairer run smaller risks, as to reticulation as well as to consolidation, than does the collier; that work on the surface screens has a still lower risk; and that surface work apart from the screens is without risk as to X-ray abnormalities of any kind. On the other hand, further comparisons suggest that, for similar periods of service, hard-heading work carries a greater risk of the production of consolidation than the occupation of collier, and that firemen and shotsmen also incur a special risk.

It should be mentioned that, while the surface screen workers have a relatively low risk of X-ray abnormalities, the data from colliery A.3 suggest that their *absolute* risk, after prolonged exposure, is not negligible. (This suggestion is supported by the data from other collieries, to be discussed later.)

These occupational results provide a useful broad test of the criteria of X-ray diagnosis adopted for the present investigation, *since the films and the occupational histories were obtained and analysed independently*. Reticulation was diagnosed in 104, and consolidation in 84, of the 396 men comprising the underground working population of colliery A.3, but neither of these categories was diagnosed in any of the 57 surface workers who had experienced little or no exposure to colliery dust. The inference is that films classed as reticulation and consolidation have not been confused with X-ray appearances occurring at all widely in the general male population of the neighbourhood. This distinction is, of course, of particular importance in respect of reticulation, as already pointed out (p. 166) when reviewing the literature on this type of X-ray pattern. The possibility that a certain percentage of the ordinary town-dwellers in some industrial areas may inhale sufficient dust from their general environment to produce similar striking X-ray pictures, does not affect the present conclusion of the predominantly occupational origin of reticulation in the Welsh coalminer.

It has been stated above that hard-heading work may be a more dangerous employment than that of collier (for similar periods), but that the colliers are the main source of the pulmonary abnormalities actually found at colliery A.3. If, as is probable, this conclusion is applicable to anthracite mines in general, it is in agreement with the similar inferences that may be drawn from compensation statistics for certified silicosis (see Chapter 1). No contradiction is, of course, involved in the hard-heading man running the greater risk but the collier providing the greater problem, since the number of hard-heading men in a colliery who have had any important length of service is usually small, while colliers and their assistants form roughly one-half of the underground population when the coal is mined by hand.

The occupational distribution of pulmonary abnormality in the bituminous mines of Great Britain outside South Wales would appear, from the reports available (Chapter 12), to differ from that just described for the Welsh

anthracite mines. In the English mines the hard-heading and other rock workers seem to be relatively more important sources of the recognised pulmonary disease, and the colliers a correspondingly less important source.

It is not possible to compare satisfactorily the general incidence of pulmonary abnormality found at colliery A.3 with that reported for the Pennsylvania anthracite mines, since the X-ray classifications are not comparable. However, the two inquiries agree in revealing a serious amount of pulmonary abnormality of characteristic type among underground workers; in showing that the incidence is considerable among colliers at the face, as well as among rock workers; and in stressing the close relationship between length of service in an occupation carrying a dust hazard and the amount of pulmonary abnormality developed. Our inquiry has focussed attention further upon the colliers as the chief source of the pulmonary abnormality, and has demonstrated the frequency of reticulation and the similarity of its occupational distribution to that of consolidation. It has provided further information upon the development and progression of the X-ray changes after varying periods of exposure, and has compared the time-risks of the chief occupations with one another.

Similarly, although, in the Donetz report, the incidences recorded are on a somewhat different basis from those in the present inquiry, that report, too, draws attention to an important amount of occupational pneumokoniosis among the workers in anthracite mines, this being mainly in the men with long service underground. Allowing for the difficulties of comparison, the incidence at the Don anthracite mine examined (p. 150) seems, however, to be lower than that at colliery A.3 (Tables XI and XII, pp. 60 and 61). If such a difference between the Donetz and the South Wales anthracite mines were real and could be generalised, obviously many factors would have to be considered in seeking for its causation. In any case, certain factors (some of which have been mentioned on p. 151) have undoubtedly tended to make the recorded incidence of disabling pneumokoniosis among working miners in the Soviet Union lower than in South Wales. Chief among these factors are periodical medical examinations of the workers, coupled with the comparative ease of transfer of the relatively unfit to suitable alternative employment. The consequence must be that workers tend to leave underground mining while still in the earlier stages of pneumokoniosis; the accumulation of fully-developed cases with varying degrees of disability but continuing to work underground—which is a serious feature of certain South Wales anthracite mines—is thereby avoided\*.

(iii) *Incidence of X-ray changes among colliers in different parts of the South Wales coalfield*

To sketch out the distribution of incidence of pulmonary changes attributable to dust in South Wales it has been considered necessary to compare only the incidences of X-ray abnormalities of colliers, since the examination of the entire population at anthracite colliery A.3 showed that the high incidence at this mine lay mainly in this occupational class. The colliers to be examined at each selected mine were chosen so as to exclude, so far as possible, the influence of other occupations carrying a dust hazard, as well as the influence of work as collier at collieries other than the one under consideration; the men thus selected can be termed "home-colliers". The detailed methods of statistical selection have been given in Chapter 4, and it is believed that adequate comparability between mines has been attained.

The selection of the 16 collieries themselves has been fully described in Chapters 2 and 4. They are well spaced geographically (see Fig. 1, p. 11), and include representatives of the chief ranks of coal found in South Wales (see

\* The rank of the Donetz anthracite coal is not known to us; difference in rank might be a factor in producing an incidence of pneumokoniosis lower than in Wales (see p. 173).

Fig. 3, p. 16). Thus, eight of the collieries mine anthracite and are mainly in the west, five mine steam coal and are in Glamorganshire, and three mine bituminous coal and are in Monmouthshire. All work seams in the Lower Coal Series (see Fig. 2, p. 14), from which most of the output of South Wales is obtained; and more than half of them include the Nine Feet or one of its correlatives among their more important seams. As shown in Chapter 4, they are representative also of the different levels of incidence of certified silicosis in this coalfield. The total number of home-colliers selected at these 16 collieries (including A.3) was 1,496.

In comparing the incidence of X-ray abnormalities among the selected colliers from one mine to another it is desirable to have a single figure for each colliery. Chapter 7 describes the calculation, for each colliery, of such overall figures denoting (a) the incidence of all X-ray abnormalities (i.e. including reticulation and consolidation), and (b) the incidence of consolidation (these figures being standardised for differences in the proportion of men who had worked for different lengths of time, by relating, as a percentage, the number observed in each of these X-ray groups at a mine to the calculated number expected on the incidence-rates of the eight anthracite mines taken together). It was found (Table XXIII, p. 91) that the order of the 16 collieries based upon the amount of consolidation in them was very similar to that based upon their amount of all X-ray abnormalities. It was decided to use the standardised figure for consolidation, rather than that for all abnormalities, to represent the relative incidences at these collieries; and the "incidence of X-ray abnormalities" is used in this sense in Chapter 7. The collieries have also been arbitrarily divided into four classes of incidence on the basis of their consolidation figures—high, medium, low-medium and low—just as (in Chapter 1) they were divided into high, medium and low on the basis of certified silicosis incidence.

(a) *Incidence of X-ray abnormalities at the 16 collieries.* The incidence of X-ray abnormalities among the selected colliers at the 16 different collieries (Chapter 7) shows much variation, as might be expected from the mode of choice of these mines. These variations provide strong contrasts between the anthracite and the bituminous collieries as groups, and also between anthracite mines themselves. The range of individual variation in the 16 collieries is shown by the following figures for the observed numbers with consolidation expressed as per cent. of those expected (from Table XXIII) :—

<i>Colliery.</i>	<i>Observed consolidation per cent. of expected (all lengths of employment).</i>
A.1 .. .. .	233
A.6 .. .. .	176
A.3 .. .. .	172
A.8 .. .. .	146
S.3 .. .. .	110
A.7 .. .. .	95
S.1 .. .. .	87
S.2 .. .. .	60
A.4 .. .. .	55
B.1 .. .. .	39
S.5 .. .. .	35
A.2 .. .. .	12
S.4 .. .. .	12
B.3 .. .. .	4
A.5 .. .. .	0
B.2 .. .. .	0

A chief object has been to correlate these variations in X-ray incidence with the more salient natural characteristics of the coalfield, namely, the geographical position of the collieries, the ranks of the coals mined, the depth and humidity of the underground workings, and the position in the coal series of the seams worked. (Correlations of the variations in incidence with differences in methods of working will be discussed to some extent in this chapter, while correlations with the detailed composition of the air-borne dusts and strata will be given in the subsequent environmental reports.)

The incidence of X-ray abnormalities among the colliers has a fairly consistent geographical distribution. An "incidence-map" derived from the present small sample (see Fig. 11, p. 74) suggests that there is a decreasing rate of abnormality across the coalfield from west to east, the change being gradual and continuous, without any sharp break. Considerable differences are, however, evident also among the mines within the western part of the field itself. It has been suggested in Chapter 7 that this geographical distribution of incidence may be the result of similar geographical differences in the rank of the coals mined, anthracite being situated in the western, and bituminous towards the eastern part of the coalfield.

Rank of coal, indeed, appears to be the most important broad natural characteristic related to the incidence of X-ray abnormalities at these different mines. The highest incidences have been found at the anthracite end of the scale of rank, and the lowest at the bituminous end, with a fairly gradual change through the steam coal between these extremes. This association is well shown in Fig. 12 (p. 74), which makes an interesting comparison with Fig. 11. If the two anthracite mines which showed low incidences of X-ray abnormalities are regarded as examples of a special case—their coalface humidity conditions are thought to justify such treatment (see below)—the relation between incidence and coal rank becomes stronger. It is particularly interesting, and in conformity with such a relationship, to find no sharp reduction in incidence in passing from anthracite to steam coal, the latter mines showing on the whole an intermediate incidence of X-ray abnormalities.

These associations agree with the work of Cox (1938), who, from personal investigation of working histories of silicosis compensation cases, noted a parallelism between the incidence of certified cases from various South Wales collieries and the different ranks of the coal mined by them.

Two other natural characteristics, found to be related to the incidences of X-ray abnormalities at these collieries, are atmospheric moisture conditions and working depth at the coalface, these two characteristics being themselves fairly closely correlated. Owing to the criteria used in selecting the 16 collieries for investigation (see Chapter 4), only the anthracite group has a sufficiently wide range of depth and humidity for these factors to be at all suitably compared with incidence of X-ray abnormalities (dampness and depth could hardly be important factors within the steam and bituminous coal areas, since the mines found to be of low incidence in this series were all comparatively deep and dry). Such a comparison shows that the mines with a high or medium incidence of X-ray abnormalities had smaller relative humidities and greater working depths than those with a low or low-medium incidence; in particular, the two anthracite mines which showed a low incidence of abnormalities had the dampest coalface conditions. The suggested correlation of incidence of X-ray abnormalities among the colliers with depth and atmospheric humidity of the underground workings, which has been found in this small sample of eight anthracite mines, is supported by the figures of certified silicosis for the Welsh anthracite mines in general.

At this point we may consider how far the X-ray survey at the 16 collieries agrees with the general incidence-distribution of certified silicosis in South Wales, bearing in mind that certification figures apply to all underground workers and not to colliers alone. There is



agreement in that both sets of figures indicate a high incidence of abnormality in anthracite mines in general, and a low incidence in bituminous mines. Certified silicosis figures, however, suggest that the change in incidence from anthracite to non-anthracite is sudden, whereas, in fact, it is gradual and continuous, with an incidence of abnormality that is not negligible in some of the steam coal mines. Furthermore, while in certain of the anthracite mines with a low incidence of certified silicosis a low incidence of abnormality has been found by X-ray (these being damp and relatively shallow mines), in others (drier and deeper mines) the low incidence of certified silicosis has been actually associated with a medium incidence of X-ray changes. Although the evidence, in certain classes and groups of mines, of a somewhat higher incidence of pulmonary disease than is shown by certified silicosis figures may be disturbing, it is satisfactory to find that the relative freedom from pulmonary abnormality of the bituminous area (Lower Coal Measures), suggested by the compensation data, is confirmed by the X-ray examinations at the limited number of these mines now investigated.

The findings that have been described above are based on the relatively small sample of 16 collieries. However, from a combination of the statistics of certified silicosis incidence of South Wales mines in general with the radiographic data from these 16 collieries, certain generalisations can be reached. It may be stated with some assurance that if we regard the minority of mines which are classed as shallow and damp (whatever this appellation may connote) as a special case, it is characteristic for South Wales anthracite colliers to show a high or medium incidence of X-ray abnormalities, and for non-anthracite colliers to show a medium or low incidence—in carbonaceous steam coal the incidence tending to be medium and in bituminous coal it tending to be low. Chronic pulmonary trouble among colliers in South Wales is, therefore, mainly concentrated in the anthracite area, though its incidence cannot be neglected in the steam coal mines of the non-anthracite parts of this coalfield.

This conclusion is useful in defining the two-fold nature of the problem of the environmental part of the present investigation. We have in South Wales a coalfield where, at one end, seams are being mined in which the coal is anthracite, and, at the other end, similarly-placed and often equivalent seams are worked in which the coal is bituminous—with a continuously changing rank of coal extending between these two geological and geographical extremes. Correspondingly, the main problem is why the incidence of X-ray abnormalities is characteristically high in the anthracite mines, comparatively low in the bituminous mines, and intermediate in the intermediate-rank, steam coal, mines. But there is also the second problem of why a minority of the anthracite mines differs from the general run by showing a low incidence of X-ray abnormalities (a more limited group than is suggested by certified silicosis figures), and why this minority coincides on the whole with anthracite mines that are relatively damp and shallow.

In stating the two-fold problem, we have also implied certain directives for the environmental investigation. The relationship between incidence and coal rank suggests that some geological or other factor, correlated with the regular transition in the rank of the coal across the field, may play a part in producing the former. Factors correlated with differences in rank could not, however, explain the occasional low incidences within the anthracite group of mines. Here the relationship between incidence and the humidity and depth may have a bearing, and the examination of possible factors correlated with these natural differences in working environment is suggested as desirable.

In concluding this part of the discussion, it may be mentioned that at the International Conference on Silicosis at Geneva in 1938 (held while this inquiry was in progress), the question was raised as to whether the apparently selective distribution of pulmonary disease in Great Britain was due to differences in the numbers of men in hazardous occupations at different mines, or to differences in the hazard of the same occupation (Middleton, 1938b). The present inquiry answers this question by showing definitely that differences in the incidence of pulmonary abnormality among colliers at mines in the different parts of the

coalfield overshadow any differences in the numbers of the men employed either as colliers or in other hazardous mining occupations, e.g. hard-heading work.

(b) *Development of the different X-ray changes.* In Chapter 7 a study has been made of the development and progress of the different types of X-ray change in the colliers at the 16 collieries, after varying periods of exposure at the coalface. Particular attention has been given to the questions as to how this development varies between mines with a high incidence of abnormality and those with a low incidence, and as to whether there are differences according to rank of coal mined. (It must be stressed that, for such a study, since a follow-up of cases is impracticable, it is necessary to assume that the findings at the present time in groups of different lengths of employment represent the sequence of X-ray changes through the working life of a generation of the colliers.)

There is found to be a consistency in the *types* of X-ray change throughout the series of mines, both anthracite and non-anthracite, the main abnormalities being reticulation and consolidation. As would be expected, however, the *amount* of the different types shows wide variations between mines. If the 16 collieries are placed in descending order of incidence of X-ray abnormalities, the types described as massive shadows and multiple fluffy shadows, coalescent nodulation, nodulation, reticulation, tend to drop out in this order, with reticulation present alone and in infrequent amount at certain of the bituminous mines. The absence of a particular type of X-ray appearance at a mine can in most cases, therefore, be related to the general level of incidence of abnormalities prevailing there, without assuming a qualitative difference in the changes that are present. The finding that in some mines reticulation is the predominant or sole change, while in others reticulation and consolidation are both frequent, gives no reason to suppose that the reticulation in the two cases is not the same entity. The differences lie in the quantity and, as will be seen below, the subsequent progression of the reticulation, which latter is probably the precursor of consolidation.

In certain respects the development of the different X-ray appearances after increasing duration of employment at the coalface is similar at all these mines, non-anthracite as well as anthracite. There is, in general, a progressive increase in total X-ray abnormalities with length of exposure, and an orderly progression of the different individual X-ray changes. Reticulation is the first abnormality to appear, and consolidation, where it occurs, is a later change. Subdividing consolidation, nodulation precedes major consolidation (i.e. coalescent nodulation, massive and multiple fluffy shadows) in time of development.\* In all these respects the analysis for the 16 collieries gives results similar to that for colliery A.3 alone (see above, pp. 169-170).

In other respects the development of the changes at the high incidence mines (including A.3) tends to differ from that at the mines with low incidences of X-ray abnormalities. At the former, there is, in the main, a progressive increase in incidence of consolidation with duration of exposure, while reticulation, after its initial increase, remains the same or may even show a reduction at the later employment periods. At the latter, consolidation, if present at all, remains much the same at the later work-periods, while reticulation continues to increase, albeit only to a low level. In the high incidence mines, moreover, reticulation, which at all the mines of the series is the commonest abnormality among the younger colliers, is exceeded in frequency by consolidation among the older colliers, though even among them it still forms a fair proportion of the total abnormalities. In the low incidence mines, on the other hand, reticulation remains the predominant or the sole type of abnormal X-ray appearance throughout the working lives of the colliers.

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\* Histological examination suggests that massive shadows can follow reticulation without the intervening phase of nodulation (see Belt, p. 210).

From the statistical analysis of the trends, after increasing length of employment, of the X-ray changes at the different collieries, it has been inferred in Chapter 7 that at least part of the consolidation found among the colliers is derived from normals by way of reticulation, and not from normals direct. From the observation (Chapter 5) that reticulation is generally visible also on films classed as consolidation—an observation supported by the almost constant presence of the pathological changes corresponding to reticulation in the lungs of South Wales colliers containing grosser indurations due to dust (p. 208)—it has been further inferred that the above is the main, if not the only, path for the development of consolidation in the collier. In other words, reticulation constitutes an essential phase, preceding consolidation, in the time-sequence of the X-ray changes attributable to dust. This is not to say that reticulation necessarily represents an early *stage* in the pathological pneumokoniotic process which may culminate in the lesion corresponding to the X-ray category of consolidation (i.e. really consolidation *plus* reticulation), since the two types of X-ray change, when present together, might be no more than co-existent. Obviously, however, the above considerations do suggest the possibility, or even probability, that reticulation and consolidation are related in pathological development as well as in time-sequence, i.e. that reticulation is not only a “pre-phase” but also a “pre-stage”. This suggestion receives support from the pathological finding that “dust-reticulation” seems to provide a basis upon which the coarser lesions of pneumokoniosis in coalminers may develop.

It has been stated above that at all the mines of the present series reticulation is the commonest abnormality among the younger colliers; but that while in the low incidence mines it is the predominant change also among the older colliers, in the high incidence mines it is exceeded in frequency in this group by consolidation. If the consolidation cases have all passed through the phase of reticulation, we may say that at the high incidence (anthracite) mines the majority of colliers who develop reticulation on the X-ray film will have progressed to consolidation before the end of a normal working life, whereas at the low incidence (anthracite or non-anthracite) mines reticulation tends to persist without further progress.

We have now to consider whether the incidence of reticulation among colliers does or does not follow that of consolidation, from one mine to another, across this coalfield. For the purpose of this comparison, in Chapter 7, the incidences of these abnormalities at a mine have been measured by the ratios of their numbers (all lengths of employment) to the number of normals, so as to avoid the “crowding out” effect that might occur, particularly at high incidence mines, if they were measured by their percentages based upon the total examined. Further, as a more complete measure of the total reticulation produced at a mine (taking into consideration the probable derivation of consolidation from the earlier change), the sum of reticulation *plus* consolidation has been used, as well as the reticulation figure alone as it stands. These various ratios, representing the incidences of reticulation and consolidation at each of the 16 collieries, have been tabulated, the arrangement of the mines being in descending order of their incidence of consolidation—from a very high level to nil. The result of the comparison has been to show that reticulation incidence follows a broadly similar trend, from mine to mine, to consolidation incidence. In mines in which the incidence of consolidation is high, reticulation incidence also tends to be high, in spite of the large amount of transference that has taken place from reticulation to consolidation; in mines in which the incidence of consolidation is low or nil, reticulation also is comparatively infrequent, contrary to what might have been expected if its production were independent of consolidation. That reticulation incidence is on a somewhat higher level than consolidation is demonstrated by the fact that at the point in

the descending scale of the series at which consolidation incidence becomes nil, reticulation is still present though comparatively infrequent; indeed in no mine of this series is it entirely absent.

The parallelism between reticulation incidence and consolidation incidence from one mine to another means that in certain areas of the coalfield (e.g. the bituminous area) in which consolidation appears to be infrequent, a high incidence of reticulation need not be expected. On the contrary, the latter's incidence tends to be low in proportion. Furthermore, if the present findings could be justifiably extrapolated to the low rank bituminous coals of the English coalfields, and if the incidence of consolidation among colliers in England be lower than in South Wales (a probability suggested from compensation statistics), then the incidence of reticulation also would be expected to be low.

The similarity of the distributions of reticulation and consolidation among colliers in different parts of the South Wales coalfield supports the suggestion, mentioned above, that there is a basic inter-relationship between these two types of X-ray abnormality—indicating that both are due to similar or related causes. It will be recalled that the close similarity of the distributions of reticulation and consolidation among the different occupations at the same colliery (A.3) has also been considered (p. 169 above) to provide evidence of a similarity of origin of the two changes.

As pointed out on p 148, the Pennsylvania anthracite inquiry was not primarily concerned with the distribution of incidence of pulmonary abnormalities in different parts of the coalfield, or in mines working different classes of coal. Consequently, there is in that inquiry no counterpart to this section of the South Wales investigation. Taken in conjunction with the more recent Utah bituminous survey, however, the incidence of anthraco-silicosis is shown to be lower in bituminous than in anthracite mines—though the coalfields considered are widely separated.

In the Donetz investigation, however, anthracite and bituminous mines in the same region were compared. As in Wales, the incidence of pneumokoniosis was found to be lower in the bituminous mines than in the anthracite. In the bituminous mines, the condition was found comparatively rarely, and mainly in a mildly expressed form. The difference between the two classes of Don mine was, however, apparently small (it would possibly have been somewhat increased, had it been practicable to give—as in the present inquiry—comparative time-risks for colliers only, as well as for all underground workers together).

(iv) *Incidence of X-ray changes among (a) Surface screens workers exposed to coal dust, and (b) Underground hauliers exposed to shale dust*

It is convenient at this point to discuss the results of these subsidiary investigations, which have been described in Chapter 8.

(a) *Surface screens workers.* It has already been suggested (p. 170), from the examinations at anthracite colliery A.3, that the risk of the development of abnormal X-ray pictures by screens workers after prolonged exposure is not negligible. A fuller analysis has been made (Chapter 8) of 49 long-term screens workers with little or no underground experience, selected from a number of anthracite and non-anthracite collieries; this total includes the men from colliery A.3.

The analysis shows a significant number of X-ray abnormalities similar to those found in colliers underground, the frequency being greatest in men with more than 20 years of exposure. Consolidation, as well as reticulation, is present. There is a suggestion that the incidence of abnormalities is greater among the screens workers from the anthracite collieries than among those from the non-anthracite mines.

In some of these screens workers with X-ray abnormalities, other underground occupations (although of short duration), or employments outside the

industry, might have been responsible for the changes found. Even if these cases be omitted there remain, however, sufficient to indicate that a certain, though relatively infrequent, risk is incurred by these men after prolonged exposure to the dust of the colliery screens. Such a conclusion supports Harper's (1935) report of the occurrence of X-ray changes, of the type found by him in anthracite colliers, among anthracite surface screens workers who had had no underground experience.

(b) *Hauliers*. The question has frequently been raised as to whether the introduction of stone-dusting may have provided an additional risk to underground workers in the non-anthracite coalmines. A short account of stone-dusting practice in South Wales has been given in Chapter 8. The relevance to the present issue is that as the place of application of the dust includes the stall roads, the collier inhales some of it; and also that the stone-dust has often been in the past, and in some mines still is, composed of crushed shales from the roof strata overlying the seams in the same or neighbouring mines. In the majority of mines, however, limestone dust, which carries a theoretically smaller hazard than shale dust, has replaced the latter.

An opportunity to examine the effects on underground workers of shale stone-dusting was found in two of the bituminous mines. The colliers at these mines had been examined in the course of the main survey (Chap. 7), and on the basis of their X-ray abnormalities the incidences at these two mines had been classed as low-medium and low. This does not support the existence of any serious hazard introduced by stone-dusting over and above the risks due to ordinary coalface dust. As a subsidiary investigation, all hauliers at these two mines who had been exposed for long periods to shale used for stone-dusting were examined radiographically, 60 men in all. The results (Chap. 8) do not suggest any considerable hazard in the inhalation of stone-dust under these conditions; the abnormalities were comparatively low in incidence, and were limited to reticulation. While this finding is gratifying, two reservations must be stressed. The first is that the periods of exposure to the shale dust by the hauliers studied are for the most part between 10 and 20 years; no effective study of the results of longer exposure is practicable, owing to the limits fixed by the date of introduction of the practice of stone-dusting, and to the use in many mines of limestone dust instead of shale. The second reservation is that the present findings can only be held to apply to the *bituminous* mines in South Wales. It is conceivable that a similar study of underground hauliers in those *steam coal* mines that use their own local shales might yield different results.\*

By re-grouping the hauliers from these two bituminous mines according to the total period in this occupation, instead of according to the period exposed to shale dust, it has been possible to compare their risks with those of similar hauliers from the anthracite colliery A.3. The results (Chap. 8) show little difference between them; in other words, the marked contrast in incidence of pulmonary abnormality found between anthracite and bituminous coal colliers is not reflected in the incidences among the hauliers in the same mines.

(v) *Incidence of X-ray changes among coaltrimmers in South Wales*

While the collier is exposed to dust from all the mining operations carried out at the coalface during the coal-getting shift, and the surface screens worker is exposed to dust derived from the coal as it is won, but without the underground environment, the coaltrimmer is exposed to dust derived from coal as it is marketed. For certain commercial grades, e.g. "through coal", there is little change between its condition at the colliery surface and at the docks, but for others, particularly washed and sized coals, the dust-forming propensities of the coal have been materially altered, both qualitatively and quantitatively.

\* The question of the relation of the practice of stone-dusting to the general distribution of pulmonary disease in the South Wales coalfield is discussed in a later part of this chapter.

The view was taken early in the present investigation that a survey of the incidence of X-ray abnormalities among South Wales coaltrimmers handling anthracite, steam coal and bituminous coal, due for export, would provide valuable information to be related to the parallel survey upon colliers in corresponding classes of coalmines. In Chapter 4 the method of statistical selection of the trimmers has been described, the aim being to secure comparability between the men at each of the four ports investigated. In that chapter also a brief description of these coal-exporting ports has been given. They comprise all but one of the main coal ports of South Wales. Although there is overlap, it is true to say that, in the main, one of the ports derives its coal from the anthracite area, two from the steam coal area, and one from the bituminous mines of Monmouthshire. This selectivity of sources of the coal, together with the lack of migration of the men from port to port and the tendency for them to remain in this occupation once they have entered it (a situation completely altered since the survey was finished in the summer of 1940), has been a factor favourable to the inquiry. The total number of long-term coaltrimmers selected for examination at the four coal ports was 470.

The results of this survey have been given in Chapter 9. Considering the four ports together, a large number of these trimmers shows X-ray abnormalities which, apart from minor differences, conform sufficiently in type to those found among colliers to be classified under the same headings. The main abnormalities are, as with the colliers, reticulation and the composite category consolidation, the former occurring in 29 per cent. and the latter in 10 per cent. of the men of 20 or more years service (all ports together). An interesting difference from the X-ray appearances in the miners is that the categories of massive shadows and multiple fluffy shadows are more frequent than are nodulation and coalescent nodulation, the other two components of consolidation. The reason for this tendency towards massive, and away from nodular, shadows may become clear as knowledge of causation accumulates. The inhalation of a higher proportion of coaly material, as opposed to adventitious mineral matter, might be a factor, but so also, conceivably, might a complicating tuberculous element.

Considering the ports individually, there are, as among the colliers from the different mines, variations in incidence of X-ray abnormalities among the trimmers from one port to another. The incidence is highest at the two steam coal ports, intermediate at the bituminous coal port, and lowest at the anthracite port. At the steam coal ports consolidation, including the changes termed major consolidation, is present, as well as reticulation, in fair quantity, whereas at the anthracite port the abnormalities are practically confined to reticulation. These findings are in strong contrast to the distribution of incidence found at the 16 collieries, where the anthracite colliers show generally higher incidences of X-ray abnormalities than either the steam or the bituminous coal colliers.

As with the colliers, the X-ray changes increase in frequency and degree as the duration of employment in trimming increases. Similarly also, reticulation is the earlier change and consolidation a later development. But at none of the ports is the development of consolidation sufficient to exceed the incidence of reticulation, even among the oldest groups of trimmers, and at each of the ports reticulation remains the predominant abnormality throughout the working life. In this the trimmers resemble the colliers at the lower incidence mines.

In Chapter 12 (pp. 159-161) an account of the previous work published upon pulmonary abnormalities in coaltrimmers has been given, and the apparent conflict of evidence between the reports of serious pneumokoniosis at Cardiff (mainly steam coal) and the more or less negative findings at Swansea (mainly anthracite) has been pointed out. This conflict of evidence has now been resolved as a result of the present comparisons between the X-ray appearances of the trimmers at the four ports investigated. The previous findings both at Swansea and at Cardiff have been substantiated, and the contrast shown to be

real except that some of the Swansea films classed as showing evidence of fibrosis, though not at that time considered to be associated with dust inhalation, would, with the knowledge gained in the present inquiry, undoubtedly be classed as reticulation attributable to dust).

We are, however, left with a paradox that, whereas anthracite colliers have a generally higher incidence of pulmonary X-ray abnormalities than colliers mining steam coal, the reverse is the case with trimmers handling corresponding classes of coal. This has been shown probably to arise from the incidence of abnormalities among anthracite trimmers being unexpectedly low as compared with that in anthracite colliers, rather than from the incidence among the steam coal trimmers being peculiarly high.

A possible explanation is that, whereas the excess incidence of pulmonary abnormalities among anthracite colliers over steam coal colliers appears to be related to differences in the *rank* of the coal mined (anthracite or non-anthracite), the smaller incidence among anthracite trimmers as compared with steam coal trimmers may be associated with differences in the relative proportions of the various *commercial grades* (e.g. washed or unwashed coals) exported—with consequent differences in the amount and mineral content of the dust to which the men are exposed. The dust-forming propensities of the chief grades shipped from the anthracite port might thus be considerably less than from the steam coal ports. On this explanation, the washing of the coal after it has been raised to the surface would be responsible for a reduction in hazard between the anthracite mines and the corresponding ports of export, a reduction that is not evident in the case of the steam coal mines and their ports of export. If this be the true explanation, it shows the efficacy of the application of water to coal in reducing the associated pneumokoniosis hazard.

From previous published work, together with the present inquiry, it may be concluded that coaltrimmers handling certain types of coal have a not inconsiderable risk of developing X-ray abnormalities similar in nature to those found among coalminers. From the post-mortem descriptions, these X-ray appearances would seem to be associated with pathological changes that in certain cases may even be the cause of death.\*

#### B. ASSOCIATION OF RESPIRATORY DISABILITY AND OTHER CLINICAL MANIFESTATIONS WITH THE X-RAY ABNORMALITIES

The association of clinical manifestations with the different X-ray changes has been considered in detail in Chapter 10. The main basis of this study is the extensive information obtained upon the whole population at anthracite colliery A.3, supplemented by more restricted data from the colliers at the further 15 collieries, and also from the coaltrimmers at the four ports. The chief interest has been to compare the frequency and degree of respiratory disability† associated with the different types of X-ray abnormality; in particular, to determine whether men with reticulation show an excess frequency of disability over normal X-ray controls, and, if so, what position in this respect reticulation occupies in relation to nodulation and major consolidation.

##### (i) *Respiratory disability*

The results concerning respiratory disability (a) at colliery A.3, (b) at the further 15 collieries, and (c) among the coaltrimmers, will be discussed in turn. (Full details of the methods and procedure have been given in Chapter 4, and of the results in Chapter 10.)

\* The clinical association of disability with X-ray abnormalities in coaltrimmers is discussed in Section (B).

† For definition of respiratory disability as used in the present report, see p. 109, footnote.

(a) *Population at anthracite colliery A.3.* At this colliery respiratory disability has been independently assessed upon (1) the symptom of breathlessness on exertion, (2) the result of a simple exercise tolerance test, and (3) various types of cough. The estimations of total lung volume and its subdivisions have provided additional information, and various clinical symptoms and signs have also been found of interest.

To show on a comparative basis the frequency and degree of disability associated with the different X-ray categories, these anthracite miners have been conveniently considered in three age-groups: 20-39, 40-64, and the inclusive age-group 15-79. Some of the salient findings are indicated by the following figures, extracted from the tables of Chapter 10:—

ENTIRE COLLIERY POPULATION (560 MEN\*)

(i) *Breathlessness:*

<i>Age-group.</i>	<i>X-ray category.</i>	<i>Total men.</i>	<i>Per cent. breathless.</i>	<i>Observed breathless per cent. of expected.</i>
20-39 ..	Normal .. .. .	139	7.9	100 (base)
	Reticulation .. .. .	59	10.2	107
	Consolidation† .. .. .	41	29.3	194
40-64 ..	Normal .. .. .	131	26.7	100 (base)
	Reticulation .. .. .	57	43.9	155
	Consolidation† .. .. .	67	67.2	263
15-79 ..	Normal .. .. .	307	15.6	100 (base)
	Reticulation .. .. .	121	26.4	145
	Nodulation .. .. .	52	32.7	170
	Major consolidation‡ .. .. .	61	70.5	321
	All consolidation† .. .. .	113	53.1	256

(ii) *Impaired exercise tolerance: §*

<i>Age-group.</i>	<i>X-ray category.</i>	<i>Total men.</i>	<i>Per cent.</i>		<i>Observed per cent. of expected.</i>	
			<i>Classes B+C.</i>	<i>Class C.</i>	<i>Classes B+C.</i>	<i>Class C.</i>
20-39 ..	Normal .. .. .	138	7.2	0.7	100	(100) (base)
	Reticulation .. .. .	58	8.6	—	104	—
	Consolidation† .. .. .	40	25.0	5.0	227	(222)
40-64 ..	Normal .. .. .	122	37.7	9.0	100	100 (base)
	Reticulation .. .. .	52	53.9	15.4	133	148
	Consolidation† .. .. .	66	69.7	34.8	193	442
15-79 ..	Normal .. .. .	293	22.8	4.4	100	100 (base)
	Reticulation .. .. .	114	30.7	8.8	122	156
	Nodulation .. .. .	49	38.8	10.2	168	238
	Major consolidation‡ .. .. .	60	65.0	35.0	203	512
	All consolidation† .. .. .	109	53.2	23.8	190	413

\* Including compensation cases.

† i.e., nodulation and major consolidation.

‡ i.e., coalescent nodulation, massive shadows and multiple fluffy shadows. Percentages with breathlessness and with impaired excessive tolerance, respectively, among the 19 men with massive or multiple fluffy shadows, are 90 and 72.

§ Exercise tolerance classed as A, B or C; classes B and C regarded as indicating impairment.



(iii) *Cough:*

<i>Age-group.</i>	<i>X-ray category.</i>	<i>Total men.</i>	<i>Percentage with "all coughs".</i>	<i>Percentage with "continual cough and chest colds".</i>
40-64 ..	Normal .. .. .	131	24.4	1.5
	Reticulation .. .. .	57	31.6	7.0
	Consolidation† .. .. .	67	59.7	14.9

For each X-ray category there is thus an increase in incidence of breathlessness and impaired exercise tolerance in passing from the younger to the older age-group, reaching very high proportions for consolidation in the older age-group.

Considering the population group as a whole (ages 15-79), the proportion of men with breathlessness or impaired exercise tolerance increases progressively in the succeeding X-ray categories—normal (controls), reticulation, nodulation, and major consolidation (i.e. coalescent nodulation, massive shadows and multiple fluffy shadows). This is evident both from the simple percentage-incidences and from the observed numbers with the disability expressed as percentages of those expected. With massive and multiple fluffy shadows the incidence of disability of some degree is nearly 100 per cent. It is noteworthy that the order of the X-ray categories in this ascending scale of disability is what might be reasonably expected from the types of the appearances on the film, and that it is also the same as the order in which these changes develop with increasing duration of the exposure to risk.

Considering separately the two age-groups 20-39 and 40-64, in both of them an excess over the incidences of breathlessness and of impaired exercise tolerance among the normal controls is shown for the composite category consolidation (i.e. nodulation *plus* major consolidation), and the differences are statistically significant. For reticulation, the excess incidences of these disabilities over the incidences among the normal controls are very small at ages 20-39, but in the age-group 40-64 they are definite—though not as great as they are for consolidation. In this older age-group, the differences in incidences of breathlessness and of impaired exercise tolerance between reticulation and normals on the one hand, and between reticulation and all consolidation on the other, are twice the standard errors of these differences, and therefore unlikely to be due to chance; it is clear, therefore, that reticulation is distinguishable, in its associated frequency of disability, both from consolidation and from normal X-rays.

At ages 20-39, the proportion of men with various classes of cough shows no definite excess for the abnormal X-ray categories over the normal (except for the most advanced X-ray changes). In the older age-group, 40-64, a progressive increase is shown in incidence of cough from normal to consolidation, similar to that found for breathlessness and impaired exercise tolerance.

It is to be noted that the incidences of breathlessness, of impaired exercise tolerance and of cough, that are found for nodulation, are not markedly different from the incidences found for reticulation; while, on the other hand, the incidences of these disabilities found for major consolidation are considerably higher than those either for nodulation or for reticulation.

If, in the age-group 15-79, the number in exercise tolerance class C for each X-ray category be expressed as a percentage of the corresponding number in classes B + C, the *average degrees* of disability associated with the different X-ray categories, instead of merely the *frequency* of the different degrees of

\* Including compensation cases.

† i.e., nodulation and major consolidation.

disability, can be compared. The results are : normal, 19 per cent. ; reticulation, 29 per cent. ; consolidation, 45 per cent.—thus showing a progressive increase in the average degree of the disability.

(b) *Colliers at the further 15 collieries.* At these collieries, respiratory disability has been assessed only upon the symptom of breathlessness on exertion, and since the medical histories were taken by other observers, the results can be regarded only as supplementary to those obtained at colliery A.3. The proportion of colliers with breathlessness has, however, been found to show a similar progressive increase in the succeeding X-ray categories—normal, reticulation and consolidation (see tabulations in text of Chapter 10, p. 121).

The incidence of breathlessness among the surface screens workers may also be mentioned here (see p. 122). A greater proportion of the men with abnormal X-ray films than of those with normal pictures was found to have breathlessness. The group is, however, very small and the results can be regarded as no more than suggesting that screens workers may also suffer disability as an accompaniment of radiographical pulmonary abnormalities.

(c) *Coaltrimmers at the four ports.* For the coaltrimmers, respiratory disability was assessed as for (b), but figures for those with severe breathlessness, as well as figures for total breathless, were obtained. The results (see pp. 122–123) show the usual progressive increase in incidence of breathlessness for the X-ray categories, normal, reticulation and consolidation. To compare the average degree of disability associated with these categories, the number with severe breathlessness in each category may be expressed as a percentage of the total number breathless. The results are : normal, 24 per cent. ; reticulation, 34 per cent. ; consolidation, 42 per cent.—thus showing that there is a progressive increase in degree as well as in incidence of disability. These findings are in general agreement with those for the miners. As with the latter, the progressive development of the different X-ray abnormalities recognised among coaltrimmers is accompanied by a progressive increase in the frequency and degree of respiratory disability. This association in the living supports Gough's conclusion that pneumokoniosis may be a cause of death in this occupation.

From the standpoint of this South Wales inquiry, perhaps the most important conclusion from these various comparisons among miners and trimmers is that, as regards associated frequency and average degree of respiratory disability, reticulation occupies an intermediate position between normal and consolidation, not much below the nodulation component of the latter composite category but considerably below its more advanced component, major consolidation. Even where, in the tables of Chapter 10, the difference between reticulation and normal does not reach the formal level of statistical significance, it still occupies its expected position in the ascending scale of X-ray categories. Reticulation, although a non-nodular X-ray appearance, indicates, therefore, like consolidation, a pulmonary condition which may cause respiratory disability, though the frequency and, on the average, the degree of such disability is less, and it occurs mainly in the second half of life.

The occurrence of the disability of reticulation mainly in the second half of life cannot be taken to indicate that age itself is necessarily a factor. The great majority of these miners have been in the industry most or all of their working lives, so that there is a very high correlation between age and period of service. The above finding among the older men might, therefore, be due to a greater accumulation of dust, with its possible harmful constituents, after their prolonged period of exposure.

It may be questioned whether the respiratory disability attributed to reticulation may not in reality be due to the additional presence, in the lungs, of a

certain amount of the more advanced pathological changes, the latter either being insufficient to cast shadows on the X-ray films, or casting shadows on the films but in insufficient amount to result in their being classed in the category of consolidation. In answer to this question, it may be stated: (1) that reticulation on the X-ray film has a well-defined histological basis ("dust-reticulation"), which is sufficient to account for some impairment of respiratory function (see Belt, p. 220); (2) that the incidence of respiratory disability associated with nodulation, the X-ray category next in order of development after reticulation, is not markedly higher than the incidence associated with reticulation; and (3) that if the incidence of disability found in the group classed as reticulation has, in fact, been raised by the presence of unrecognised nodulation, so also may the incidence in the normal control group have been elevated by the unintentional inclusion of a certain number of reticulation cases—so that a mere scaling-up of incidences may have resulted. There seems, therefore, no reason to suppose that any disability associated with reticulation is due to undetected, more advanced, pneumokoniotic changes. On the other hand, since reticulation persists when consolidation develops, the former may well contribute to the increased disability associated with the latter.

It must be stressed that when we state that disability is associated with a certain category of X-ray abnormality, we mean that in a group of men with the particular X-ray picture a larger number will show evidence of disability than will a group of men with normal films, i.e., that the chances that an individual will show disability are increased if he has the X-ray abnormality. But, in the present inquiry at any rate, a proportion of the men in each of the chief abnormal X-ray categories has shown no evidence of respiratory disability by any clinical criterion used. This proportion is not inconsiderable both for reticulation and for nodulation, while a small number of men even with coalescent nodulation has appeared to be similarly unaffected; only in the relatively infrequent categories of massive and multiple fluffy shadows has the presence of disability been almost universal. In other words, not every individual with an abnormal X-ray picture, whether it be reticulation or all but the most advanced changes of consolidation, may be expected on clinical examination to show evidence of respiratory disability; the reasons for such individual differences, in spite of identical X-ray appearances, are, however, not yet clear.

Taking another point of view, when we state that there is a progressive increase in frequency and degree of disability in an ascending scale of X-ray categories, we mean that the chances that an individual will show some evidence of disability, and that this disability will be severe, increase progressively, according to the position in this scale of his particular X-ray abnormality. There are, of course, frequent individual variations from this general association. For example, some men with consolidation have shown slight or no disability, and others with reticulation only have shown severe disability. On the average, however, the amount of the disability corresponds with the category of X-ray abnormality. As a corollary, the X-ray picture indicates the probability of disability *in general*, while clinical examination assesses its presence and degree in the particular individual.

Finally, it should be emphasised that "disability", unless otherwise stated, is used to refer to any degree (slight or severe) of disability on the criteria adopted. Differentiation of degree of disability has been undertaken only (1) as to exercise tolerance impairment, by recording, for the population at colliery A.3, the numbers in class C alone as well as those in classes B + C, and (2) as to breathlessness, by recording, for the trimmers, the numbers with severe breathlessness as well as the total breathless. Breathlessness among the population at colliery A.3, and among the colliers at the further 15 collieries, has not been differentiated as to degree.

The present investigation agrees with the Pennsylvania anthracite inquiry in revealing a serious incidence of respiratory disability among coalminers with evidence of pneumokoniosis, and in showing an increasing frequency and degree of disability with increasing development of the pneumokoniotic process. The stages of the Pennsylvania classification are, however, not properly comparable with the X-ray categories of the present investigation. In the latter, moreover, the association of disability with reticulation has been made a subject of special study.

(ii) *Other clinical manifestations*

The detailed examination of the population at anthracite colliery A.3 has allowed assessment of a number of other clinical manifestations besides respiratory disability (see Chapter 10), and these will now be briefly discussed.

(a) *Cardiovascular disease.* The evidence indicates that the development of pneumokoniosis in Welsh anthracite coalminers is not accompanied by a significant rise in blood pressure—at any rate not by a progressive hypertension comparable with the progressive increase in breathlessness. It is true that the cases examined have been in the ambulatory stage, and it is possible that during the terminal phase the blood pressure may rise. Such a rise, however, is irrelevant to the present issue, which is concerned with the development of the disease over many years. The present experience agrees with the views of Sayers and Jones (1937) and of Riddell (1937, 1939) upon silicosis in general. Riddell considers that the blood pressure readings obtained in a group of silicotics would correspond very closely to a comparable random sample of the general population.

Examination for cardiac involvement during the ambulatory stages of pneumokoniosis has also given generally negative results in this inquiry. No particular association has been found between cardiac enlargement—judged clinically or, by the cardio-thoracic ratio, radiographically—and the abnormal pulmonary changes. The experience in South Wales of Enid Williams (1933) and Sen (1937) has been similar. Williams found little evidence of clinical cardiac failure or enlarged heart in her series of miners of the older age-groups who had retired from active coalmining, and Sen, in his series of pneumokoniosis cases, failed to detect any with cardiac failure.

Not all investigators have found cardiac involvement to be unassociated with pneumokoniosis in coalminers in its ambulatory stages. In the Pennsylvania report, evidence of cardiac enlargement was obtained in 6.5 per cent. of the group of employed anthracite miners with anthraco-silicosis, as against 3.3 per cent. in a control group. Giering and Charr (1939), describing a series of 25 cases of anthraco-silicosis with dyspnoea on exertion but no congestive failure, with practically normal circulation times and venous pressures, and—except in two cases—with cardiac shadows of normal size, claimed that the majority, nevertheless, showed evidence of myocardial damage when examined electrocardiographically.

Whatever be the cardiac involvement during the ambulatory stages of pneumokoniosis in coalminers, there seems to be general agreement that cardiac failure is a common terminal feature. Williams (1936), following up her original series, found that a fair proportion of the certificates of those who had died gave cardiac disease as the main or a contributory cause. She suggested that heart failure occurred as a comparatively sudden terminal complication to the respiratory condition. Charr, Cohen and Bettag (1938) reported the finding of heart disease at autopsy twice as frequently in a series of anthracite miners in Pennsylvania as in a comparable group of non-miners. In the present inquiry, the opinion of local doctors has been that cardiac failure is one of the commoner clinical modes of death in anthracite miners suffering from pneumokoniosis.

(b) *Tuberculosis*. Since few men with much hard-heading experience have been included in the present survey, any inferences as to the complication of tuberculosis apply to colliers rather than to coalminers in general.

We have not attempted either to interpret any of the categories of our X-ray classification as indicative of co-existent tuberculosis, or to introduce, for classification purposes, any additional category or notation for pneumokoniosis complicated by tuberculosis, diagnosed radiographically. Certainly at colliery A.3, where the examinations have been the most complete, *clinically obvious* tuberculosis has not been seen. Sputum tests at this colliery have been negative (though among the coaltrimmers investigated at the ports three positives were obtained). At colliery A.3 there was also, at the time of examination, no evidence of gross wasting in association with the pneumokoniosis, though, according to local medical opinion, wasting is commonly a terminal feature. The tuberculin reactions of a sample age-group at this colliery showed no evidence of any special association of hyper- or hypo-sensitivity with any of the main types of X-ray abnormality; and 95 per cent. of the whole group (including normals) reacted positively.

Despite the present findings, tuberculosis, nevertheless, is given by local practitioners as one of the clinical modes of death in anthracite miners suffering from pneumokoniosis, although it is stated to be a less frequent cause than either cardiac failure or non-tuberculous respiratory affections. Moreover, in the report by Belt (p. 211) upon post-mortem appearances in South Wales miners, tuberculosis appears as a definite finding in eight of the 42 lung specimens (including some of those from anthracite colliers), while suggestive changes were found in a number of other cases.

From these various considerations, together with a review of the literature (pp. 155-157), tuberculosis in association with pneumokoniosis appears to be more common among anthracite miners—colliers as well as rock workers—than has sometimes been supposed; but the disease tends to be modified in such cases and may be difficult or impossible to recognise clinically, and it may even require considerable care for its identification at autopsy.

While tuberculosis in significant amount may accompany pneumokoniosis as seen in anthracite miners, the incidence appears to be considerably less than in classical silicosis. Thus, in silicosis among gold miners on the Rand, tuberculosis, although modified by the silicosis, is a more frequent clinical mode of death than it is with pneumokoniosis in coalminers, and an active tuberculosis is present at autopsy in the majority of fatal silicosis cases (see Irvine, 1938; Miners' Phthisis Medical Bureau, 1939). As another example, an analysis made by Riddell (1939) of the clinical modes of death in 222 cases of silicosis from various sources in Ontario may be quoted. The clinical cause of death was given as pulmonary tuberculosis in as many as 74 per cent., cardiovascular conditions in 12 per cent., and pneumonia in 5 per cent. This order of frequency may be contrasted with that in the South Wales anthracite area, where local practitioners have reported clinical tuberculosis as a less common mode of death in pneumokoniosis than either cardiac failure or non-tuberculous respiratory affections.

(c) *Physical signs in the lungs*. As a result of this inquiry and other clinical experience, we agree with the view that is becoming prevalent (see, for example, Riddell, 1939), that physical signs should be used in conjunction with the X-ray findings and not as a separate means of diagnosing the presence or the type of pneumokoniosis. We may refer also in this connection to Amor and Evans (1934), who consider that in pneumokoniosis in South Wales coalminers "physical signs are most variable and not pathognomonic"; and to Glyn Jones (1938) who, writing of Monmouthshire coalminers, states that "generally speaking, there are few distinctive signs in a case of silicosis, owing to the masking effect of the emphysema". Indeed, the chief use of physical signs in

pneumokoniosis would appear to be to indicate complications such as emphysema and tuberculosis ; and even for this purpose they may be misleading.

(iii) *Lung volume determinations*

The results of Dr. J. McMichael's determinations (to be published in detail elsewhere), on a selection of the population at colliery A.3, can be discussed here only briefly. As stated in Chapter 10, they have shown some average reduction in total lung volume and in vital capacity for the abnormal X-ray categories. As in the case of clinically estimated respiratory disability, reticulation occupies a position intermediate between normal and consolidation, and the changes are evident mainly at the older ages. These findings are based on averages for groups, and so aid in the understanding of the effects of the dust-process on the lung, but the marked scatter of the individual values about their means offers little hope that such methods in their present form may be usefully employed to estimate disability in individual cases applying for compensation.

C. RETICULATION SUMMARISED

Since reticulation is a condition such as was envisaged under object (b) on p. 162, it is desirable to draw together the threads of this discussion in so far as they refer to it. This will be done under headings of (i) characteristics of reticulation, (ii) compensation aspects, and (iii) nomenclature.

(i) *Characteristics of reticulation*

The following summary refers solely to reticulation in the coalmining industry, the question of other industries having already been briefly discussed.

An X-ray appearance of well-marked fine reticulation is found frequently among coalminers in certain areas. In these men it is as characteristic a pulmonary abnormality as the discrete nodular and the conglomerate shadows grouped under the heading, consolidation. Furthermore, in nearly all X-ray films classed as consolidation, reticulation is present as well.

Reticulation in South Wales miners has a very similar occupational distribution to consolidation, occurring, like the latter, mainly among colliers. In this occupation it is the first abnormality to appear, and at all types of mine it is the commonest change among the younger colliers. In mines (anthracite) with a high incidence of pulmonary abnormalities, reticulation is exceeded in frequency by consolidation among the older colliers, but in low incidence mines (anthracite or non-anthracite), it remains the predominant type of X-ray abnormality throughout the working lives of the colliers.

Reticulation has not been seen in South Wales colliery workers unexposed to colliery dust, and if it does occur at all in the general male population of this area, its frequency does not approach in any notable degree that among the miners. It may be that the ordinary town-dweller of advancing years in some industrial areas has inhaled sufficient dust to produce similar striking X-ray changes in a certain percentage of cases, but this does not affect the present issue. The practical point is that well-marked reticulation discovered in a South Wales coalminer may, like typical consolidation, be accepted with a very high degree of probability as a dust condition caused by his occupation.

Study of the development and appearance of the X-ray changes, supported by the pathological findings (see below), indicates that colliers who develop nodulation and the other changes comprising consolidation have all passed through a phase of reticulation ; it further suggests that, whether due to silica or to other constituents of colliery dust, reticulation in colliers represents an actual stage in the pneumokoniotic process that may lead to the lesions of consolidation.

The incidence of reticulation among colliers varies considerably from one mine to another. The distribution of this incidence across the South Wales coalfield is similar to that of the incidence of consolidation; the incidence of the reticulation produced is correlated fairly well with the incidence of the consolidation in the various mines investigated. Like consolidation, reticulation is produced most frequently in certain anthracite mines, and the incidence is lowest in the mines of the bituminous area. In the former mines, the majority of colliers who develop reticulation on the X-ray will have progressed to consolidation before the end of a normal working life, whereas in the latter mines, reticulation tends to persist without further progress. In no mine of the series examined has reticulation been entirely absent.

Since incidence of pulmonary abnormalities and rank of coal appear to be related, extrapolation of the South Wales findings to the low rank bituminous coals of the English coalfields would suggest that among the colliers of these latter, reticulation would, on the whole, have as low, if not a lower, incidence than in the Monmouthshire bituminous mines.

The similarity of reticulation to consolidation, both in its distribution among the different colliery occupations, and in the trend of its incidence from one anthracite mine to another and across the South Wales coalfield through the steam coal to the bituminous area, suggests that these two main types of abnormality are due to similar or related causes. (This relationship receives support from the fact (see below) that reticulation is associated with the same symptoms as consolidation, though in a less degree).

Reticulation has a well-defined histo-pathology, termed "dust-reticulation" (Belt). Dust-reticulation is seen alone post-mortem, but it is also almost constantly present in the lungs of colliers showing the coarser indurations of pneumokoniosis. Indeed, it seems to provide a basis upon which these coarser lesions may develop.

Reticulation in South Wales coalminers is not infrequently associated with some degree of respiratory disability, mainly in the second half of life, i.e. a man with this X-ray picture is more likely to have some disability than if he shows a normal picture. The frequency and, *on the average*, the degree of such disability are less than in consolidation—considerably less than in major consolidation but not much below the nodulation category of this composite X-ray group. Although total incapacity may occur in individual cases of reticulation, the incapacity will more often be partial than in comparable consolidation cases. As a corollary to the above general association, a not inconsiderable proportion of men with reticulation shows no detectable clinical disability on examination, and this negative finding applies also to a significant proportion of all but the relatively infrequent and most advanced of the changes of consolidation.

Even when reticulation is not accompanied by clinical disability, its presence still implies the risk—considerable in high incidence mines—of the later progression to consolidation, with its more serious accompaniments.

Like the nodulation category of consolidation, reticulation, although it may cause disability, does not usually seem to be fatal while in this stage. Both reticulation and nodulation, however, provide the basis on which further changes may develop which are likely to prove fatal.

The occurrence of disability in reticulation mainly in the second half of life does not necessarily mean that age itself is an important factor, since length of employment—and consequently the amount of dust inhaled—are highly correlated with age in these miners.

Since reticulation is practically always still recognisable radiographically and pathologically after consolidation has developed, the disability ascribed to the latter refers really to consolidation together with reticulation, and so reticulation may itself be contributory to this disability.

In some respects nodulation seems to show a closer similarity to reticulation than to coalescent nodulation, massive shadows and multiple fluffy shadows, i.e. to those more advanced categories of consolidation which are grouped together as major consolidation. Thus, (1) both nodulation and reticulation are usually fairly generalised—though it must be understood that this is from the X-ray standpoint and that, pathologically, nodulation is more sporadic and less generalised than reticulation (Belt, p. 210), (2) nodulation is the next abnormality in order of appearance after reticulation, (3) the incidence of disability associated with the two changes does not show a marked difference—a fair proportion of men with either of them showing no detectable disability, and (4) neither change seems usually to be fatal until it has passed on to further radiographically recognisable stages (see also below, p. 191).

(ii) *Reticulation and compensation*

Compensation procedure for silicosis varies in different countries and is not the same in all industries. (For an account of the history of compensation in Great Britain, see Middleton, 1938a.\*) In Great Britain the principle in the coalmining industry is that compensation is payable for disability *provided that the standard recognised as silicosis (or silicosis accompanied by tuberculosis) has been reached.*† While no official rules have been laid down to define this standard, authoritative classifications of silicosis published about the time when, under the Silicosis and Asbestosis (Medical Arrangements) Scheme, 1931, the Medical Board for Silicosis and Asbestosis first began its examinations of coalminers, probably serve as an indication of the criteria (although these classifications were all concerned with silicosis in general and not with coalminers in particular).

The general classification drawn up in 1927 at Stoke-on-Trent, and given in the report on sandstone workers by Sutherland and Bryson (1929), defines the X-ray appearances in the first stage of silicosis as being "not less than the presence of nodular shadows". The 1930 International Conference on Silicosis (Johannesburg) decided that for general purposes silicosis did not exist unless the X-ray showed discrete shadows indicative of nodulation, or unless at autopsy the lungs showed characteristic silicotic nodules (International Labour Office, 1930; Middleton, 1931). These two publications indicate the state of expert opinion about 1930.

The report of the 1938 International Conference on Silicosis (Geneva) reaffirmed the decision of the 1930 Conference, that nodulation was in general the minimum X-ray standard for a diagnosis of silicosis (International Labour Office, 1938). At the same time, opinions were expressed by some of the delegates which suggested that this rigid standard was not altogether accepted in practice. For example, anthraco-silicosis, with its nodules that did not always present the characteristic features of the classical silicotic nodules, was included as a form of silicosis. Again, the tendency in recent years for the South African Miners' Phthisis Medical Bureau to regard as incipient silicosis for compensation purposes certain cases showing increased striation, without nodulation on the X-ray film, was pointed out by Irvine. In view of this departure from the general standard of the International Conference, together with the fact that the South African viewpoint had naturally exercised a considerable influence upon the Stoke-on-Trent general classification of 1927 (see above), it is relevant to discuss the trend of the South African compensation standards for early silicosis in rather more detail.

When the South African Miners' Phthisis Medical Bureau was instituted in 1916 the earliest stage of silicosis compensated in gold miners was termed the primary stage, but in

\* The chief enactments and schemes relevant to silicosis compensation in the coalmining industry in Great Britain are given on p. 2, footnote.

† Rights to compensation include: (1) death caused by silicosis or by silicosis accompanied by tuberculosis; (2) total disablement from either of these conditions; and (3) "that a workman, though not totally disabled, is suffering from silicosis or from silicosis accompanied by tuberculosis to such a degree as to make it dangerous for him to continue work in the industry or process, and is for that reason suspended from employment". Cases of (3) are subdivided according to whether the general physical capacity for employment is (a) impaired by reason of the disease, entitling the workman to partial disablement compensation while impairment continues, or (b) is not impaired by reason of the disease, in which case he is entitled in certain circumstances to compensation up to a maximum period of 13 weeks.



1919 an ante-primary stage was designated as compensatable. For some years the radiographical appearances in the ante-primary stage may be said to have corresponded approximately to those of "not less than the presence of nodular shadows" in the first stage of the classification given in Sutherland and Bryson's report. More recently, however, the ante-primary stage has been liberalised, so that the selection by the Board of cases for compensation has come to include those showing well-marked linear striation or generalised arborisation, even without nodular shadows, provided that the history is unequivocal and definite evidence of respiratory disability is present. This course has been justified by the finding that about half such cases show significant typical nodulation at autopsy. They can, therefore, be regarded as incipient silicosis under the accepted pathological definition, even though they would be excluded on the general X-ray standard.\*

One of the main objects of the present inquiry has been to determine whether disabling pulmonary conditions due to employment exist among South Wales coalminers which do not come under the present definition of silicosis for purposes of compensation. On the assumption that the criteria followed in Great Britain for compensation of coalminers in respect of silicosis are those agreed upon for general use by the two International Conferences, this question can be answered in the affirmative; reticulation appears to represent such a condition. It is a pulmonary condition in coalminers due to dust, which may cause respiratory disability,† but which has a non-nodular X-ray appearance and does not show the characteristic silicotic nodules post-mortem. On the general standards quoted above, it cannot, therefore, come within the definition of silicosis for purposes of compensation, even if it be accompanied by disability. On the other hand, nodulation and the various other categories grouped together under the composite heading, consolidation, do conform to such a standard, and can be awarded compensation.

This position is well recognised by medical opinion in Wales. In 1940 a Report and Memorandum upon Industrial Pulmonary Fibrosis in Wales, by Dr. D. A. Powell (Principal Medical Officer) and Dr. T. W. Davies (Tuberculosis Physician), were issued by the Welsh National Memorial Association. In his memorandum, Davies places under the heading of "non-compensatable industrial fibrosis" certain conditions which evidently include that which is here termed reticulation. After pointing out the frequency, he states that "there is no doubt that the fibrosis is industrial in origin and is accompanied by a reduced capacity for work" and that "some of these cases who continue to work exposed to the same dust hazard develop more serious disease later on"; and he remarks that these early stages are not compensatable "as the standard laid down at which the incapacity qualifies for compensation is not reached".

If the present assumption as to the British standards for diagnosis of silicosis for compensation is correct, then the incidences of consolidation among the colliers at work at the different representative collieries of the present series (Chapter 7) can be used to provide a rough indication of the amount of *latent* compensatable pneumokoniosis in different parts of South Wales at the time of the present inquiry. Since, however, evidence of disability is required in an individual case before compensation is awarded for a period longer than three months, it is necessary also to estimate the proportion of these latent cases that has disability. The only satisfactory estimate is that made for the whole underground working population of colliery A.3 (p. 169), which indicates that, in anthracite mines at least, a high incidence of latent consolidation is accompanied by a serious amount of disability—albeit insufficient to prevent accustomed work within a limited range of effort. In the lower incidence mines of the steam coal and bituminous coal areas, it may be estimated that the amount of latent compensatable pneumokoniosis, and consequently the numbers of men with disability, are considerably smaller.

Estimates such as these are essential for the future planning of health measures and compensation finance for the South Wales coalfield. A corollary to the above considerations is that if a system of periodical examinations were to be instituted on what is presumed to be the present compensation diagnostic standards, the incidence-rate of certified cases

\* For further details of the history of the legal notification stages on the Witwatersrand the reader is referred to Irvine and Steuart (1930), Fraser and Irvine (1930), Irvine, Mavrogordato and Pirow (1930), Union of South Africa (1937), Irvine (1938), International Labour Office (1938), Miners' Phthisis Medical Bureau (1939).

† See p. 109, footnote.

would be considerably increased during an initial, limited period. Examples of this on a local scale have already been seen shortly after the closure of certain collieries. The increased supply of cases would, however, be focal, probably distributed according to the rough incidence "map" sketched out in Fig. 11 (p. 74). Moreover, even during this initial phase (and much more so after such a system had been established for some time), the proportion of earlier cases, with X-ray changes near the minimum standard, and with the less severe degrees of disability, would exceed that which is found under the present system.

The preceding two paragraphs are concerned with consolidation, of which the component categories are assumed to conform to the standard at present recognised as constituting silicosis. A further important consideration is the probable effect should reticulation in coalminers also become accepted as reaching the standards of compensatable pneumokoniosis. Consideration may here be restricted to the present system, whereby claims for compensation are made on the volition of the individual miner; and it will be assumed that, as under present procedure, some degree of disability would be required, as well as the diagnostic standard being reached, for compensation of more than a few months duration to be awarded in a given case. At first sight it might appear that such a change in minimum standards would result in a very large increase in the numbers compensated, and that these additional cases would be generally distributed over all parts of the South Wales coalfield. This is, however, unlikely, for two reasons. The first is that the incidence of reticulation, like that of consolidation, appears on the whole to be considerably lower in the Monmouthshire bituminous area than in the anthracite area of the west (Chapter 7). The second is that the proportion of men showing disability is smaller for reticulation than for consolidation, and the proportion of these disabilities that are severe rather than slight is also less (Chapter 10).

### (iii) *Nomenclature*

The causation of the pathological lesions in coalminers represented radiographically by reticulation and by consolidation—including the respective rôles of uncombined silica, silicates, coal and the tubercle bacillus—is in course of investigation as part of this inquiry. From the preceding subsection, and also from the accompanying report of Dr. Belt, it is clear that reticulation could not at present, without distortion, be included under the term silicosis; anthracosis, on the other hand, may be objected to, both on account of historical confusion and because, without adequate proof, the term designates coal and excludes silica as the causative agent. Furthermore, even some of the lesions in coalminers represented by consolidation on the X-ray film are not typical of classical silicosis, and this is recognised in Belt's classification, which includes nodulation of three types as well as confluent fibrosis.

From these considerations, two immediate practical alternatives for nomenclature suggest themselves: (a) that the condition in coalminers described radiographically as reticulation and pathologically as dust-reticulation be termed "dust-reticulation", and that the more advanced changes, described radiographically as consolidation—viz. nodulation, coalescent nodulation, massive shadows and multiple fluffy shadows—and pathologically either as nodulation—the nodules of which may be reticular (nodular reticulation), silicotic, or of mixed type—or as confluent fibrosis, continue to be termed, as at present, "silicosis" or "anthraco-silicosis"; (b) that until the causes of the various lung changes due to dust in the coalmining industry are more fully established, some general term be used for legal purposes to cover both reticulation and consolidation. "Pneumokoniosis of coalminers" might answer the purpose. Pneumokoniosis is a general term used to designate any dust-ridden state of the lungs severe enough to impair health. "Pneumokoniosis of coalminers" has the advantage of indicating only what is definitely known—that both reticulation and consolidation are due to dust, and that the changes are somewhat peculiar to the coalmining industry. The fact that the fibrous reaction in reticulation is described as being of the limited reticular tissue type, whereas in consolidation it is more often a redundant fibrosis, seems to be no objection to the use of this term.

From Belt's pathological study (Tables I, II) it will be seen that there is a broad correlation between X-ray reticulation and post-mortem dust-reticulation, on the one hand, and between X-ray consolidation and post-mortem nodulation and confluent

fibrosis (both accompanied by dust-reticulation), on the other. Taking the categories of consolidation individually, X-ray nodulation (category (c)) appears to be correlated with post-mortem nodulation; coalescent nodulation (d) with nodules coalesced by confluent fibrosis; massive shadows (e) with confluent fibrosis.

In Belt's terminology, "nodular reticulation" (or reticular nodulation)—an exaggerated form of dust-reticulation—and pure silicotic nodulation are the two extremes of post-mortem nodulation, with "mixed nodulation" as an intermediate, and the commonest, type. There is the suggestion (Belt, Table I) that in rock workers with nodulation and coalescent nodulation radiographically, the nodules post-mortem are usually of the pure silicotic type, while in coalface workers with these X-ray pictures, the nodules tend either to be of the reticular (nodular reticulation) or of the mixed type. These finer correlations can be no more than slightly suggestive, owing to the small numbers involved; the scantiness of cases of simple nodulation (c) in the pathological series is quite disproportionate to the frequency of this appearance among abnormal X-ray pictures of coalminers, particularly colliers. If further research should indeed show that in colliers "nodular reticulation" is commonly the histological basis of simple nodulation on the X-ray film, it would provide a stronger argument for a pathological and aetiological relationship between X-ray nodulation and X-ray reticulation than is at present available. In that case, the major groupings in the X-ray classification for colliers might need to be modified: X-ray nodulation, instead of being grouped, as at present, with coalescent nodulation, massive shadows and multiple fluffy shadows under the heading of consolidation, might be grouped with reticulation, while the more advanced radiographical changes would still be classed as major consolidation, their present term.

These considerations of possible development in the conception of pneumokoniosis, as it affects colliers, seem to favour the second of the alternative nomenclatures for this condition given above.

#### D. RELATION OF THE PULMONARY ABNORMALITIES TO CERTAIN OF THE METHODS AND PROCESSES OF MINING

In seeking for the cause or causes of the very unequal distribution in incidence of pulmonary abnormalities among colliers in the South Wales coalfield, particularly of the high incidence in many anthracite mines, it is obviously of practical importance to determine whether simple differences in the methods and processes used at the various mines could be responsible. Some information of a limited and negative nature has been forthcoming from this medical survey. This information has been given in Chapter 11; it relates to the various systems of mining (pillar and stall, longwall, etc.), to ripping work, to the practice of blasting, to stone-dusting, and to the use of "spakes" for riding the men from and to the surface; each of these has been variously suggested as mainly responsible for the present situation.

The increased use of intensive mining by means of coalcutters and conveyors in the coalmining industry has undoubtedly raised the dustiness at and near the coalface. As shown in Chapter 11, however, intensive methods cannot have played any part in producing the prevalence of pulmonary disease in the anthracite area, since their introduction has so far been negligible in this part of Wales. Another system of mining, to which is usually ascribed a high degree of dustiness, is pillar and stall work, and this method has been prominent in certain of the anthracite mines of the present series. It has, however, never been employed in two out of the three high incidence anthracite mines. The inference is that, while the dustiness at the coalface may, indeed, be greater with this system than with longwall work, pillar and stall working is not an essential factor in the geographical selectiveness of the chronic pulmonary abnormalities. Complete transfer from pillar and stall to longwall methods might reduce the amount of pneumokoniosis in South Wales but could not alone eliminate it. Neither, of course, can the longwall stall system, as such, be of essential significance in the high incidence in the anthracite area, for although prominent there, it has also been popular in the steam and bituminous coal areas, where the incidence of pulmonary abnormality is comparatively low. It is hardly necessary to point out that the difference in dustiness between two mines using different systems of mining, e.g. longwall stalls and pillar and stall, may be less than that between two mines in both of which, say, longwall

methods of work are employed, though with markedly different success in ventilation. The levels of dustiness associated with different methods of working are probably governed largely by such factors as the ventilation, the presence of water, etc.; and since, with any given system of working, these factors vary substantially from mine to mine, it would scarcely be expected that a high or low incidence of pulmonary abnormalities would necessarily be associated with a particular system of working.

The importance or otherwise of ripping work in contributing to the risk incurred by the collier has been difficult to assess from the present data. The medical evidence (Chapter 11) suggests that the dust from the coal seam itself can provide an important risk, even where little or no ripping of the adjacent roof or floor strata is carried out by the collier; hence the abolition of ripping by the latter would probably not entirely remove pneumokoniosis from the coalfield. The finding by Bedford and Warner that, although the non-coal *percentage* of the air-borne dust at the coalface is increased during the process of ripping the roof, the actual *concentration* of the non-coal fraction, i.e. its amount per unit volume of air, is substantially the same as during actual getting and handling of the coal, also suggests that ripping is not an essential factor in the causation of the high incidence of the disease in the anthracite mines. However, the chemical analyses of the air-borne coalface dusts at certain mines of the present series (to be given by Dr. G. Nagelschmidt in another of the environmental reports) indicate that even if ripping operations do not affect the non-coal dust-concentration at the face, they change the latter's chemical composition in the direction of an increased quartz-content; this, by raising the quartz-concentration in the air inhaled, might conceivably make ripping an important contributory factor. In that case, abolition of ripping by the collier might be expected to improve the position, although not to eradicate the disease completely. Such abolition, even on the longwall stall system, has, indeed, recently been made effective at certain mines in the steam coal area of South Wales, where other classes of workmen rip and pack in the stall roads, leaving the collier to win the coal.

A somewhat similar conclusion has been arrived at about blasting. Blasting is carried out systematically, both in coal and in rippings, in the anthracite area, and it is the usual practice to fire mainly on the coal shifts. In the steam and bituminous areas, on the other hand, blasting is practically confined to rippings, and is carried out when the colliers are absent. Nevertheless, the evidence is that even such marked general contrasts cannot be the chief explanation of the geographical distribution of pneumokoniosis in South Wales. On the contrary, the medical data suggest that, even in those few anthracite mines where there is no systematic shot-firing at the coalface, an unsatisfactorily high incidence of pulmonary changes can yet occur. This suggestion is supported by the results in coaltrimmers, in whom, of course, the direct influence of shot-firing is entirely excluded. Blasting, whether through the fumes produced or through its effect upon dustiness, does not appear, from these limited data, to be an essential factor in the present problem. It may, however, well be a contributory factor, if only from its effect in increasing the average total dustiness—an effect which will be emphasized by Bedford and Warner. If that be so, universal transference of all blasting to the back shift or to between shifts, by contributing to a reduction in dustiness, would be expected to help in reducing the pneumokoniosis risks. Such transference, it may be noted (Chapter 11), has already been found practicable in certain important anthracite collieries.

The general contrast between the absence of the practice of stone-dusting from the anthracite mines and its systematic use in steam and bituminous coal-mines, could only account for the selectively high incidence of pulmonary abnormalities in the former area if the stone dust exerted an antidotal action

in the latter areas. Such an explanation would have to assume that the antidotal action is ascribable both to shale dusts and to limestone. At certain carbonaceous steam coal mines using shale dusts (see Chapter 11), the incidence of X-ray abnormalities has been classed as medium in the present investigation. This finding does not support the existence of any high degree of protective property in shales, unless it is local even within the non-anthracite areas. As regards the possible antidotal action of limestone, the present medical data do not give any information.

The view that the "spake" trains, so commonly used to convey men along the slants from and to the surface at anthracite collieries, conduce to the development of chest colds and bronchitis in men coming from warm working places, is *a priori* a reasonable one. T. David Jones (1936) has gone much further in suggesting that "the apparent harm attributed to the dust in anthracite mines is, in reality, dependent on bronchitis resulting from exposure to cold on the spakes, with secondary accumulation of coal dust in the lungs in consequence of the normal process of elimination of dust from the lungs being paralysed"—a suggestion that was accepted in substance by the late J. S. Haldane (see p. 143). In support of this interesting hypothesis, Jones gives figures showing that the incidence-rates of certified silicosis in anthracite collieries with spakes is higher than in those that lack spakes. It should be noted, however, that the collieries with spakes are, on the whole, deeper than those without them, so that other factors may enter into the above association. For while the deeper mines are generally the warmer, and so would be expected to be associated with considerable temperature changes between coalface and surface, they are also generally the drier, and might therefore be expected to be the more dusty.

Although, as indicated in Chapter 11, much of the evidence available from the present inquiry is inconclusive, there is little doubt that spake travel in anthracite mines can produce severe chilling. No clear support, however, is given to the hypothesis that this chilling is of primary importance in causing the pneumokoniosis prevalent in such mines, though it may be a contributory factor. The condition occurs at certain steam coal collieries that have no spakes to the surface; and, on the other hand, at another colliery, where all the underground workers, including both the hauliers and the colliers, are subjected to a fair degree of chilling on account of the spake, the hauliers have shown no significant excess of coughs or bronchitis nor any considerable incidence of X-ray abnormalities, whereas among the colliers of this mine the incidence of coughs and radiographical pneumokoniosis is seriously high. More convincing evidence, perhaps, against the importance of spakes in the anthracite pneumokoniosis problem is supplied by the Pennsylvania anthracite mines, in which slants appear to be the exception, but in which, nevertheless, the incidence of pulmonary disease, designated as anthraco-silicosis, is also serious.

From the above considerations, none of the processes and methods of mining discussed would seem to be an essential or indispensable factor, or even the main factor, in the production and maintenance of the generally high incidence of pneumokoniosis among colliers in certain anthracite mines in South Wales, although some of them are probably of contributory importance, through their influence upon the air-borne dust or upon the miner himself. While the quantity and quality of the dust produced at the coalface would undoubtedly be affected by a general change in the system of mining, it would be unwise to assume that a mere substitution of any one system for another, at a given colliery, would in itself result in the desired improvements. Yet, since longwall working favours the maintenance of brisk air currents at the coalface, the general use of this system, combined with strenuous efforts to improve ventilation, might be expected to contribute to an improvement. Reduction of the exposure of the collier to the dust produced during ripping, and relegation

of shot-firing to times when the collier was absent, would probably also be beneficial measures, though they would almost certainly be insufficient alone, as the collier would still inhale considerable amounts of dust derived from the coal seam. The stone-dusting issue has been shown to be probably irrelevant to the situation in the anthracite area; and there is no clear indication that protection from chilling on spakes, while highly desirable in itself and possibly useful in preventing colds, would strike at the root of the trouble.

Beyond these limited inferences as to mining methods the data of the present medical survey do not permit us to go. Probably, as the results of environmental inquiries in this industry accumulate, it will be possible to indicate more clearly the factors—such as particular constituents of the dust—concerned in the causation of the pulmonary abnormalities, and to suggest suitable lines of attack on the practical problem. At present, the main hope for improvement lies in the radical reduction of the amount of dust at the coalface. Greater care in the application of what is now recognised as good mining practice will assist, but the use of more definitive methods for the prevention or allaying of dust at the coalface is also desirable.

### CONCLUSIONS\*

#### *X-ray classification*

1. A convenient classification of the pulmonary X-ray changes caused by dust in coalminers has, as its main divisions, "consolidation" and "reticulation", consolidation being a composite category containing discrete nodulation and the various forms of conglomerate shadow, and reticulation not being further subdivided. Consolidation corresponds to the changes which generally go under the name of silicosis in coalminers, and it is approximately co-extensive with the disease as seen in men certified as silicosis for compensation; special emphasis has not hitherto been laid upon reticulation. (Chapters 5, 13.)

#### *Pulmonary abnormality of the consolidation type*

2. In addition to the disease in men who have left work through chest illness with or without compensation, there is in the South Wales coalfield a considerable amount of pulmonary abnormality of the well-recognised consolidation type among the working miners. This latent pneumokoniosis is the cause of a serious amount of respiratory disability, taking the coalfield as a whole, although the affected men are often able to continue their accustomed work for some years, within a limited range of effort. Fortunately, however, not everywhere in this coalfield are the miners severely afflicted; in a fair number of mines, and particularly in certain areas (see (5) below), they are comparatively free from this pulmonary trouble. (Chapters 6, 7, 13.)

3. The greater part of the pulmonary abnormality of the consolidation type in the anthracite miners of South Wales is found among the colliers; and, other things being equal, the longer they work at the coalface in a given mine the more likely they are to develop it. The present inquiry has therefore been concentrated mainly upon this occupational class and upon its conditions of exposure. In the South Wales non-anthracite mines, hard-heading and other rock workers account for a relatively larger proportion of the abnormality, while in English and Scottish bituminous mines, judging by compensation statistics, the rock workers appear to be the predominant occupations affected. These regional differences in the relative prominence of colliers and rock workers are due chiefly to differences in the hazard of the former. In anthracite mines hard-heading work carries actually greater risks than the occupation of collier, but the latter accounts for most of the abnormality found, because there are

\* Summaries will be found at the ends of most of the chapters, and reticulation is summarised more fully in Chapter 13, pp. 187-192.

far more colliers than hard-heading workers; in bituminous mines, owing to the lower hazard of the colliers, the importance of the rock workers in the production of the pneumokoniosis is relatively increased. (Chapters 1, 6, 12, 13.)

4. A satisfactory estimate of the distribution of pulmonary abnormality due to dust among the colliers in various parts of the South Wales coalfield is obtained by comparing the incidences of X-ray abnormalities among statistically selected groups of colliers at different mines who have served periods of under 10 years, 10-20 years, and 20 + years, in this occupation. This method is more efficient than comparing the incidence-rates of certified silicosis, which tend to under-estimate the amount of pulmonary abnormality actually present in certain classes of mine. (Chapter 7.)

5. Like the silicosis compensation cases, the incidence of X-ray abnormality of the consolidation type among the working colliers is very unequally distributed over the South Wales coalfield. The distribution of this X-ray abnormality is broadly correlated with the disposition of the differing ranks of the coals mined in this field. Thus the highest incidences are found in the anthracite mines, which are situated in the western half of South Wales, and the lowest in the bituminous mines of Monmouthshire (only mines working seams in the Lower Coal Series are considered); and there is a fairly gradual decrease in incidence of the X-ray abnormality between these extremes through the steam coal mines, which are situated more towards the centre of the coalfield. There is also a low-incidence minority among the anthracite mines themselves, coinciding on the whole with those mines whose workings are relatively damp and shallow. The incidence of the pulmonary abnormality is considered to be a function more of the rank of the coal mined than of geography; the latter relationship is probably secondary, due to the geographical trends of the rank of the South Wales coals. (Chapter 7.)

In showing that this pulmonary abnormality among colliers is mainly concentrated in the anthracite mines, and that its incidence is relatively low in the bituminous area, the above conclusions agree with the compensation statistics; but the latter suggest that the change in incidence in passing from anthracite to non-anthracite is sudden, whereas in fact it is gradual and continuous, with a not negligible amount of abnormality in some of the steam coal mines. (Chapter 7.)

#### *Pulmonary abnormality of the reticulation type*

6. In addition to the consolidation type of X-ray appearance, the condition termed reticulation seems to be established as an important form of pulmonary radiographic abnormality among South Wales coalminers. Reticulation may be described as a characteristic non-nodular pulmonary X-ray change found frequently among these miners, which may be associated with respiratory disability, but which does not conform to the criteria generally accepted as indicating silicosis for compensation purposes. It represents a dust condition of occupational origin; and owing to its characteristic X-ray appearance, and to the strong contrast between its frequency among the South Wales miners and the infrequency of any similar appearances among the general male population of the area (represented by the colliery workers not exposed to dust), errors of diagnosis are unlikely. (Chapters 5, 13.)

7. Reticulation is an earlier X-ray change than the better recognised, discrete nodular and conglomerate shadows, and in films showing these latter appearances it is generally visible in addition to the more noticeable consolidation; the evidence further suggests that it represents an essential part of the pneumokoniotic process leading to consolidation—i.e. that it is a pre-stage of the latter group of changes. The causation of reticulation is under investigation, but the medical evidence so far indicates that it is similar or related to that of consolidation. (Chapters 5, 6, 7, 13.)

8. Reticulation, like consolidation, is found mainly among colliers. Its incidence among colliers follows a broadly similar trend to that of consolidation, from mine to mine, tending to be higher in those mines where consolidation is more frequent, but being on a somewhat higher level than the incidence of the latter. Like consolidation, the production of reticulation tends, therefore, to decrease across the South Wales coalfield from west to east, being greatest in certain anthracite mines and smallest in the mines of the bituminous area. In the former mines, colliers who develop the changes of reticulation will usually have progressed to those of consolidation before the end of the normal working life ; in the latter mines, what reticulation there is tends to remain without further progression. (Chapters 6, 7.)

9. Reticulation in South Wales coalminers is not infrequently associated with some degree of respiratory disability, i.e., men with this X-ray picture are more likely to have reduced exercise tolerance, breathlessness on exertion, or coughs, than those with a normal picture. The frequency with which such disability accompanies reticulation, and also, on the average, its degree when present, are less than for consolidation—considerably less than for the conglomerate changes of the latter composite X-ray category, but not much below its earlier change of discrete nodulation. Moreover, the occurrence of disability with reticulation is mainly in the second half of life, though this does not mean that age in itself is necessarily a factor. (Chapters 10, 13.)

As a corollary to this general association, by no means every individual with reticulation may be expected to show clinical evidence of respiratory disability on examination—as is also true to some extent of all but the most advanced types of consolidation. (Chapter 10.)

Even when reticulation is not accompanied by clinical disability its presence still implies the risk—considerable in certain mines—of the later progression to consolidation, with its more serious accompaniments. Indeed, reticulation, although it may cause disability, does not usually seem to be fatal in this stage, and in this it resembles discrete nodulation, the earliest change of consolidation. (Chapter 13.)

10. Reticulation has a well-defined histological counterpart, described in the accompanying pathological report, which is termed "dust-reticulation". Dust-reticulation seems to provide a basis upon which may develop the coarser indurations of pneumokoniosis in coalminers, represented radiographically by the consolidation type of changes.

11. The identification of reticulation as an industrial condition in coalminers, which does not conform to the accepted standard of silicosis, but which may cause disability, is not in conflict with there being cases of clinical disability, sometimes severe, in which no radiographical lung changes at all are present. Such cases include emphysema and cardiac disease, indistinguishable from these conditions as found in the general population. No peculiar connection with employment in coalmining has been established for this class of case.

#### *Coaltrimmers*

12. Welsh coaltrimmers show pulmonary X-ray changes similar in type to those in coalminers, which are associated similarly with some clinical evidence of respiratory disability. But whereas anthracite colliers have a generally higher incidence of pulmonary abnormality than colliers mining steam coal, the reverse is the case with trimmers handling the corresponding classes of coal. This paradox appears to arise from the incidence of abnormality among the anthracite trimmers being low as compared with that among anthracite colliers, without there being the same difference for the steam coal trimmers ; a possible explanation of this selective reduction in hazard between the anthracite coal-face and the corresponding port of export lies in a differential tendency, in anthracite as compared with steam coal collieries, towards certain methods of



preparation of the coal for marketing purposes, e.g. by washing and sizing, with the consequent effect upon the dust produced during trimming. (Chapters 9, 10.)

#### *Nomenclature*

13. Since reticulation is undoubtedly due to dust of some kind but cannot, at present, be termed a form of silicosis, and since consolidation itself shows certain characteristics post-mortem which are rather different from classical silicosis, it is suggested for simplicity of nomenclature that the changes represented both by reticulation and by consolidation be included under the term "pneumokoniosis of coalminers". Alternatively, it is suggested that "silicosis" (or "anthraco-silicosis") continue to apply to the consolidation type of abnormality, and that the term "dust-reticulation" be introduced, leaving the latter's exact causation to be elucidated by further research. The first of these alternatives is preferred. (Chapter 13.)

#### *Influence of certain methods used in mining*

14. The medical data, together with information derived from the industrial histories upon certain of the methods and processes used in mining coal (including various systems of mining, ripping work, shot-firing and use of spakes), suggest that none of these is the main factor in producing and maintaining the high incidence of pulmonary abnormality among the colliers at certain anthracite mines, although some of them are probably contributory factors. Mere substitution of any one system of mining at present in vogue for another, at a given anthracite colliery, could not in itself be expected to result in the desired improvement. Reduction of exposure of the collier to dust produced in ripping would probably be beneficial, but it could not be expected alone to eliminate pneumokoniosis, since the evidence suggests that the dust from the coal seam itself is an important factor. Relegation of shot-firing to times when the collier was not present also would probably be helpful, through reduction of the level of dustiness. Protection from chilling on spakes, while desirable in itself, is considered unlikely to strike at the root cause of the present trouble, which is the dust at the coalface. (Chapter 11.)

15. It is hoped that further researches may indicate more clearly the factors—such as particular constituents of the coalface dust—which are responsible for the pulmonary abnormality under consideration, and for its especially high incidence in certain anthracite mines. As a result of such work, it is hoped also that suitable lines for mining procedure will be suggested. At present the main hope for improvement lies in the radical reduction of the amount of dust at the coalface, either by the more intensive use of methods at present available or by the introduction of new methods.

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## REFERENCES

- AMERICAN PUBLIC HEALTH ASSOCIATION. (1933) *Amer. Publ. Hlth. Yr. Bk.*, 1932-33 pp. 100-102.
- AMOR, A. J. (1941) *An X-ray Atlas of Silicosis*, Bristol.
- AMOR, A. J., and EVANS, R. G. PROSSER. (1934) *Practitioner*, 132, 700.
- ARLIDGE, J. T. (1892) *Hygiene, Diseases and Mortality of Occupations*, London.
- ASLETT, E. A., HART, P. D'ARCY, and McMICHAEL, J. (1939) *Proc. Roy. Soc., B*, 126, 502.
- ASLETT, E. A., HART, P. D'ARCY, MARTIN, W. J., and RUSSELL, W. T. (1941) *J. Hyg., Camb.*, 41, 169.

## 200 PULMONARY DISEASE IN WELSH COALMINERS

- BADHAM, C. (1939a) *Arch. Mal. prof.*, **2**, 1; (1939b) in *Rep. Roy. Comm. Safety and Hlth. of Workers in Coalmines, New South Wales*, Sydney, N.S.W., p. 351.
- BADHAM, C., and TAYLOR, H. B. (1933) *Med. J. Aust.*, **1**, 511; (1936), in *Ann. Rep. Dep. Hlth., N.S.W.*, p. 100; (1939) in *ibid.*
- BATHGATE, G. W. (1936) ref. Cummins, 1936.
- BELLIAEV, and SHAVININ. (1931) ref. Moshkovsky, 1941.
- BLOOMFIELD, J. J., DALLAVALLE, J. M., JONES, R. R., DRESSEN, W. C., BRUNDAGE, D. K., and BRITTEN, R. H. (1935) Anthraco-Silicosis among Hard Coal Miners, *U.S. Publ. Hlth. Bull., Wash.*, No. 221.
- BOEHME, A. (1925a) *Fortschr. Roentgenstr.*, **33**, 39; (1925b) ref. Harrington and Davenport, 1937, p. 162; (1930a) in International Labour Office, 1930, pp. 354-356; (1930b) in *ibid.*, p. 364.
- BRIDGE, J. C. (1938) in *Ann. Rep. Insp. Fact. Wksh.* (Cd. 6081), p. 80.
- BRUNDAGE, D. K. (1933) The Mortality of Coal Miners, *U.S. Publ. Hlth. Bull., Wash.*, No. 210.
- BRUNDAGE, D. K., and FRASIER, E. S. (1933) in The Health of Workers in Dusty Trades, *U.S. Publ. Hlth. Bull., Wash.*, No. 208, pp. 7-19.
- CHARR, R., COHEN, A. C., and BETTAG, O. L. (1938) *Internat. Clin.*, N.S., **3**, 195.
- CLARKE, B. G., and MOFFET, C. E. (1941) *J. Industr. Hyg.*, **23**, 176.
- COLLIS, E. L. (1915) *Public Health*, **28**, 252, 292; (1922) *J. Industr. Hyg.*, **4**, 256, 307; (1926) *ibid.*, **8**, 457; (1931) in Welsh National Memorial Association, 1931, p. 23.
- COLLIS, E. L., and GILCHRIST, J. C. (1928) *J. Industr. Hyg.*, **10**, 101.
- COOKE, W. E. (1932) *Practitioner*, **129**, 483; (1933) *Tubercle, Lond.*, **19**, 289.
- COOMBS, B. L. (1941) *Fortnightly, Lond.*, No. 889, p. 78.
- COURTOIS, R. ref. Langelez, 1938.
- COX, A. HUBERT. (1938) *Proc. S. Wales Inst. Engrs.*, **54**, 161.
- COX, W. I. (1857) *Brit. Med. J.*, p. 491.
- CUMMINS, S. LYLE. (1927) *J. Path. Bact.*, **30**, 615; (1931) *Lancet*, **1**, 235; (1934), *Amer. Rev. Tuberc.*, **29**, 17; (1935) *Brit. Med. J.*, **2**, 287; (1936) *J. Hyg., Camb.*, **38**, 547.
- CUMMINS, S. LYLE, and EVANS, A. CEINWEN. (1933) *Brit. Med. J.*, **1**, 815.
- CUMMINS, S. LYLE, and SLADDEN, A. F. S. (1930) *J. Path. Bact.*, **33**, 1095.
- CUMMINS, S. LYLE, and WEATHERALL, C. (1931) *J. Hyg., Camb.*, **31**, 464; (1933) *ibid.*, **33**, 295.
- CUMMINS, S. LYLE, and WILLIAMS, ENID M. (1938) *J. Hyg., Camb.*, **38**, 638.
- DANIEL, G. H. (1937) *J. Roy. Anthropol. Inst.*, **67**, 143; (1940) Personal communication.
- DAVIES, T. W. (1940) *Memorandum on Industrial Pulmonary Fibrosis in Wales*, Welsh Nat. Mem. Ass., Cardiff.
- DOUGLAS, S. R., and HARTLEY, P. (1934) *Tubercle, Lond.*, **16**, 105.
- DRESSEN, W. C., DALLAVALLE, J. M., EDWARDS, T. I., SAYERS, R. R., EASOM, H. F., and TRICE, M. F. (1940) Pneumokoniosis among Mica and Pegmatite Workers, *U.S. Publ. Hlth. Bull., Wash.*, No. 250.
- DRESSEN, W. C., and JONES, R. R. (1936) *J. Amer. Med. Ass.*, **107**, 1179.
- EDLING, L. (1926) *Acta radiol., Stockh.*, **6**, 369.
- FARRELL, J. T. JR., SOKOLOFF, M. J., and CHARR, R. (1940) *Amer. J. Roentgenol.*, **44**, 709.
- FISHER, S. W. (1935) *Trans. Instn. Min. Engrs., Lond.*, **88**, 377, 409.
- FLINN, R. H., SEIFERT, H. E., BRINTON, H. P., JONES, J. L., and FRANKS, R. W. (1941) Soft Coal Miners—Health and Working Environment, *U.S. Publ. Hlth. Bull., Wash.*, No. 270.
- FRASER, D. SPENCE, and IRVINE, L. G. (1930) in International Labour Office, 1930, p. 618.
- GARDNER, L. U. (1933) in Brundage and Frasier, 1933, pp. 16-19; (1934) *J. Amer. Med. Ass.*, **103**, 743; (1937) in Saranac Laboratory, 1937, p. 103; (1940) *Proc. 5th Ann. Meeting Air Hygiene Foundation of America*, p. 26.
- GIERING, J. F., and CHARR, R. (1939) *J. Amer. Med. Ass.*, **113**, 574.
- GOUGH, J. (1940) *J. Path. Bact.*, **51**, 277.
- GREENHOW, E. HEADLAM. (1858) in *Sanitary State of People of England*, Gen. Bd. Hlth., p. 68; (1862) in *4th Rep. Med. Off. Privy Coun., Lond.*, pp. 145, 158-166; (1869) *Trans. Path. Soc., Lond.*, **20**, 41, 45, 46.
- HALDANE, J. S. (1916) *Trans. Instn. Min. Engrs., Lond.*, **51**, 469; (1918) *ibid.*, **55**, 264; (1931) *ibid.*, **80**, 415; (1935) in Fisher, 1935.
- HALDANE, J. S., HAYNES, F., SHAW, A., and GRAHAM, J. IVON. (1939) *Trans. Instn. Min. Engrs., Lond.*, **97**, 40.
- HALDANE, J. S., MARTIN, J. S., and THOMAS, R. ARTHUR. (1904) *Report on Health of Cornish Miners* (Cd. 2091), London.
- HALL, J. A. MOORE. (1937) *J. Industr. Hyg.*, **19**, 506.
- HARPER, A. (1934) *Brit. Med. J.*, **1**, 920; (1935) *ibid.*, **1**, 1264; (1937) *35th Ann. Rep. Med. Off. Hlth. Ammanford Urb. Distr. Coun., S. Wales.*
- HARRINGTON, D., and DAVENPORT, SARA J. (1937) Review of the Literature on the Effects of Breathing Dusts, *Bull. U.S. Bur. Min.*, No. 400.
- HART, P. D'ARCY. (1932) The Value of Tuberculin Tests in Man, *Spec. Rep. Ser. Med. Res. Coun., Lond.*, No. 164.

- HAYTHORN, S. R. (1913) *J. Med. Res.*, **29**, 259.
- HERRALD, F. J. C., and McMICHAEL, J. (1939) *Proc. Roy. Soc.*, B, **128**, 491.
- HOME OFFICE. (1933) *Workmen's Compensation, Statistics of Compensation and Proceedings, for 1933* (Cd. 4784); (1935) *ibid. for 1935* (Cd. 5557); (1938) *ibid. for 1938* (Cd. 6203).
- HOUSE OF COMMONS. (1941) *Rep. Parliamentary Debates*, April 22, col. 38.
- HUDSPETH, H. M., and PHILLIPS, D. W. (1937) in Mines Department's *Pap. Safety Min. Res. Bd., Lond.*, No. 98.
- ICKERT, F. ref. Moshkovsky, 1941.
- INTERNATIONAL LABOUR OFFICE. (1930) *Proc. Internat. Conf. Silicosis, Johannesburg* (Series F, No. 13, Geneva); 1938, *Proc. Internat. Conf. Silicosis, Geneva* (Series F, No. 17, Geneva).
- INTERNATIONAL LIST OF CAUSES OF DEATH. (1929) *Manual based on 4th Decennial Revision, H.M.S.O.*, London, 1931.
- IRVINE, L. G. (1938) in International Labour Office, 1938, pp. 151-166.
- IRVINE, L. G., MAVROGORDATO, A., and PIROW, H. (1930) in International Labour Office, 1930, p. 178.
- IRVINE, L. G., and STEUART, W. (1930) in International Labour Office, 1930, pp. 269-294.
- JONES, J. GLYN. (1938) in *Ann. Rep. Welsh Nat. Mem. Ass.*, p. 237.
- JONES, T. DAVID. (1936) *Proc. S. Wales Inst. Engrs.*, **52**, 157; (1938) *ibid.*, **54**, 95.
- JONES, W. R. (1933) *J. Hyg., Camb.*, **33**, 307.
- JORDAN, N. T. K. (1930) in *Ann. Rep. Welsh Nat. Mem. Ass.*, p. 156.
- KETTLE, E. H. (1930) *Proc. R. Soc. Med.*, **24**, 79.
- KING, J. G., MARIES, M. B., and CROSSLEY, H. E. (1936) *J. Soc. Chem. Ind., Lond.*, **55**, 277 T.
- KLOTZ, O. (1914) *Amer. J. Publ. Hlth.*, **4**, 887.
- KOHLER, A. (1935) *Roentgenology*, London, 2nd Eng. Tr.
- LAENNEC, R. T. H. (1829) *Diseases of Chest*, London, 3rd Ed. (Eng. Tr.), pp. 393-395.
- LANGELEZ, A. (1938) in International Labour Office, 1938, p. 140.
- LANZA, A. J. (1938) *Silicosis and Asbestosis*, London.
- LANZA, A. J., and CHILDS, S. B. (1917) *Miner's Consumption, U.S. Publ. Hlth. Bull., Wash.*, No. 85.
- LANZA, A. J., and VANE, R. J. (1939) *Amer. Rev. Tuberc.*, **39**, 419.
- LECLERCQ, J. (1933) ref. Middleton, 1938a.
- McMICHAEL, J., HART, P. D'ARCY, and ASLETT, E. A. (1942) In course of preparation.
- MAGNIN, J. (1935) ref. Middleton, 1938a.
- MAVROGORDATO, A. (1922) *Publ. S. Afr. Inst. Med. Res.*, No. 15.
- MEDICAL RESEARCH COUNCIL'S INDUSTRIAL PULMONARY DISEASE COMMITTEE. (1934) *Brit. Med. J.*, **1**, 198.
- MIDDLETON, E. L. (1930) in International Labour Office, 1930, p. 429; (1931) *Report on the Internat. Conf. on Silicosis, held at Johannesburg in 1930*, Home Office, London, p. 12; (1936) *Lancet*, **2**, **1**, 59; (1938a) in Lanza, 1938, pp. 346-404; (1938b) in International Labour Office, 1938, p. 36.
- MILLER, J. W. (1935) in *U.S. Publ. Hlth. Bull., Wash.*, No. 221, pp. 69-73.
- MINERS' PHTHISIS MEDICAL BUREAU. (1939) *Triennial Rep. for 1935-38*, Pretoria, S. Afr.
- MINES DEPARTMENT. (1931-37) *Ann. Repts. Secy. Min., Lond.*, and *Ann. Repts. Insp. Min., Lond.*; (1938) *List of Mines in Gt. Britain and Isle of Man*.
- MOORE, K. R., and BADHAM, C. (1931) ref. Badham, 1939a.
- MOSHKOVSKY, I. I. (1941) *Tuberculosis and Pneumokoniosis among Underground Workers, U.S.S.R., State Publ. Dept. Med. Lit., Moscow-Leningrad*.
- ODDO, C. (1899) *Marseille Méd.*—ref. *Arch. Elect. méd.*, 1900, **8**, 471.
- OLIVER, T. (1902) *Dangerous Trades*, London; (1909) in Allbutt and Rolleston, *System of Medicine*, London, 2nd Ed., **5**, 450.
- PANCOAST, H. K., and PENDERGRASS, E. P. (1926) *Pneumokoniosis*, New York; (1931) *Amer. J. Roentgenol.*, **26**, 556.
- PANCOAST, H. K., PENDERGRASS, E. P., RIDDELL, A. R., LANZA, A. J., McCONNELL, W. J., SAYERS, R. R., SAMPSON, H. L., and GARDNER, L. U. (1935) *Roentgenological Appearances in Silicosis and the Underlying Pathological Lesions, U.S. Publ. Hlth. Rep., Wash.*, **50**, 989-996.
- PEARSON, C. (1813) ref. Cummins and Sladden, 1930.
- PETERSON, J. N., PETERSON, J. M., and STARTUP, C. W. (1939) *Lancet*, **1**, 147.
- POLICARD, A. (1930) *Bull. Histol. Tech. micr.*, **7**, 337.
- POWELL, D. A. (1940) *Report on Industrial Pulmonary Fibrosis in Wales*, Welsh Nat. Mem. Ass., Cardiff.
- RAVVIN, V. A., and ENIAKOV, P. A. (1940) *Experimental Data on the Aetiology of Anthracosis, Publ. Donets Inst. Industr. Hyg. and Occup. Dis., U.S.S.R.*
- REGISTRAR-GENERAL. (1921) *Decenn. Supp. Eng. and Wales*, Part II (Occupational Mortality, etc.); (1931) *ibid.*, Part IIa (Occupational Mortality).
- RIDDELL, A. R. (1937) in Saranac Laboratory, 1937, p. 188; (1939) in *ibid.*, 1939, p. 51.
- ROYAL COMMISSION UPON COAL. (1871) *Rep.*, **2** and **3**.
- ROYAL COMMISSION ON COAL SUPPLIES. (1905) *Final Rep.* (Cd. 2353-2365).

202 PULMONARY DISEASE IN WELSH COALMINERS

- SAMPSON, H. L. (1937) in Saranac Laboratory, 1937, p. 168; (1939) in *ibid.*, 1939, p. 155.
- SARANAC LABORATORY. (1937) *3rd Symposium on Silicosis*; (1939) *4th ibid.*
- SAYERS, R. R. (1938a) in International Labour Office, 1938, pp. 124-133; (1938b) in *ibid.*, pp. 191-203.
- SAYERS, R. R., and JONES, R. R. (1937) in Saranac Laboratory, 1937, p. 18.
- SCHNURER, LUCY, ALLISON, W. C., BOUCEK, C. M., and HAYTHORN, S. R. (1935) *J. Industr. Hyg.*, **17**, 294.
- SEN, P. K. (1937) *J. Industr. Hyg.*, **19**, 225.
- SEYLER, C. A. (1900) *Proc. S. Wales Inst. Engrs.*, **21**, 483; (1931) *ibid.*, **47**, 547, 557; (1938) *ibid.*, **53**, 254.
- SHUFFLEBOTHAM, F. (1914) *Brit. Med. J.*, **1**, 588.
- SILICOSIS AND ASBESTOSIS (MEDICAL ARRANGEMENTS) SCHEME. (1931) S.R. & O. (No. 341), p. 680.
- SIMON, J. (1861) *4th Rep. Med. Off. Privy Coun., Lond.*, p. 21.
- SIMSON, F. W., STRACHAN, A. SUTHERLAND, and IRVINE, L. G. (1930) Silicosis in South Africa, *Proc. Transv. Mine Med. Offrs' Ass., Sp. Suppl.*
- SLADDEN, A. F. S. (1933) *Lancet*, **2**, 123.
- SOKOLOFF, M. J. (1936) *Amer. Rev. Tuberc.*, **34**, 700.
- SOUTH WALES COAL ANNUALS. (1901-36) Cardiff.
- SOUTHERN RHODESIA. (1938) *Rep. Comm. into Silicosis, etc., in Southern Rhodesia*, Salisbury, S. Rhodesia, p. 89.
- STEWART, M. J. (1933) *Lpool Med-Chir. J.*, **41**, 142.
- STOCKS, P. (1938) *J. R. Statist. Soc.*, **51**, 669.
- STOYANOVSKY, VALCHUK, and ZELENSKY. (1936) ref. Moshkovsky, 1941.
- STRATTON, T. M. L. (1838) ref. Cummins and Sladden, 1930.
- SUTHERLAND, C. L. (1940) *Lancet*, **1**, 893.
- SUTHERLAND, C. L., and BRYSON, S. (1929) *Report on the Occurrence of Silicosis among Sandstone Workers*, H.M.S.O., London, p. 17.
- TATHAM, J. (1902) in Oliver, 1902, p. 159.
- TATTERSALL, N. (1926) *J. Industr. Hyg.*, **8**, 466.
- THACKRAH, C. TURNER. (1831) *The Effects of Arts, Trades and Professions on Health and Longevity*, London, p. 27.
- THOMSON, W. (1836) *Med-Chir. Trans.*, **20**, 230.
- TSUKATA, J. (1938) in International Labour Office, 1938, p. 75.
- UNION OF SOUTH AFRICA. (1937) *Prevention of Silicosis on the Mines of the Witwatersrand*, Johannesburg, pp. 237, 244.
- UNITED STATES DEPARTMENT OF LABOR. (1938) *Bull. U.S. Div. Lab. Stand.*, No. 21, Pt. 1, Nat. Silicosis Conf., Final Rep. Comm. Prev. Silicosis through Med. Control.
- VARIOUS INDUSTRIES (SILICOSIS) AMENDMENT SCHEME. (1934) S.R. & O. (No. 1155) II, p. 735; (1939) S.R. & O. (No. 634).
- VARIOUS INDUSTRIES (SILICOSIS) SCHEME. (1928) S.R. & O. (No. 975), p. 823; (1931) S.R. & O. (No. 342), p. 743.
- WAINWRIGHT, J. M., and NICHOLS, H. J. (1905) *Amer. J. Med. Sci.*, **130**, 403.
- WELSH NATIONAL MEMORIAL ASSOCIATION. (1931) *J. Industr. Hyg.*, **13**, 19.
- WILLIAMS, ENID M. (1933) *The Health of Old and Retired Coalminers in South Wales*, Cardiff; (1936) Unpublished report.
- WILLIS, H. S. (1921) *Amer. Rev. Tuberc.*, **5**, 189.
- WORKMEN'S COMPENSATION ACT. (1925) *15 & 16 Geo. 5*, c. 84.
- WORKMEN'S COMPENSATION (SILICOSIS AND ASBESTOSIS) ACT. (1930) *20 & 21 Geo. 5*, c. 29.
- ZIPRINSKY, M. B. (1940) Radiological Diagnosis and Classification of Silicosis, *Publ. Donetz Inst. Industr. Hyg. and Occup. Dis., U.S.S.R.*

# CHRONIC PULMONARY DISEASE IN SOUTH WALES COALMINERS.—I. MEDICAL STUDIES.

## C.—PATHOLOGICAL REPORT

### HISTOLOGY OF COALMINERS' PNEUMOKONIOSIS

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## INTRODUCTION

This report is based upon the pathological examination of tissues from 42 selected autopsies on cases of pneumokoniosis occurring in the coalmines of South Wales. It is in a sense complementary to the clinical work by Dr. P. D'Arcy Hart and Dr. E. A. Aslett reported in the preceding pages. The cases from which material was examined were selected by them from among a larger number, on the basis of suitability for correlating clinical and pathological findings. Both anthracite and non-anthracite colliers are included, and a number of subsidiary occupations (coaltrimmers, firemen, rock workers,

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TABLE I

Tabulation of 42 Cases of Pneumokoniosis in Coalminers according to Occupation, Histological Changes and X-ray Classification

Chief occupation.	Case number.	Years of exposure to mine dust (total mining experience).	Histological changes							X-ray classification.	
			Reticulation.	Nodulation.			Confluent fibrosis.	Coupled with dust lesion.			
				Reticular.	Mixed.	Silicotic.		Fibro-caseous reaction.	Cavitation.		
Anthracite collier ..	P 115	35	+++	::	::	::	::	::	::	(b)	C C H H C C C C C C
	P 123	24	++	::	+++	::	::	+	::	(b)	
	P 135	41	+++	::	::	::	::	::	::	(b)	
	P 145	43	+++	::	++	::	::	+	::	(b)	
	P 147	42	+++	::	+	::	::	::	::	(b)	
	P 152	35	++	::	+++	::	::	+	::	(b)	
	P 153	49	++	::	+++	::	::	::	::	(b)	
	P 154	42	+++	::	::	::	::	::	::	(b)	
	P 162	44	++	::	+++	::	::	+	+	(b)	
	P 163	45	++	::	+++	::	::	+	+	(b)	
	P 168	23	++	+++	::	::	::	::	::	(b)	
	P 175	23	++	+	+	::	::	+++	+++	(b)	
	P 177	47	++	::	+++	::	::	++	++	(b)	
	P 178	33	+	::	++	::	::	+++	+++	(b)	
	P 179	21	++	::	++	::	::	+++	+++	(b)	
	P 180	36	+	::	++	::	::	+++	++	(b)	
	P 183	34	++	::	+	::	::	+++	+	(b)	
	P 184	23	++	::	::	::	::	+++	::	(b)	
P 185	38	++	::	+	::	::	+++	+	(b)		

PATHOLOGICAL REPORT

Steam coal collier ..	P 156	18	+	..	++	..	+++	+	::	(e)	C T
	P 158	26	++	..	+	..	+++	::	::	(e)	T
	P 160	36	++	..	+	..	+++	::	::	(e)	C C T
	P 167	31	+	++	..	..	+++	+	+	(d)	T
"Rock" collier*	P 150	33	+++	..	++	..	::	::	::	(b)	C
	P 157	18	+	..	++	..	+++	+	+	(d)	C
	P 187	18	++	+++	..	..	::	::	::	(c)	
Screens worker ..	P 117	21	++	..	..	..	+++	+	+	(e)	C C
	P 133	20+	++	..	..	..	+++	+	+	(e)	C
Trimmer .. ..	P 174	39	++	..	..	..	+++	+	+	(e)	
Fireman or shotsman..	P 121	36	++	..	+++	..	+	::	::	(d)	C
	P 132	39	++	..	..	..	+++	+	::	(e)	
	P 151	27	++	..	+	..	+++	::	::	(e)	
	P 169	45	+	++	+++	..	..	::	::	(c)	
Rock worker** ..	P 148	46	++	..	+	..	+++	+	+	(e)	
	P 159	22	..	..	..	+++	++	::	+	(d)	
	P 166	20	..	..	..	+++	++	::	+	(c)	
	P 170	20	..	..	..	+++	++	::	+	(d)	
	P 176	30	+	..	++	..	+++	+	::	(e)	C C C
	P 181	28	..	..	..	..	+++	++	+	(e)	C C C
P 186	11	..	..	..	..	+++	++	+	(d)		
Miscellaneous ..	P 128	50	++	+++	..	..	+	::	::	(b)	
	P 141	31	+++	..	+	..	+	::	::	(b)	

\* Colliers in certain non-anthracite mines handling sandstone strata as well as coal.

\*\* Hard-heading workers, borers and repairers.

C = Certified silicosis.

T = Proven tuberculosis.



screens workers) are also represented (see Table I). Most of the men had worked a lifetime in and about the collieries and had relatively uncomplicated industrial histories. All had pneumokoniosis, but in more than half the cause of death was intercurrent disease. In 14 cases silicosis had been officially recognized as either a primary or contributory cause of death, and an additional five had been certified as silicosis accompanied by tuberculosis. In all 42 we had the advantage of adequate clinical records, including occupational history, X-ray and progress notes. Many of the clinical details were supplied through the courtesy of Dr. Charles L. Sutherland and other officers of the Silicosis Medical Board, and much of the autopsy material was made available to us through the good offices of Dr. A. F. S. Sladden, Professor W. H. Tytler and Dr. J. Gough.

The histology of colliers' pneumokoniosis has been a subject of perennial interest, particularly in Great Britain, where it has, perhaps, received more attention than in any other country. Just over a century ago, a young Perth physician named Thomas Stratton, at that time (1838) but newly qualified, described the black lungs of Fife coalminers and coined for them the term anthracosis (ἀνθραξ: charcoal). The subject was brought up to date in 1930 in an excellent paper by Cummins and Sladden, who made many significant observations on the collier's lung of South Wales and reviewed the extensive literature. We have not much that is new to add to their observations, nor to those of Gough (1940) on coaltrimmers in Cardiff, but a few points which we hope to make may, perhaps, justify this further study of the disease. Though our observations, like those of Cummins and Sladden and of Gough, are confined to South Wales, it seems evident from the literature that much the same form of pneumokoniosis is to be found among coalminers in other parts of the world. Thus, similar histological findings have been recorded by Cooke (1932) in Lancashire, Badham and Taylor (1930) in Australia, Policard and Doubrow (1929) in France, Böhme (1934) in the Ruhr, Gardner (1933) in West Virginia, and Miller (1935) in Pennsylvania.

#### HISTOLOGY OF DUST LESIONS

In the coalminer's lung we are dealing essentially with a mixed type of pneumokoniosis, due partly to silica, partly to coal dust and in some cases partly to infective processes. In it can be recognized at least three more or less distinct types of dust lesion, namely: (a) nodulation, (b) confluent fibrosis, and (c) simple anthracosis, or, as we prefer to call it, dust-reticulation, each of which has certain characteristic radiological features (see Table II). There is inevitably a good deal of overlapping between them, as will be seen in Table I, for in most instances there is some admixture of all three changes; it will, nevertheless, afford a convenient approach to the subject if we now consider each of them separately. The grosser changes, namely, nodulation and confluent fibrosis, have already received a great deal of attention from other observers, and we shall be concerned not so much with them as with the third type of lesion which we have called dust-reticulation, instead of anthracosis, and which we believe to merit closer attention than it has been given in the past. We shall start with a discussion of dust-reticulation, for it is the one outstanding feature common to all cases and seems to represent the primary dust-effect or the initial lesion upon which the coarser types of induration tend to develop.

##### (1) *Dust-reticulation*

A large number of cases seen clinically by Hart and Aslett showed neither nodular nor confluent shadows when examined by X-ray, but their lung fields were diffusely altered by fine net-like shadows, to which the investigators applied the term reticulation. It so happened that material from nine



FIG. 1.—*Dust-reticulation*, large section of lung unstained ( $\times 1.5$ ), from case P.135 (anthracite collier for 41 years), showing cobweb-like black dust deposits, also emphysema. There is some oedema present, which makes lung look partially consolidated, but no nodules and no silicotic fibrosis. Total silica, 1.19 per cent. dryweight; ratio of coal to silica about 2 : 1.

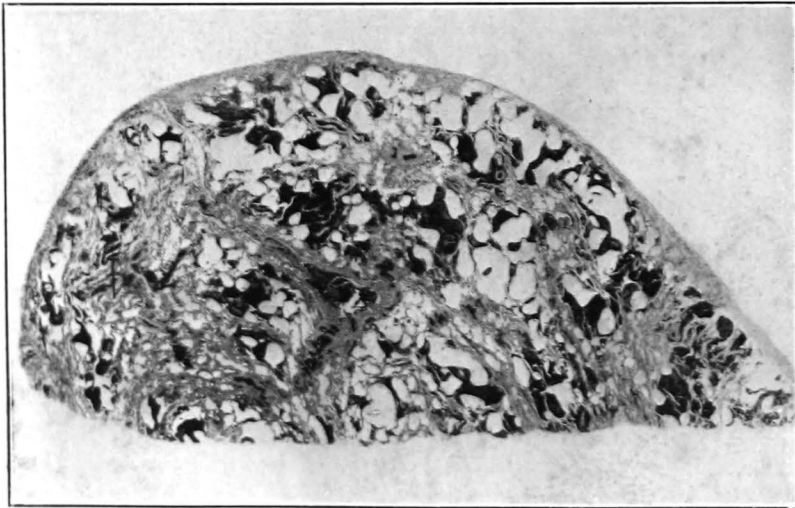


FIG. 2.—*Dust-reticulation*, large section of lung ( $\times 5$ ), from case P.115 (anthracite collier for 35 years), showing cobweb-like black dust deposits and very marked emphysema. Total silica, 1.38 per cent. dry weight.

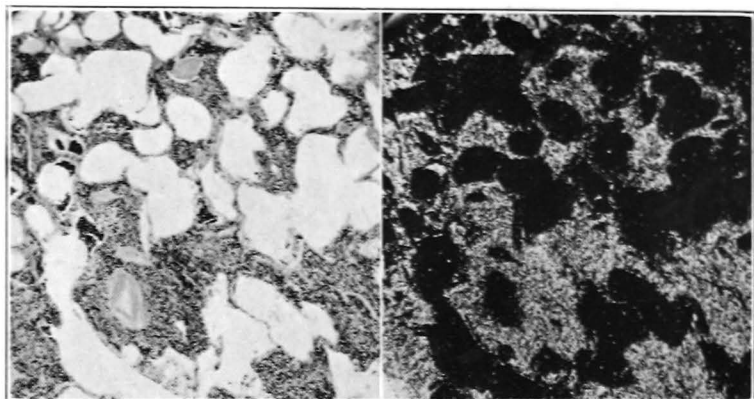


FIG. 3.—Low-power photomicrograph ( $\times 9$ ) of lung of case P.175 (anthracite collier for 23 years). **Left**—H. and E. section, showing *dust-reticulation* around vessels and in alveolar septa. **Right**—same field after micro-incineration and treatment with HCl, showing silica residue corresponding to distribution of dust-reticulation (dark field illumination). Formerly regarded as simple anthracosis, dust-reticulation has heavy silica ash in all cases.

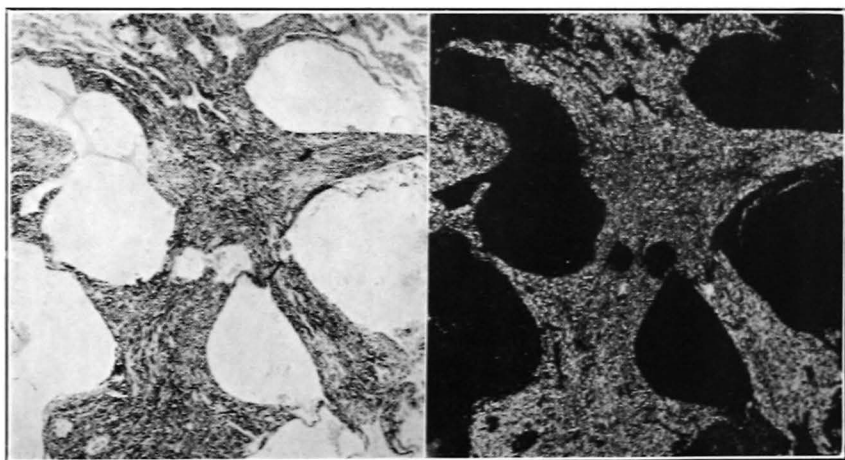


FIG. 4.—Photomicrograph ( $\times 25$ ) of lung of case P.163 (anthracite collier for 45 years). **Left**—H. and E. section of alveolar walls thickened by *dust-reticulation*. **Right**—same field after micro-incineration and treatment with HCl, showing silica residue by dark field illumination. Elastic tissue in parts like these is splinted and rendered ineffective.

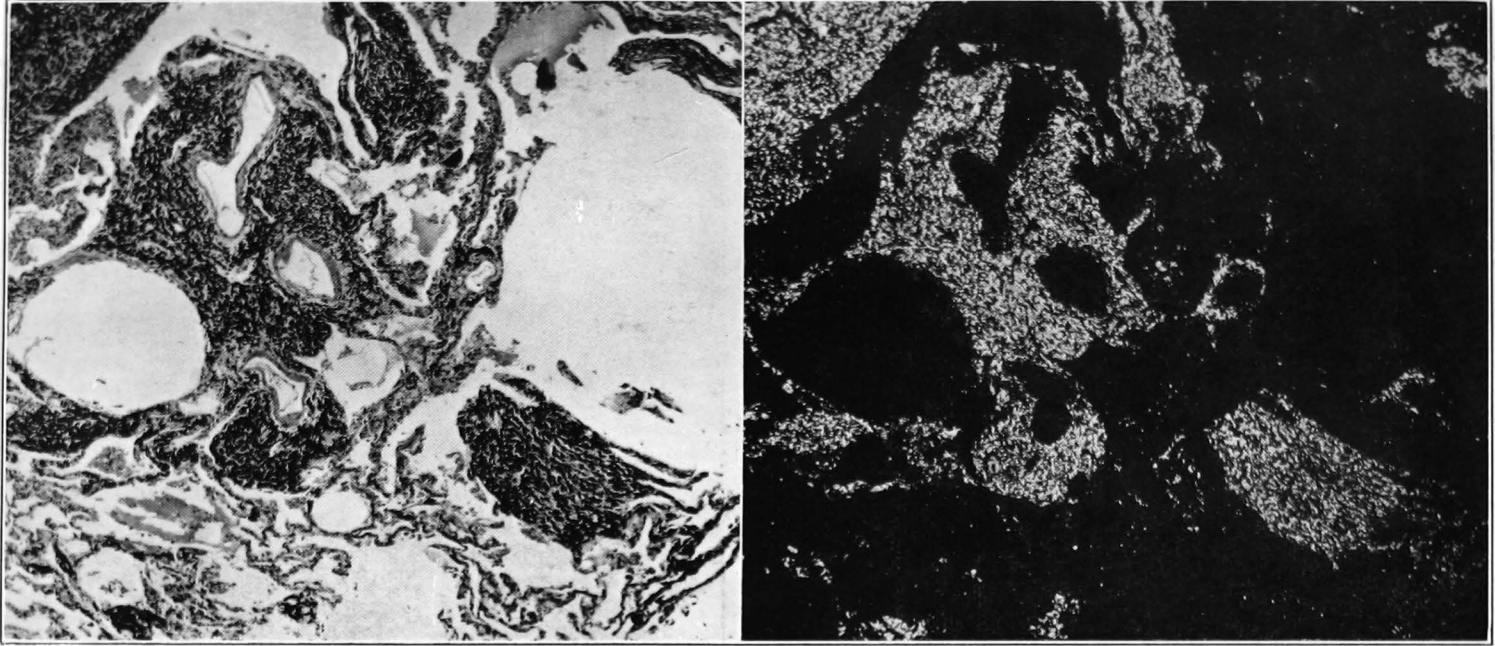


FIG. 5.—Photomicrograph ( $\times 40$ ) of lung of case P.168 (anthracite collier for 17 years). **Left**—H. and E. section of *dust-reticulation*. **Right**—silica ash of same field by dark field illumination. Black dust deposits on left correspond to silica deposits on right. Coal and silica have the same distribution, occur in the same ratio (in this case approximately 2 to 1) everywhere in the individual lung.

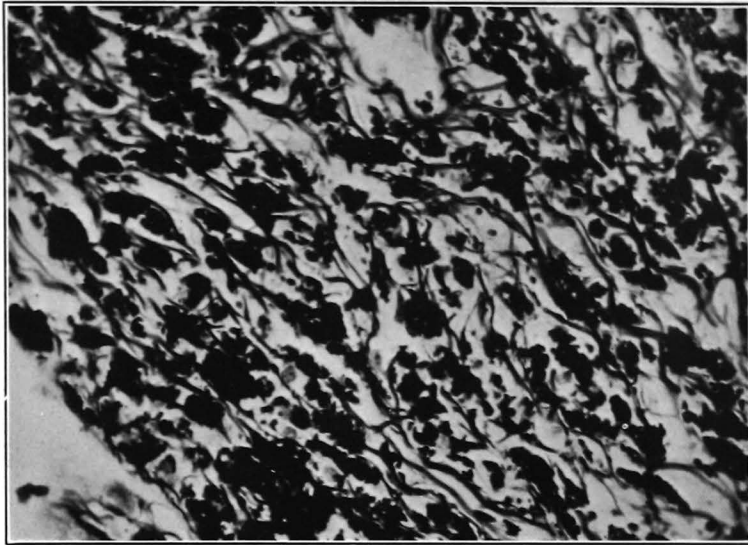


FIG. 6.—Photomicrograph ( $\times 350$ ) of lung of case P.168. High power magnification of *reticulation* area in lower right-hand corner of Fig. 5, showing rich network of argentophil reticulum fibres enmeshing dust. Foot's reticulum stain. Silica is masked by coal dust (see Fig. 7).

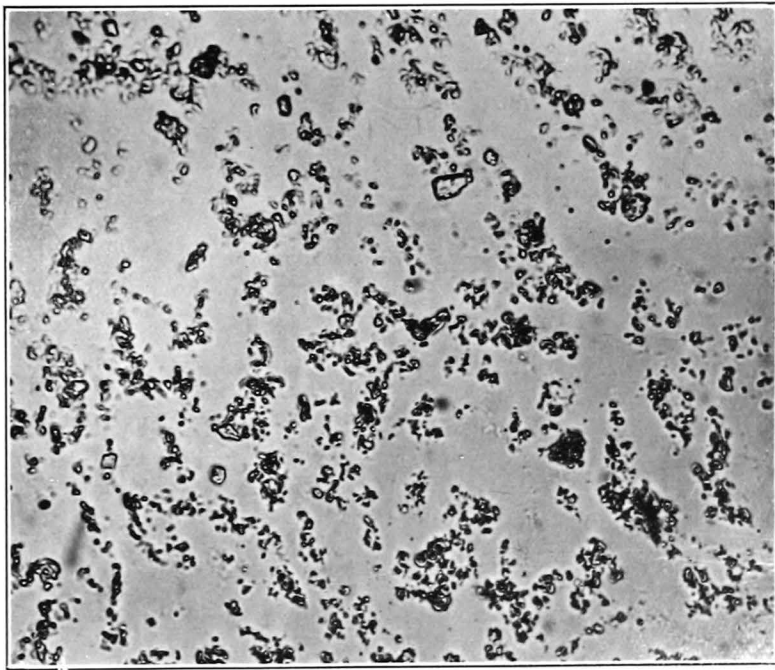


FIG. 7.—Photomicrograph ( $\times 525$ ) of silica ash from same area as Fig. 6 (though not quite the same field). Particles are small, averaging less than  $2\mu$  in diameter, colourless, crystalline, amorphous, optically active. Many of the smaller fragments are fibrous silicates belonging to the mica group and including sericite. Larger, angular fragments are quartz.

individuals of this type who had died from intercurrent disease or accident was made available for pathological examination. A good opportunity was therefore provided for an analysis of the histological changes associated with X-ray reticulation.

In brief, the changes found in these lungs are those which would ordinarily be designated as simple anthracosis, but this designation proves to be unsuitable if for no other reason than that there is a great deal of silica\* present in these lungs, as well as coal dust. Another objection to the use of the word anthracosis for this purpose is that by common usage it has come to mean something quite innocuous; to most people the term, if it means anything at all, signifies a harmless state of pigmentation like tattooing of the skin, whereas the condition we wish to describe seems to have definite pathological features. As an alternative, therefore, we have adopted tentatively the non-specific term "dust-reticulation". This apparent innovation in terminology will perhaps seem justifiable as we look further into the condition.

While the word reticulation has come into the terminology of pneumokoniosis via radiological channels, it is, by coincidence, also applicable as a descriptive term to the corresponding histological changes, though for a somewhat different reason, for here the network to which the term applies is a microscopic structure composed of dust-laden cells and their connecting fibres. The dust-laden tissue in these cases is, in fact, nothing else than reticular tissue.† It seems appropriate enough, therefore, to use the term reticulation to describe a generalized increase in such tissue. Where it is necessary to distinguish between the radiological and the histological meanings of the term, it may serve the purpose if we call the one "X-ray reticulation" and the other "dust-reticulation", but in some instances, for the sake of convenience, it may not be amiss to refer to the composite picture simply as reticulation.

The condition is so well known under the mistaken designation of simple anthracosis that a detailed account of it may seem superfluous. Even at the risk of repetition, however, we should like to describe the condition carefully, because it seems desirable that it should be reconsidered in the light of certain new findings which point to its being more in the nature of a disease than was formerly thought.

The general characters of the lesion are best seen in large histological sections (Christeller technique), under low power magnification (Figs. 1 and 2). For this purpose the sections may be mounted on lantern slides and examined to good effect by simply projecting them on to a screen.

The dust deposits are scattered in a lace-like pattern of fine streaky processes throughout both lungs, in a manner corresponding to the diffuse lattice-work shadows seen by X-ray. The change is diffuse and symmetrical, affecting all parts of the lung more or less uniformly, with the exception of the extreme base, where it is often less marked than elsewhere. The distribution is essentially that of the lymphatic pathways and depots. The root glands are packed with dust, while in the lung itself there is a heavy storage along the interstitial tracts in the perivascular and peribronchial sheaths (particularly the former), as well as in the interlobular septa and subpleural tissues; often enough, moreover, there is some extension even into the interalveolar septa (Fig. 3). Under high power, the collections are distinctly patchy, with a notable tendency towards localized concentrations. The appearance may be likened to that of innumerable small dust-ridden cobwebs, all linked up with each other, more or less in continuity, or in series. They represent traps where dust-laden phagocytes have been brought to rest and transformed into fixed-tissue

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\* This term includes silicates as well as free silica (see Glossary, p. 221).

† As defined by Maximow & Bloom (1938), *Textbook of Histology*, 3rd ed., p. 66 (see Glossary, p. 221).

phagocytes which then became knit together into a meshwork by the elaboration of reticulum fibres. These fibres are argentophil and may be demonstrated in abundance by impregnation with ammoniacal silver solution by Foot's technique (Fig. 6). The condition is actually a form of fibrosis, but it is important to note that the fibres are reticular, of very fine calibre and of loose mesh, quite different in structure from collagenous fibrosis, in which the fibres are coarse, close-grained and non-argentophil. The term fibrosis commonly connotes collagenous connective tissue, and in that sense it is not applicable to dust-reticulation.

The process involved is analogous to tattooing, in the sense of being a permanent storage of particulate matter by fixed macrophages. At first the dust is intracellular, or at least it is collected into small dense packets corresponding to the bodies of macrophages, though the internal structure of the cell itself is usually completely obscured. In older deposits the cell bodies seem to disintegrate, allowing the dust to scatter somewhat in the spaces between the reticulum fibres. But whether the dust deposit is old or recent, whether the particles are intracellular or interstitial, the tissue response is almost exactly proportional to the amount of foreign particles. No more cells take part in the reaction than are necessary to accomplish a simple segregation of the particles. There is no redundancy of reaction, not even a semblance of encapsulation around the localized collection. Dust-reticulation differs sharply in this respect from silicotic fibrosis, which is characterized by encapsulation and by a disproportion between the amount of fibrosis and the amount of dust. In other words, silicosis shows redundant fibrosis (Belt, 1939), whereas dust-reticulation does not. One might carry the distinction further by noting that dust-reticulation appears to be a foreign body reaction of the simplest type, whereas the silicotic reaction is something more complex and elaborate. The probable mechanism by which dust-reticulation develops will be referred to later (p. 215).

In the more advanced cases, localized accumulations tend to become exaggerated to the point of forming small masses up to 3 or 4 mm. in size. The appearance then becomes somewhat altered, the X-ray picture shows a fine, rather soft and diffuse nodulation superimposed upon reticulation, and histologically the disposition of the dust becomes partly nodal, though the general characters of dust reticulation are maintained. This development, which may be called "nodular reticulation" or "reticular nodulation" in order to distinguish it from other forms of nodulation, will be referred to again under the heading of *Nodulation* (see below).

As to the *character of the dust* itself, there are one or two important observations to record. Firstly, it is invariably a mixed dust, containing a good deal of silica\* as well as coaly particles. On ordinary microscopic examination the latter dominate the picture. Indeed, if one relied entirely on this method one might easily fall into the error of judging the dust deposits to be composed almost entirely of carbonaceous material. But micro-incineration (Irwin technique) shows a heavy siliceous residue, exactly parallel in distribution to the anthracotic deposits (Figs. 3, 4, 5, 7). Whether the histological change is reticulation, nodulation or confluent fibrosis, the general character of the dust seems to show no major variation except in the case of the rock workers. Further discussion of it may therefore be deferred until the other histological changes have been considered.

Dust-reticulation was present in more or less pure form in the nine cases mentioned above. It occurred also as a prominent feature in all but a very few of the others (see Table I), and was recognizable even when more advanced changes had partly obscured it.

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\* This term includes silicates as well as free silica (see Glossary, p. 221).



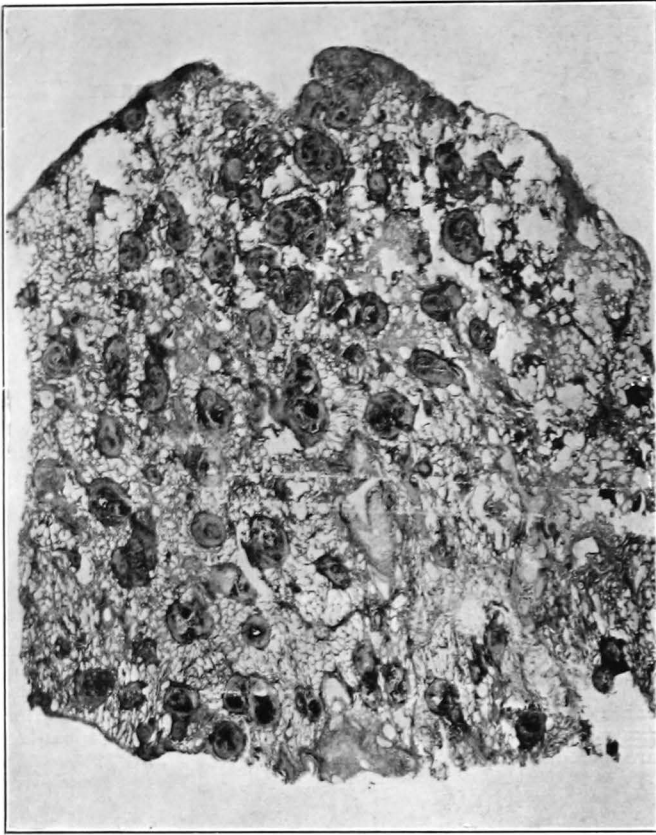


FIG. 8.—Large section of lung ( $\times 1.5$ ) from case P.166 (rock worker for 20 years), showing classical *silicotic nodulation*, not much dust-reticulation, marked emphysema. Many of the nodules have granular, necrotic centres. Total silica, 1.06 per cent. dry weight. Ratio of coal to silica dust = about 1 : 4.

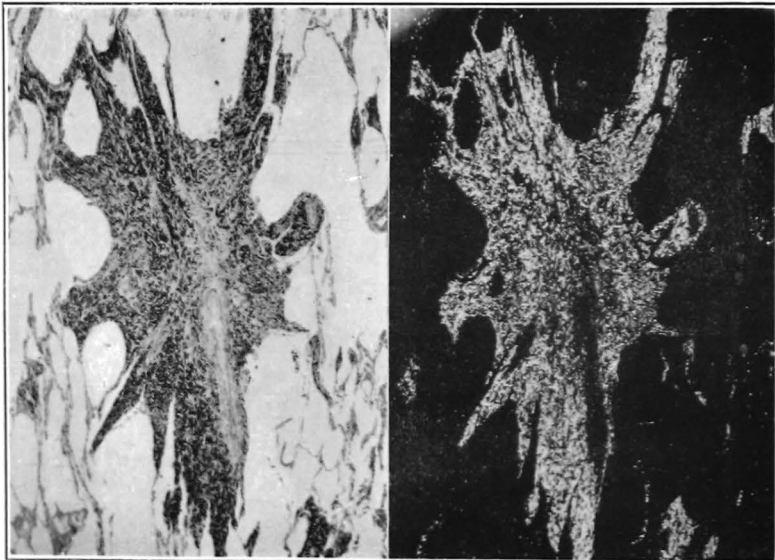


FIG. 9.—Photomicrograph ( $\times 25$ ) of lung of case P.168 (anthracite collier for 17 years) Showing **left**—H. and E. section of nodular focus of *dust-reticulation* (nodular reticulation) **right**—silica ash of same field (dark field illumination). Dust-reticulation alone can produce nodules of this sort, which are quite unlike silicotic nodules.



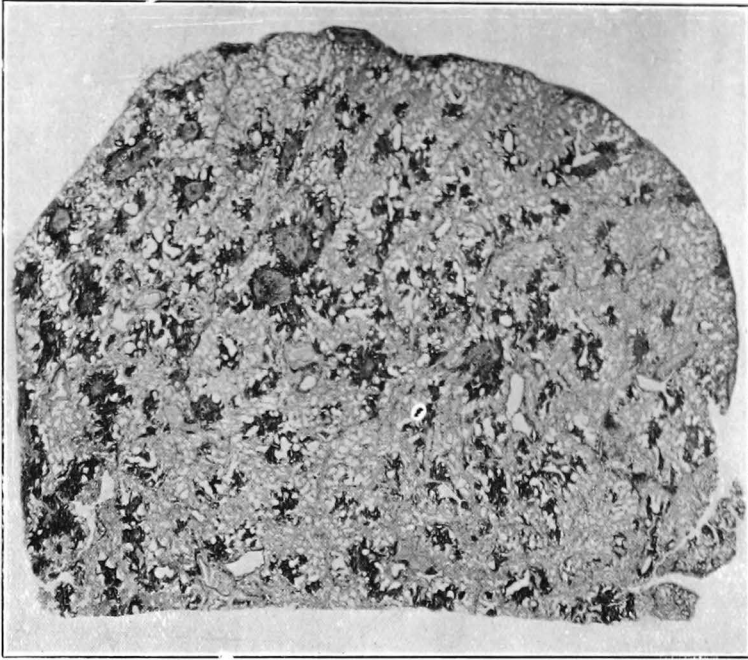


FIG. 10.—Large section of lung ( $\times 1.5$ ) from case P.147 (anthracite collier for 32 years), showing (1) *dust-reticulation*, (2) a few *mixed nodules*, some with “medusa-head” effect. The nodules are sporadic in distribution.

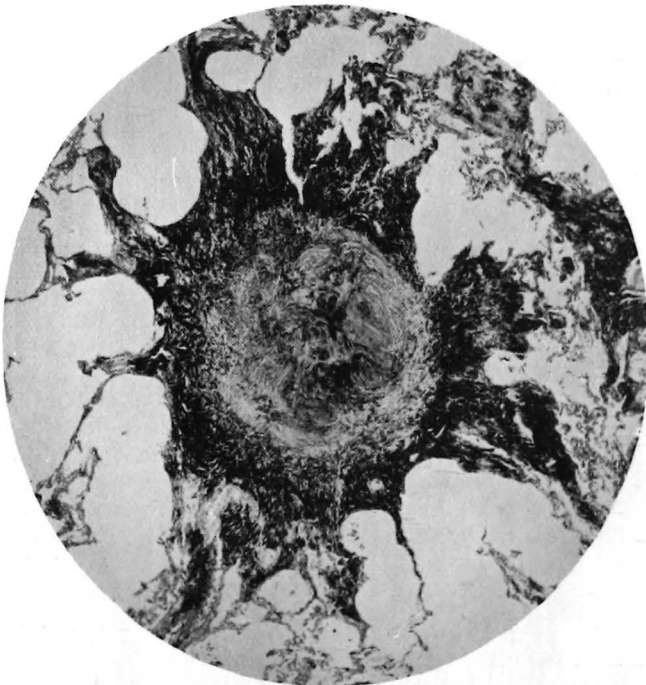


FIG. 11.—Photomicrograph ( $\times 25$ ) of lung from same case as Fig. 10. This is one type of *mixed nodule*. “Medusa-head” appearance, apparently produced by addition of dust-reticulation to a pre-formed silicotic nodule.

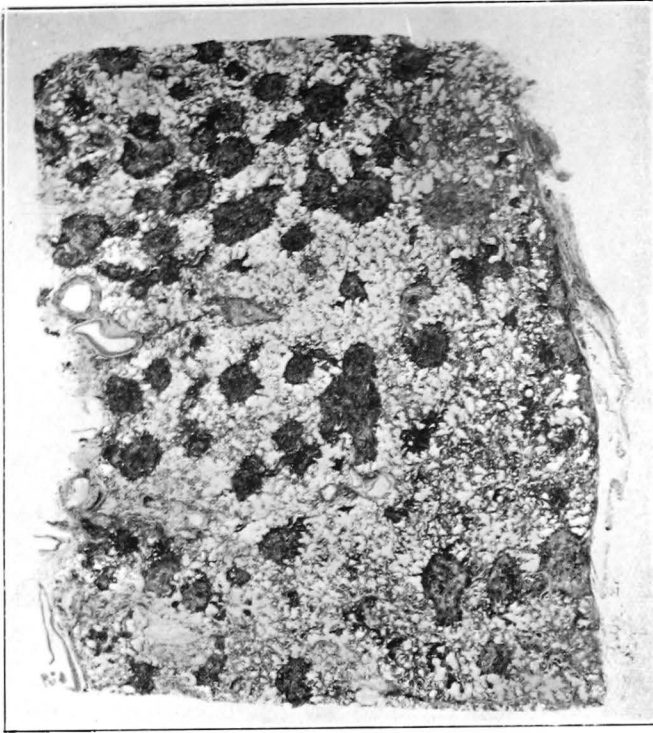


FIG. 12.—Large section of lung ( $\times 1.5$ ) from case P.121 (fireman and shotsman for many years), showing *mixed nodules*. Unlike typical silicotic nodules, they are not concentric nor encapsulated, but they have some similar features. Each nodule is a mixture of dust-reticulation and atypical silicotic fibrosis. Some contain granular, necrotic foci. Total silica, 1.5 per cent. dry weight. Ratio of coal to silica, about 5 : 4.

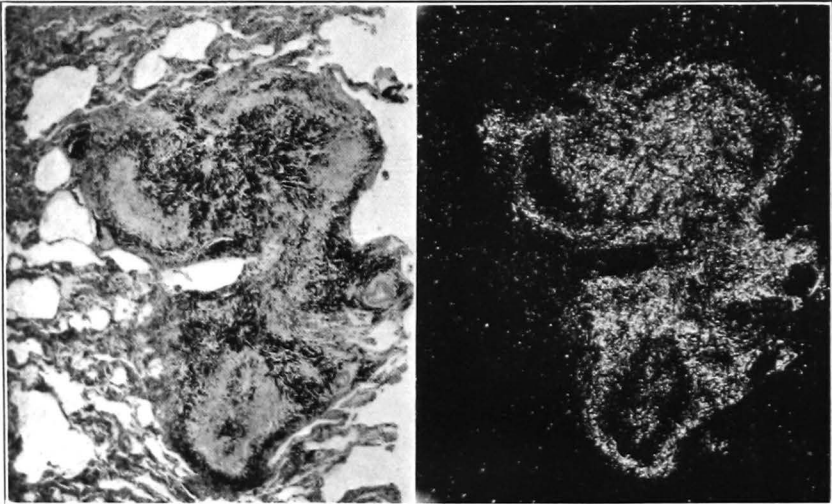


FIG. 13.—Photomicrograph ( $\times 28$ ) of lung of case P.156 (steam coal collier for 18 years). Showing **left**—H. and E. section of a *mixed nodule*, **right**—silica ash of same field (dark field illumination). Ash pattern characteristic of silicotic fibrosis, *i.e.* drifting of dust at periphery and clearing of dust from collagenous parts.

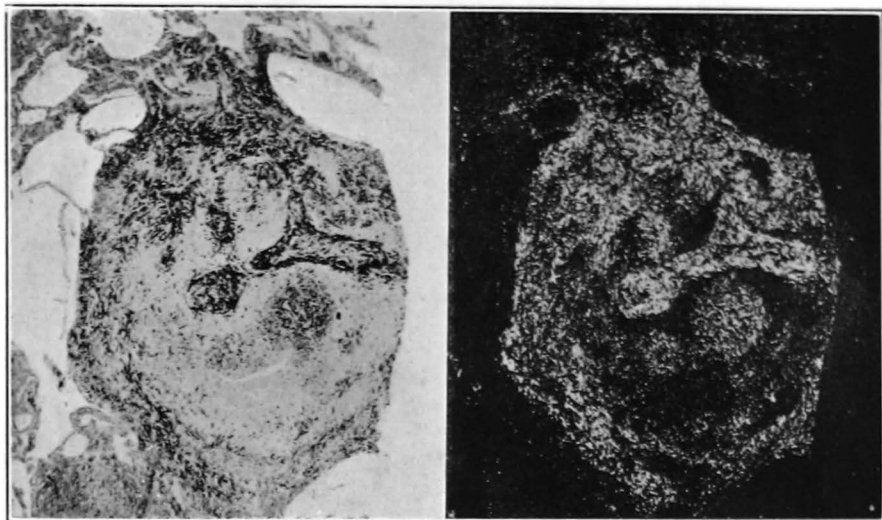


FIG. 14.—Photomicrograph ( $\times 15$ ) of lung from same case as Fig. 13. **Left**—H. and E. section of *mixed nodule*:—atypical silicotic part shows rarefaction of dust and some granular (? caseous) necrosis. **Right**—silica ash of same field (dark field illumination).

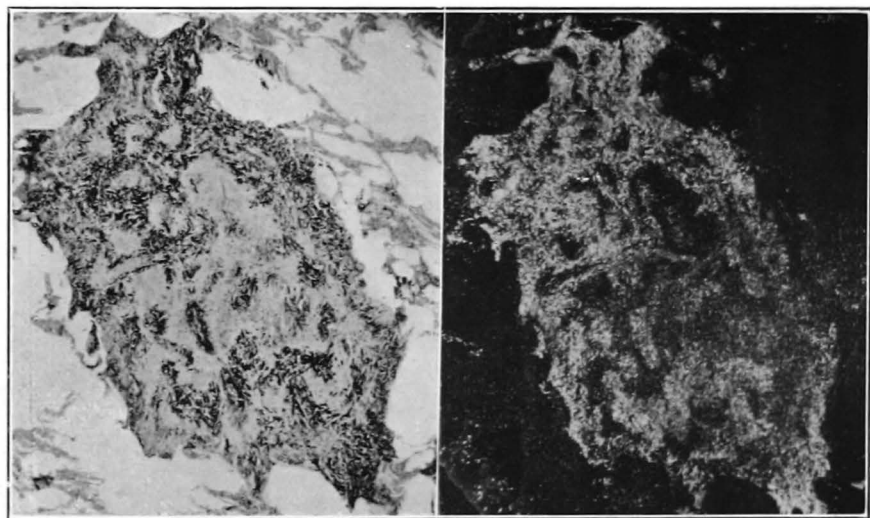


FIG. 15.—Photomicrograph ( $\times 12$ ) of lung from same case as Figs. 13 and 14. **Left**—H. and E. section of *mixed nodule* with patchy atypical silicotic fibrous change from which the dust is partly cleared. **Right**—silica ash of same field (dark field illumination), showing rarefaction of silica deposit corresponding to collagenous parts. Note complete lack of encapsulation.

(2) *Nodulation*

When we speak in general of nodules in pneumokoniosis, we usually mean simply focal indurations, whether rounded, angular, polygonal or stellate, roughly 2 to 5 mm. in diameter and visible by X-ray. The nodules in a collier's lung vary a good deal, from (a) the sharply-defined pure silicotic type on the one hand, to (b) the ill-defined maculae of dust-reticulation on the other. If we take the two extremes as starting points we shall be in a better position to consider (c) the "mixed nodule", which is the commonest type encountered.

(a) The *silicotic nodule*, such as we have described elsewhere (Belt, Ferris and King, 1940), is seldom a prominent feature of the collier's pneumokoniosis except among rock workers (including hard-headers), of whom there were seven in our series. Of these, three had more or less pure silicosis of classical type, associated with but slight dust-reticulation (Fig. 8). Two others had well marked silicotic nodulation but were also tuberculous. Isolated silicotic nodules, or even small groups of them, are to be found in most of the other cases, but not in sufficient numbers to characterize the picture. More often than not the silicotic nodule as seen in the collier's lung has a granular, necrotic centre containing a good deal of dust and sometimes cholesterol crystals as well.

(b) The other pure type of nodulation is quite different. It is what we have referred to previously as *nodular reticulation*. At first sight it would seem to be more the effect of the coal dust than of silica because it is deeply and uniformly pigmented with black coaly particles, but micro-incineration shows that it also contains an abundance of silica (Fig. 9). It is smaller, blacker and softer than the silicotic nodule, more irregular in outline, non-concentric and non-collagenous (Fig. 9). It represents essentially the same pathological change, but in an exaggerated form, as that which we have described under the heading of "dust-reticulation". Three of our cases showed this type of nodulation as the predominant change (Table I), but it was present also, though to a lesser extent, in all but a few of the others.

(c) Commonest by far, of course, is the *mixed nodule*. This is the anthracosilicotic nodule described so well by Cummins and Sladden (1930) and by Gough (1940) (Figs. 10, 11, 12); it resembles nodular reticulation, but has one notable difference, namely, the addition of hyalinized collagenous tissue in greater or lesser amount, usually towards the centre of the lesion. Sometimes this collagenous deposit takes a concentric or whorled form like a typical silicotic nodule, but more often it has no characteristic shape; it may be streaky or knot-like or radial. In other words, the silicotic fibrosis in a mixed nodule is more often atypical than typical in form. If it is typical, then the dust-reticulation tends to lie mostly at the periphery in tapering processes which extend out into the adjacent alveolar septa (Fig. 11), giving rise to the "medusa-head" appearance described by Cummins and Sladden (1930), as though it had been added after the completion of the silicotic nodule. But where the silicotic part is atypical the dust-reticulation is more intimately mixed with it and tends to divide it up into irregular collagenous parts which have no characteristic shape (Figs. 13, 14, 15), as if dust-reticulation were the primary change. From this it may be argued that atypical silicotic fibrosis seems to be a sequel to dust-reticulation.

How do we know that these atypical formations are indeed silicotic? Micro-incineration shows a characteristic ash pattern; the collagenous parts contain a much finer and more rarefied silica deposit than the surrounding reticular tissue. We may speak of them, therefore, as areas of redundant fibrosis, since the amount of tissue is no longer proportional to the amount of dust. Such redundancy is a characteristic feature of silicotic fibrosis, as has been shown elsewhere (Belt, 1939), and it seems to be produced, in part at least.

by a hyaline swelling of collagen with a corresponding rarefaction of the dust content or a pushing aside of the dust into drifts. There is also an apparent diminution in size of the silica particles associated with the collagenous change, suggesting partial dissolution.

Not infrequently the mixed nodule contains rather ill-defined foci of granular or caseous necrosis, which blend with the hyalinized collagenous parts. In the tuberculous cases of our series lesions of this sort sometimes contain tubercle bacilli.

Nodulation of all three types, like the confluent lesion to be described next, tends to be sporadic in distribution. Whereas dust-reticulation runs fairly uniformly through all parts of the lung, the coarser lesions are usually uneven and asymmetrical. They are neither as evenly nor as widely distributed as dust-reticulation, a point to be referred to again when considering the aetiology of silicotic fibrosis (see p. 217).

Eight of our cases showed mixed nodulation as the predominant histological change, while 17 other cases had it in lesser degree (see Table I). The X-ray appearances of mixed nodules are mentioned later and their occurrence in koniophthisis is referred to on page 211.

### (3) *Confluent Fibrosis*

This term signifies localized or patchy confluence of any or all the changes described above, but always including dust-reticulation. Larger, coarser areas of consolidation, demonstrable by X-ray as either coalescent or massive shadows, make their appearance. They are asymmetrical and irregular in distribution. For a detailed account of them one cannot do better than turn to the description by Cummins and Sladden (1930). The appearance at autopsy is that of hard black masses occupying large parts of the lung, often, as Gough says, like lumps of coal. Sometimes there is cavitation in the centre (see p. 213).

The process of fusing many smaller lesions into fewer larger ones is accompanied by the appearance of added collagenous fibrosis in greater or lesser degree, sometimes in the form of long sweeping bundles or partitions which may effect a sort of encapsulation (Fig. 17); sometimes in a seemingly plastic form, like a molten matrix. Gough suggests that the massive areas of black induration arise not so much by coalescence of smaller lesions as by a fibrosing process which is diffuse from the start. In other words, he inclines to the view that these massive lesions arise more or less *de novo* and do not depend upon pre-existing lesions. It is true that distinct nodules are not often found incorporated in the massive areas, but dust-laden reticular tissue is nearly always a prominent constituent. Indeed, some of the massive lesions are composed almost entirely of dust-reticulation (Fig. 16), and contain very little collagenous fibrosis. Radiological observations also show that reticulation is an earlier change and is generally present when massive shadows are visible (see Hart and Aslett above). Thus the development of the massive lesions seems to depend on the pre-existence of dust-reticulation. It is well known, of course, that dust deposition tends to increase in the neighbourhood of a scar, and it may be that much of the dust-laden reticular tissue in and around the massive lesions has been laid down as a sequel to, rather than an antecedent of, the confluent fibrosis, but this does not detract from the supposition that reticulation is the primary lesion. The massive lesion seems to represent an alternative manifestation of the same process as gives rise to the mixed nodule. As in the case of the mixed nodule, there are redundant areas of collagenous fibrosis which conform to the histological standards of a silicotic reaction (see p. 209). Small, ill-defined, crumbling (? caseous) foci, not infrequently associated with cavitation, are commonly found in the larger areas of anthraco-silicotic induration, just as they are in the nodules. These granular foci are present in some cases

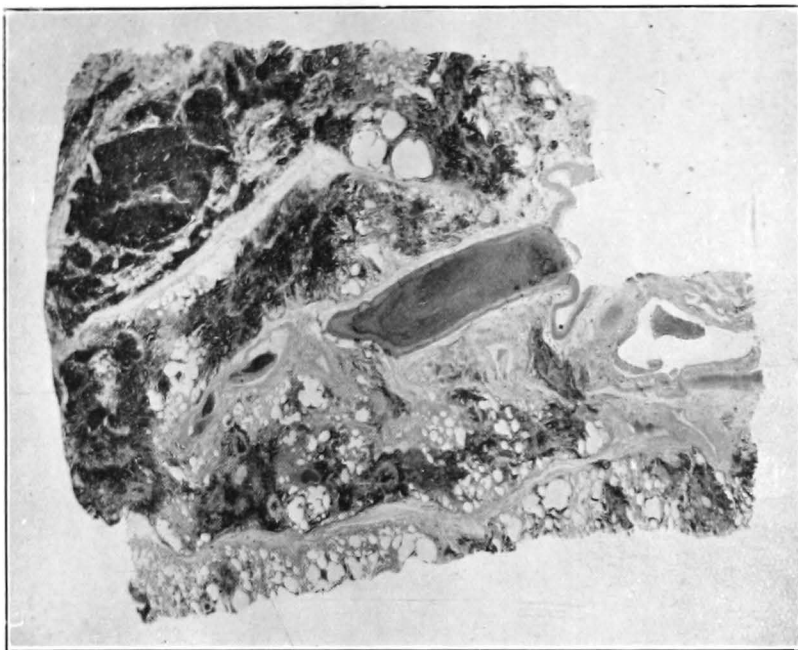


FIG. 16.—Large section of lung ( $\times 2$ ) from case P.117 (screens worker for 21 years), showing *confluent black fibrosis* composed chiefly of dust-reticulation but including a few streaks and nodules of silicotic type. Large clot (embolus) in branch of pulmonary artery. Total silica, 1.30 per cent. dry weight.

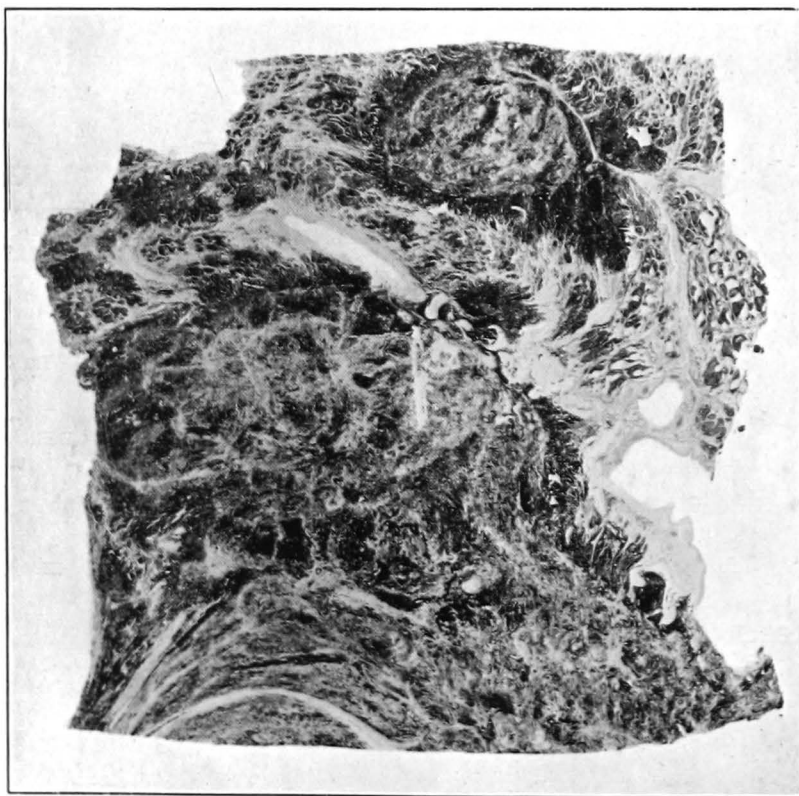


FIG. 17.—Large section of lung ( $\times 2$ ) from case P. 158 (steam coal collier for 26 years), showing *massive black fibrosis* composed of dust-reticulation and large atypical silicotic formations of collagen. Total silica, 3.01 per cent. dry weight.



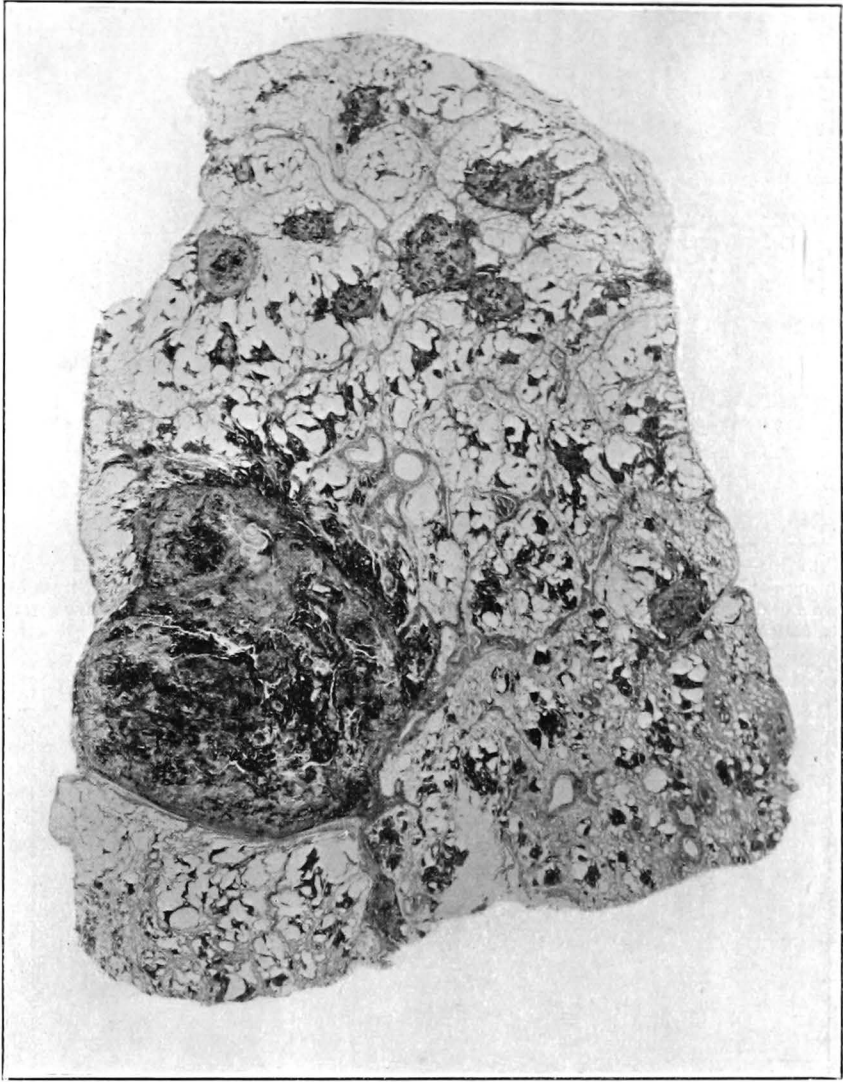


FIG. 18.—Large section of lung ( $\times 2$ ) from case P.163 (anthracite collier for 45 years), showing (1) heavy *dust-reticulation*, (2) *sporadic nodules* like those in Figs. 12 and 15, (3) single *massive anthraco-silicotic lesion* with some (? caseous) necrosis in central part, and (4) marked *emphysema*. Total silica, 1.42 per cent. dry weight.



FIG. 19.—Photomicrograph ( $\times 9$ ) of lung from case P.175 (anthracite collier for 23 years) showing active *koniophthisic nodule*. Tubercle bacilli were found in the central caseous part, but no cellular reaction characteristic of tubercle. Note "jig-saw" pattern of dust drifts within nodule, representing remains of antecedent dust-reticulation, also heavy dust-reticulation at periphery of nodule and in adjacent lung. Total silica, 1.62 per cent. dry weight.



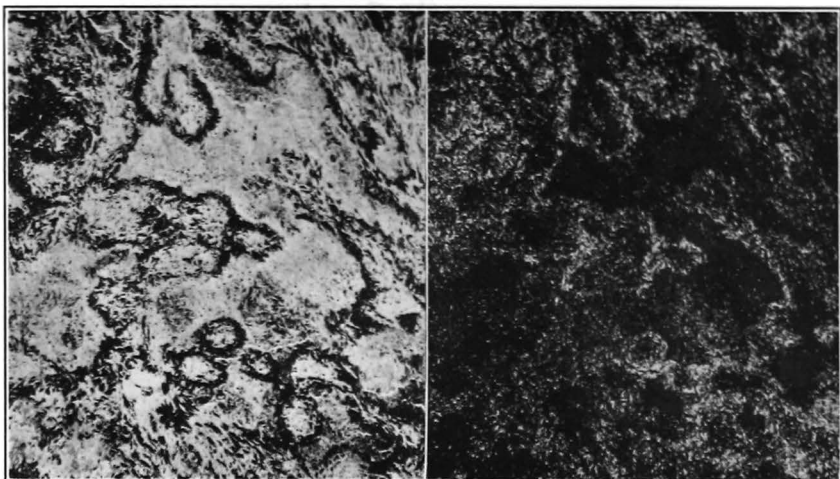


FIG. 20.—Photomicrograph ( $\times 25$ ) of part of nodule in Fig. 19. **Left**—H. and E. section. **Right**—silica ash of same field (dark field illumination), showing characteristic “jig-saw” pattern of dust drifts. Intervening caseous parts contain tubercle bacilli, though the reaction would hardly be recognised as tuberculous.

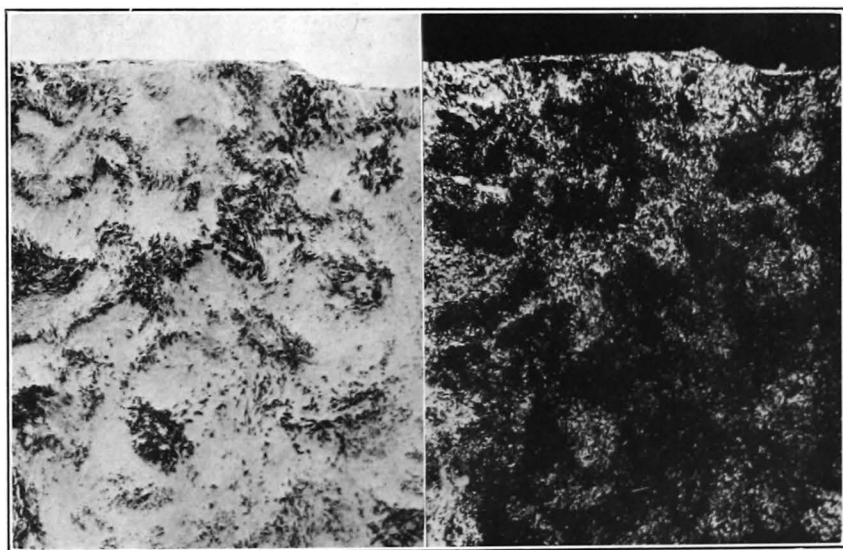


FIG. 21.—Photomicrograph ( $\times 25$ ) of lung from case P.141 (underground roadman for 31 years), showing *massive anthraco-silicotic fibrosis*, with wavy pattern of dust drifts similar to that in Fig. 20, representing remains of antecedent dust-reticulation. **Left**—H. and E. section. **Right**—silica ash of same field (dark field illumination).

regarded as non-tuberculous, as well as in the tuberculous ones. In the former they often contain cholesterol crystals, in the latter, tubercle bacilli. The appearance of the lesion is much the same, whether one can prove a tuberculous element in it or not (see p. 213). Many pathologists do not regard the mere presence of caseation as indicative of a tuberculous element. It is argued that dust alone, without tubercle, may give rise to foci of granular coagulation necrosis, especially in ageing fibrous tissue; but against this surmise may be set the fact that necrosis is not found in association with dust-reticulation, however old the lesions may be. When there are cholesterol crystals present this perhaps favours the suggestion of obsolescent tubercle, but there seems to be no conclusive evidence one way or the other, except the identification of tubercle bacilli. Our own impression is that, whether or not it is tuberculous, the characteristic black granular necrosis seen in anthraco-silicotic lesions seems less like breaking down of fibrous tissue (this leathery tissue is not readily disintegrated) than areas which have been necrotic from the first.

Of the total 42 cases, confluent fibrosis was the predominant change in 21, while in nine others it was present in lesser but still notable degrees (see Table I).

#### TUBERCULOUS CASES

Active and extensive pulmonary tuberculosis was present in eight of the 42 cases (see Table I). Five were certified during life and the other three were proven histologically. In all of these there was an intimate admixture of dust fibrosis and fibrocaseous reaction, so that it was impossible to separate them. Typical tuberculous lesions are seldom found lying side by side with typical dust lesions. It is not a question of tuberculous infection being simply a parallel of the pneumokoniosis; on the contrary, the two processes combine to form lesions which are distinctive neither of dust alone nor of tubercle alone. For one thing, a lung which is already the seat of dust-reticulation has not much dust-free space suitable for the development of tubercle, and for another, both dust lesions and tubercle have a special tendency to localize in the lymphatic apparatus. It is almost inevitable, therefore, that the two should overlap. But the result is a good deal more than a simple overlapping; it is as if the pathogenicity of the tubercle were altered by the silica, and the silica altered by the tubercle, with the result that more fibrosis is produced than would be expected of either alone.

There is no adequate term in common usage to denote this special dust-*plus*-tubercle effect, although it constitutes what is practically a separate disease. It is a highly modified form of tuberculosis, so modified indeed that the tuberculous element may be scarcely recognizable except by identification of the bacillus. The dust effect predominates, and the lesions have the character of anthraco-silicosis as described under the headings *Nodulation* and *Confluent Fibrosis*, except that caseous foci are a little more obvious in the midst of the dust lesions and sometimes contain tubercle bacilli.

"*Koniophththisis*".—We would suggest the term *koniophththisis* (see Glossary) as a useful designation for the combined disease.

Koniophththisic lesions, then, are a mixture of dust-reticulation, silicotic fibrosis and caseous necrosis. All three changes are commonly intermingled, though they shade into one another as though they had been fused by some welding process (Figs. 19, 20, 22). The pattern of the siliceous ash is much the same in the *koniophththisic* as in the silicotic type of lesion. There is the same rarefied deposit of extremely fine particles, corresponding to redundant formations of collagen, which seem rather to push aside the heavier silica deposits than to encompass them. This pushing aside or drifting of dust towards the periphery from the collagenous focus gives rise in the silicotic nodule to a well-marked outer halo of dust (Belt, Ferris and King, 1940); but

in the case of koniophthisic lesions in the collier's lung the dust drifts into curious serpigenous waves which stand out prominently like a jig-saw pattern (Fig. 20). Even when the lesion is entirely fibrous and not fibrocaseous, the same striking pattern of dust drifts (Fig. 21) is seen often enough to rank as one of the characteristic histological features of anthraco-silicosis—a fact which rather suggests that the completely fibrosed lesion was also originally tuberculous. We shall refer to it elsewhere as the wavy type of dust deposit.

Pulmonary tuberculosis as seen in the collier's lung, or, as we prefer to call it, koniophthisis, shows several modifications not seen in ordinary phthisis. The reaction tends to be more fibrous, more chronic-looking and more widespread. At the same time, it is less cellular, less caseous and seldom shows giant cell systems. There is a curious tendency to develop widespread fibro-caseous nodules, apparently localizing in foci of dust-reticulation, or large, sharply defined, dense confluent areas of fibrocaseous reaction not commonly encountered in ordinary phthisis. But perhaps the most striking difference histologically is the heavy dust impregnation of the koniophthisic lesion. Even the caseous parts contain much dust, though the heaviest deposits usually correspond to areas of dust-reticulation which have been incorporated into the lesion. So prominent is the dust content, and so inconspicuous are the conventional histological features of tuberculosis, that it is not surprising that these lesions are sometimes mistaken for a pure dust effect and their tuberculous element overlooked. Tubercle bacilli are usually few in number and dust particles add to the difficulty of finding them, but by dint of long and careful search we have been able to demonstrate them often enough to know the type of lesion with which they are likely to be identified.

In five of the frankly tuberculosis cases there were extensive *cavities*. These were located in the central parts of large massive areas of black fibro-caseous induration, and they differed from the cavities of ordinary phthisis in several respects. They were more heavily encased in solid tissue and not easily detected except by incision. One was often surprised on cutting what seemed to be large solid lesion to find the centre excavated. On the whole, the excavations are less voluminous than those of ordinary phthisis, as though the heavy fibrous induration around them exercised a limiting effect. The lining is black and crumbly and not often trabeculated. Most of them are filled with soft black pulraceous material, which, under the microscope, proves to be necrotic caseous debris with a good deal of dust in it. Occasionally we have identified tubercle bacilli in the necrotic membranous lining, but the more usual features of tuberculous histology are either lacking or obscured by the dust (Fig. 23).

It seems probable that the tuberculous process is modified in two ways, first by the silica, which tends to augment the fibrous response while at the same time perhaps favouring the growth and dissemination of the organism, and secondly by the coal dust, which, according to all the available evidence, exercises some inhibitory effect, either by adsorbing the toxic products of the bacillus, as Cummins and Weatherall have shown (1931), or by some bactericidal activity. In view of the notable histological modifications seen in these cases as compared with ordinary phthisis, it is not surprising that the clinical manifestations are different, as Tattersall (1926) and Sokoloff (1936) have noted, nor that the diagnosis during life is more difficult. It is only to be expected in these circumstances that such a modified form of tuberculosis would, in a certain proportion of cases, escape detection not only during life, but also at autopsy.

#### CASES SUSPECTED BUT NOT PROVED TO BE TUBERCULOUS

In the present series there were 13 cases, besides the eight frankly tuberculous, which showed changes at least suggestive of koniophthisis. The suspected cases are listed in Table I under the headings of *Fibrocaseous*

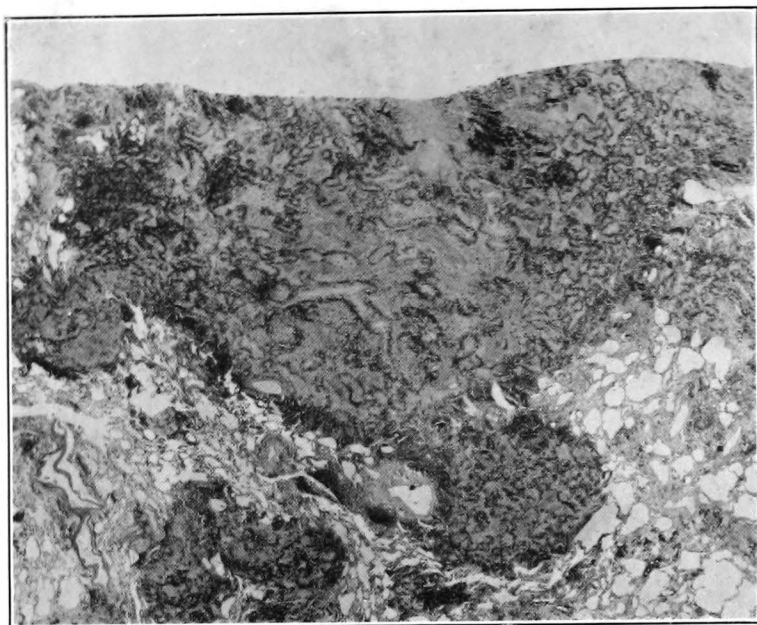


FIG. 22.—Photomicrograph ( $\times 9$ ) of lung from case of koniophthisis P.156 (steam coal collier for 18 years), showing confluent *fibrocaseous anthraco-silicotic lesion*, which contains tubercle bacilli but lacks ordinary histological features of tubercle. Characteristic drifting of dust, similar to that in Figs. 20 and 21.



FIG. 23.—Large section of lung ( $\times 1.5$ ) from case P.133 (screens worker for 20 years) ; showing *cavity* in centre of massive *anthraco-silicotic lesion*. Cavity filled with caseous debris, which was inky-black in the gross but had dust washed out of it in paraffin process and now looks pale. This type of lesion, which is common, is similar in all respects to koniophthisic cavitation but is usually regarded as non-tuberculous.

*reaction and Cavitation.* Not every case with questionable lesions is listed. By rough estimation we tried to judge whether half or more of the anthracosilicotic lesions in a given case showed evidence of caseation. If such appeared to be true, the case was listed. Similarly, in the matter of cavitation, only those cases with sizeable cavities, as in Fig. 23, are included. It will be seen from Table I that many of the suspected cases had both caseation and cavitation. Tubercle bacilli were not found in them, but the similarity of these lesions to those of proven koniophthisis is quite striking. This raises the question whether caseation is pathognomonic of tubercle or whether it may be produced by dust alone. The evidence seems rather to favour the former view but it is inconclusive (see p. 211).

*Cavitation* is a common accompaniment of anthracosilicosis. Massive hard black areas of confluent fibrosis usually show some crumbling disintegration of their central parts. The cavity so formed frequently appears to have no communication with bronchi, for it tends to remain full of soft black necrotic debris (Fig. 23). Most pathologists are inclined to regard this type of cavitation as non-tuberculous (Cooke; Cummins and Sladden; Gardner; Miller; Gough), but to us the appearance is so much akin to that of koniophthisic cavitation described above that we are not convinced of its non-tuberculous nature. We think it less likely that these cavities are formed by disintegration of fibrous tissue than that they represent areas which have been necrotic from the first (cf. p. 212).

#### EMPHYSEMA

Pulmonary emphysema is one of those diseased states which can be estimated more precisely during life than post-mortem. In life there is the advantage of being able to measure accurately the residual air, vital capacity and lung volume, all of which are characteristically altered in emphysema. Post-mortem one can but roughly estimate the degree of emphysema and point to such changes of a qualitative character as may substantiate the diagnosis. Bearing this reservation in mind, we may say that all cases in the present series show some histological evidence of emphysema, and that sometimes it is very marked (Figs. 2, 18). There is cystic dilatation of some air spaces at the expense of others, stretching and disruption of alveolar septa and disorganization of the elastic tissue elements. Now what evidence is there that dust lesions have anything to do with causing emphysema? Perhaps not very much. But we can say that dust-reticulation tends to reduce, disorganize and render ineffective the elastic fibres of the lung. The main systems of elastic tissue are located along perivascular and peribronchial sheaths, as well as in the margins of lobules (Miller, 1937) and these are the very sites where dust-laden reticular tissue tends to collect. The elastic fibres tend to be distorted and splinted by the reticular tissue, which is more or less inelastic. If, as Christie (1933) suggests, loss of elasticity contributes to the development of emphysema, then there is some reason for regarding dust-reticulation also as a contributing factor.

#### CHARACTER OF THE DUST

The analysis here reported is limited to such methods as are applicable to histological preparations, that is, ordinary microscopy, polarizing microscopy and micro-incineration. So far as we can tell by these methods, the quality of the dust does not vary much from one case to another. It is a mixture consisting chiefly of carbonaceous and siliceous particles. We may take it for granted that practically all the black pigment is carbonaceous and exogenous (cf. Cummins and Sladden, 1930). Quantitatively it comprises more than half the foreign material in most cases, perhaps averaging 60 per cent. of the total, though in the case of rock workers it is sometimes as low as 20 per cent. It is estimated

that the average lung in this series contains as much as 5 or 6 grams of inhaled carbon (cf. Klotz, 1914). The particles are amorphous, jet black and small, though somewhat larger on the average than the silica particles. They seldom exceed  $4\mu$ .

The siliceous moiety of the dust cannot be demonstrated by ordinary microscopy, but requires special methods such as the micro-incineration technique employed by Irwin (1934). The preparation is heated to  $500^{\circ}\text{C}$ . for one hour, cooled and soaked in concentrated HCl for 30 minutes, then washed with water. The resulting residue is a thin, white, powdery deposit composed almost entirely of silica. It is best seen by dark field illumination, when it shows up prominently, as in Figs. 3, 4, 5, 9, 13, 14 and 15. The particles are very small, averaging less than  $1\mu^*$ , colourless and birefringent (Fig. 7). They are lightly stuck to the glass but are easily brushed off, as anyone knows to his sorrow who has had the misfortune to touch them inadvertently. It has been suggested that micro-incineration may produce artefacts in the glass slide by blistering or by fusion of particles with the glass, but this has not been observed in our preparations, except occasionally when the oven went above  $500^{\circ}\text{C}$ . or the heat was left on for more than an hour. Another possible fallacy is that the HCl treatment may fail to remove all the non-siliceous residue, either through faulty technique or because there are more HCl-insoluble substances present than silica. Dr. E. J. King assures us, however, that there is little likelihood of error here. The residue is unlikely to contain anything more than silica and silicates, because there are few other substances in nature insoluble in HCl. Silver is one, lead sulphate and barium sulphate are others, but none of these is likely to be present in a collier's lung in sufficient quantity to confuse the issue. The impression, gained by micro-incineration, of relatively large amounts of silica in the lungs is confirmed in each case by Dr. King's chemical determinations, details of which will appear in a separate paper by King, Nagelschmidt and Belt; the average figure was 1.4 per cent.  $\text{SiO}_2$  of the dry weight of the lung, while the upper limit of normal is but 0.2 per cent.

The average lung in this series, therefore, contained somewhere in the neighbourhood of 2 or 3 grams of total silica. Now total silica, as has been explained elsewhere (p. 221), does not mean free silica. On the contrary, we know from the work of Jones (1933) that Welsh colliers' lungs contain little free silica but much silicate dust. The latter consists of minerals of the clay (kaolin) and mica groups. Jones gave great prominence to sericite, but it will be shown in a subsequent report by King, Nagelschmidt and Belt that kaolin is also present in large amounts. We may say, therefore, that the siliceous dust in a collier's lung is largely a mixture of silicates consisting chiefly of clay and mica, and containing lesser amounts of quartz.

By examination of the silica particles under high power magnification in a preparation such as that pictured in Fig. 7, it is possible to distinguish many elongated forms amongst the smaller particles. These represent fibrous silicates belonging to the mica group. Quartz particles are larger and fewer.

#### CORRELATION OF TYPE OF LESION WITH OCCUPATION

The rock workers (hard-headers, repairers and borers in colliery terms) differ notably from all the others (see Table I) in showing a more classical type of silicosis and less dust-reticulation. Their lungs contain much less coal dust, also less silicates and more quartz. The other occupations are all characterized by dust-reticulation, atypical silicotic fibrosis, retention of coal and silica, and there seem to be no special histological features to distinguish one from another.

#### CORRELATION OF X-RAY CLASSIFICATION WITH LESIONS

The basis of this correlation is to be found in Table I (pp. 204-205), where the X-ray classification made during life may be compared with the anatomical changes revealed post-mortem.

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\* Dr. T. Bedford and Dr. C. G. Warner kindly undertook measurements of particle size in some of our preparations. Their results will be published separately.

TABLE II

*X-Ray Categories with Corresponding Lesions*

(b) X-ray reticulation ..	Dust-reticulation.
(c) Nodulation ..	Dust-reticulation <i>plus</i> any or all of the 3 types of nodule described in text.
(d) Coalescent nodulation ..	As in (c) but with coalescence of nodules by confluent fibrosis.
(e) Massive shadows ..	Dust-reticulation <i>plus</i> confluent fibrosis.
(f) Multiple fluffy shadows..	(Undetermined.)

In the description of X-ray changes (see Hart and Aslett), categories (c), (d), (e) and (f) are sometimes grouped together under the general heading of *consolidation* and (d), (e) and (f) are sometimes called *major consolidation*. It will be seen from Table I that there is not always complete agreement between radiological interpretation and actual findings, but allowance must be made for certain discrepancies, since in some cases the last radiograph was taken a few years before death, and the lesions may have progressed or altered in the interval. Nevertheless, there is general agreement between the two. For example, the seven cases which at post-mortem showed dust-reticulation as the predominant change all fell into X-ray category (b), while 18 of the 21 in which confluent fibrosis was the main change were put correctly in category (e) during life, and three in category (d). The 14 cases with nodulation as the predominant lesion had a wider spread in X-ray appearances; they should all be in category (c) or (d) and 10 were so placed, 4 in (c) and 6 in (d). Nodulation seems to give greater difficulty than the other lesions in the matter of accurate recognition by X-ray and this difficulty is most marked in the case of mixed nodules; of the eight cases with these as the main change, only five were accurately interpreted by X-ray.

There are no separate X-ray categories for koniophthisic lesions. The tuberculous cases in this series fall into groups (d) and (e), that is, they show coalescent or confluent shadows which are not distinguished by Hart and Aslett from shadows of the same type seen in non-tuberculous cases.

## AETIOLOGY OF DUST LESIONS

Up to this point we have been concerned chiefly with a description of lesions. Now let us turn our attention more particularly to the processes involved. It will be evident from what has been said of the histological changes in the collier's lung that there are really three main pathological processes to be taken into account, namely, (1) dust-reticulation, (2) silicotic fibrosis, and (3) koniophthisis. These overlap a good deal, as has been seen, but if we are to attempt an assessment of aetiological factors, it seems to us that the best hope of success lies in considering each of these processes separately.

(1) *Dust-reticulation*

Dust-reticulation is a widespread elaboration of reticular tissue throughout the lung, in response to the presence of excessive quantities of inhaled dust. To put it in simple terms, it is a *storage phenomenon* or a *foreign body reaction* of the simplest type. The condition obviously arises through an inability of the lung to rid itself of inhaled particles. It must be presumed that in ordinary circumstances the lung has considerable resources for cleansing itself, which are often surprisingly effective even when dust is inhaled in quantity. The lining mucosa of the upper respiratory passages extracts dust from incoming air, prevents it from reaching the lungs, sweeps it up by ciliary action and throws it off in sputum. If dust reaches the air sacs it is taken up by motile cells which are variously called dust cells, koniophages or macrophages. These then tend to migrate in one of two directions; either they pass back into the bronchi

and are ejected in sputum, which is probably the more normal course of events, or they enter the pulmonary lymphatics and are carried off towards the hilar glands. In the latter case some of them tend to get stuck along the way, as is constantly seen in the ordinary city dweller's lung. Whether the koniophage is ejected in the sputum or taken into the lymphatics probably depends upon its degree of motility; the more active tend to move outwards, while the sluggish are trapped in the air sacs and eventually find entrance to the lymphatic channels. Now in a person exposed to excessive quantities of dust it probably makes all the difference if the koniophages are active enough to escape after they have ingested a load of dust particles (Mavrogordato, 1922); if they are sluggish they will eventually crowd together along the lymphatic system of disposal, and this is evidently what happens in the first stages of dust-reticulation. The motility of a koniophage probably depends not only on the amount but also on the quality of its dust-load. If a cell is overloaded with any kind of dust it is less likely to be able to escape, more likely to be trapped. But some dusts stimulate phagocytes, while others tend to depress their activity. Coal belongs to the former group, silica to the latter. This observation was made by Mavrogordato (1926) in animal experiments and by Lauche (1931) in tissue cultures, and we have confirmed it many times in our own experimental work. When coal dust is introduced into an animal's lungs, active phagocytes soon clear it out of the air sacs, while quartz, on the other hand, and some silicates, though quickly phagocytosed by the same sort of cell, have a tendency to remain in this location indefinitely. Only a small proportion reaches the hilar glands. When a dust cell takes on a load of siliceous particles, whether of quartz or silicate, it tends to lose amoeboid activity and become immobilized. Our own experimental observations of this phenomenon are to be reported separately by Belt, King and Ferris. Mavrogordato aptly likened the effect to that of mummification. It is as if the silica had poisoned and partially devitalized the cell. When, as must often happen in the collier's lung, the koniophage picks up a mixed load of coal and silica, the effect is intermediate; the cell begins its long journey to the hilar glands, but its motility is impaired and it tends to become trapped along the way before it has gone very far. There seem to be many little traps along the lymphatic channels in the form of saccular dilatations or out-pouchings (cf. Miller, 1937), which catch the more sluggish of the dust cells in transit. Apparently these cells migrate through the walls of the lymphatic vessel (it is difficult to be sure of this), for they come to rest in the adjacent areolar tissue where they tend to take root, apparently by shooting out reticulum fibres. The accumulation of dust cells along the lymphatic pathways seems, therefore, to be determined by a process of selective filtration rather than by lymph stasis. There is little actual choking of lymphatic vessels. The latter may sometimes be a factor but we have seen little evidence of it in either our human or experimental material.

We have been able to reproduce the early stages of dust-reticulation in animals with several different samples of mixed dust from the coal mines of South Wales, but our experimental results fall far short of a close comparison with the full development of dust-reticulation as seen in miners. In the latter the dust collections are heavier, more extensive and accompanied by the elaboration of more reticulum fibres. However, there is evidence enough that dust-reticulation develops by two stages, first, accumulation of dust cells, which, as we have seen above, is the effect more of silica than of coal, and second, elaboration of reticulum to bind these cells together. Now as far as we know, coal dust alone does not stimulate the production of much reticulum (see below) but quartz certainly does (Belt, Ferris and King, 1940). Some of the silicates also have this property, as will be reported separately in the later paper mentioned above, but the reaction is slower and less intense with them than with quartz. Pure carbon, when injected into the peritoneal cavity



of animals, produces a great deal less reticulum than either quartz or silicates. This observation, too, will be more fully described in the later paper dealing with our experimental results.

There seems to be good evidence, therefore, for regarding the dust-reticulation of colliers as due more to the action of silica than to coal. The effect of the former is twofold: firstly, a relative *immobilization of dust cells*, so that they do not escape but tend to accumulate in the lung, and, secondly, *elaboration of reticulum fibres*. Theoretically neither of these effects can be attributed to coal alone. We have never seen a black lung that did not contain an excess of silica; even the anthracotic pigmentation found in ordinary city dwellers is charged with siliceous material (Belt, Irwin and King, 1936). It seems unlikely that coal dust would be retained in the lungs to the same extent in the absence of silica, but we cannot regard the available evidence as altogether conclusive (cf. Schnurer and Haythorn, 1937). Certain it is that the coaly element makes dust-reticulation more prominent by virtue of its pigment, and more bulky than silica alone would do, but this is a fortuitous and non-specific effect which seems to be more or less duplicated by red oxide of iron in the lungs of haematite miners. The latter show much the same form of dust-reticulation and similar quantities of silica.

Crucial, perhaps, is the observation that dust-reticulation sometimes contains only siliceous dust, as could be shown in at least one of our cases, a rock worker (No. 176, Table I). One of the heaviest instances of dust-reticulation to come to our notice was a specimen sent to us by Dr. E. L. Middleton. (This case was reported by Middleton in the Proceedings of the International Conference on Silicosis, Geneva, 1938, *Studies and Reports of the International Labour Office, Series F*, No. 17, published 1940, pp. 134-6.) It was from a man who had worked for years with fuller's earth.\* Practically all the dust in the lung was fuller's earth (hydrous silicate of alumina). Dr. Middleton raised the question at the time whether dust-reticulation as exemplified in this case might be considered a characteristic reaction to silicate, in the same way that silicotic nodulation is a characteristic reaction to uncombined silica. The theory is attractive and not without circumstantial support. We shall refer to it again when considering the aetiology of silicotic fibrosis (p. 218). It is true that cases of classical silicotic nodulation tend to have a minimum of dust-reticulation and vice versa.

## (2) *Silicotic Fibrosis*

Though dust-reticulation is a form of fibrosis, and seems to be attributable to silica (see above), the term silicotic fibrosis has not been applied to it, but is reserved for that specific collagenous change which takes the form either of silicotic nodules, as in classical silicosis, or of irregular hyalinized scars intermingled with dust-reticulation, as in anthraco-silicosis. Most authorities are inclined with Gardner (1933) to regard the latter as a hyaline swelling of reticulum fibres due to a specific chemical action of silica. In support of this theory, it has been noted (Belt, 1929, 1939) that the silica fragments are smaller and less numerous in the hyalinized parts, as if they were partially dissolved. There is no satisfactory explanation as to why the change is so sporadic in any given lung, why it does not follow the distribution of silica more closely and why many cases of dust-reticulation apparently do not develop it at all (see Hart and Aslett). When the matter is put to experimental proof the results are disappointing and inconclusive. We have not succeeded in reproducing the characteristic lesions of anthraco-silicosis experimentally. None of our animals has shown collagenous fibrosis comparable to that of the human case, though

\* A detailed analysis of this dust by Brammall, Leech and Dunstall (*Geol. Mag. Lond.*, 1940, 77, 102) shows it to be about 85 per cent. montmorillonite.

we expect the experiments will not fall short of yielding some useful information. In the meantime we can shed no new light on the development of silicotic fibrosis, save perhaps to point out one peculiar feature revealed by micro-incineration, namely, that silicotic fibrosis contains less silica than does dust-reticulation. To explain this paradox it may one day be necessary to consider a revision of the current conception and to ask whether dust-reticulation is not perhaps more truly silicotic than the so-called silicotic fibrosis, and whether the latter is not perhaps a para-silicotic phenomenon, due in part to some additional factor which activates the silica in sporadic foci (see below). It is well to remember the suggestion by Watkins-Pitchford (1927), Policard (1933), Nicaud (1938) and others that silicotic fibrosis is but a fibroid modification of koniophthisis. So far as our findings go there is no convincing evidence with which to contravert this suggestion, though our experiments with combinations of dust and tubercle bacilli have so far failed to substantiate it.

It is now time to consider the *actiological relationship between dust-reticulation and silicotic fibrosis*. Does the one always precede the other? In the case of the collier's lung the answer is almost certainly yes. The so-called anthracosilicotic lesions could and do develop only on the basis of dust-reticulation. But this is a modified form of silicosis and the question will naturally follow, does the classical form of silicotic nodulation also depend upon the pre-existence of dust-reticulation? Here the answer is also in the affirmative, but we must hasten to add that dust-reticulation is a less conspicuous feature of classical than of collier's silicosis. We may say that dust retention always precedes silicotic fibrosis but in the classical form nodulation tends to develop before dust retention reaches conspicuous proportions. In the rock-working colliers of our series, as in the case of gold miners and sand-blasters, classical silicosis may make its appearance before there is much dust-reticulation (Fig. 8). The explanation of this is not easy, but probably it has to do with the quality of the different dusts and with their relative pathogenicity. With rock dust (presumably containing more free silica) the preliminary stages of the pneumokoniosis are less emphasized and the end stages are more typical of silicosis; while in the collier's lung, where the dust contains more silicates than free silica (King, Nagelschmidt and Belt) and is heavily mixed with coal, the preliminary stage, as represented by dust-reticulation, assumes greater proportions, may indeed of itself constitute a pneumokoniosis, and in case of progression beyond this stage the end result is atypical of silicosis.

It is true to say that dust-reticulation is one form of silica effect and silicotic fibrosis is another. The difference may lie in the quality of the silica associated with each. One would like some such simple explanation as that the former is due to silicates and the latter to free silica (see p. 217) but the matter is unlikely to be fully explained in this way. We have to take into account also the possible influence of coal and other adulterant substances on the solubility of silica and the possible intervention of tubercle.

Silicotic fibrosis is a sequel to dust-reticulation but evidently not an obligatory one. Hart and Aslett have shown that the latter may apparently last a lifetime without progressing to further changes. In the individual lung also some areas of dust-reticulation develop silicotic fibrosis, while others do not. The progression from one to another is sporadic, hence the need of postulating an unknown *sporadic factor X*. The main property of this hypothetical factor is that it alters the silica, perhaps by dissolving it, into a substance capable of producing redundant collagenous fibrosis, while the unaltered silica remains capable only of producing reticulation. There is some reason for thinking of *X* as a biological factor, especially when we recall how amenable is silica to biological transformation by soil bacteria. One probable identification of factor *X* is the tubercle bacillus, but there may be others; it is not necessarily a single factor.

(3) *Koniophthisis*

Our report is somewhat incomplete without a more extended bacteriological investigation of the human material. Unfortunately, this was not possible, as nearly all the specimens had been fixed before reaching us. It would have been a useful experiment to take a preparation of fresh lung in each case, and, with suitable controls, to inoculate guinea pigs.\* However, eight of the 42 cases were proven to be tuberculous, five of them during life and three post-mortem. Examination of these gave us an opportunity of familiarizing ourselves with the special histological features of collier's phthisis. In an earlier part of this report (see pp. 211 and 212) we have noted how it differs from ordinary tuberculosis and have suggested that the picture is distinctive enough to merit some such special designation as *koniophthisis*.

The appearance of *koniophthisic* lesions was so closely simulated in certain of the other cases which were regarded as non-tuberculous (see p. 212) that we came to wonder whether tuberculous infection might be playing an unsuspected role, acting under cover of the dust, so to speak, perhaps in a greater proportion of cases than have hitherto been identified clinically. The question remains unanswered for the time being, but we feel there is good reason to doubt the old teaching that tuberculosis is rare among colliers (cf. Sokoloff, 1936, and Cohen, 1939).

Dust-reticulation in its pure form is the one phase of colliers' pneumokoniosis in which tuberculosis is not suspect. But dust-reticulation, by virtue of its silicotic character, evidently favours the inception of tubercle and modifies its course. We may say that *koniophthisis* results from a combination of dust-reticulation and tuberculous infection.

## THE LUNG AS A DOSSIER

The collier's lung is, in a very real sense, his occupational log book; it retains a qualitative and an indelible record of the mineral particles breathed during life; and after death, as Cummins (1935) says, it constitutes a sort of palimpsest of the industrial history. Indeed, by way of summarizing the various pathological findings described above, we could not, we think, do better than enlarge a little on Cummins' admirable simile. The collier's lung is like a parchment which has twice been written upon. The original legend is in the form of dust-reticulation and is inscribed over the whole fabric, from top to bottom. Though the penmanship varies, it is set down always in the same spidery characters. It is like the laborious, uneven writing of a child, now in a weak and faltering hand, now with a bolder flourish. The black dust which fills the rôle of a primitive sort of ink is heavily polluted with sandy grit. The later legend is, so to speak, in a different tongue, written still more unevenly, in coarser characters and by a heavier hand. These are the hieroglyphics of silica and tubercle. Under this later influence the earlier record may well become smudged and distorted, but it remains legible.

\* An investigation on these lines has since been made by Dr. A. F. S. Sladden, and will be published separately.

## SUMMARY

Forty-two cases of pneumokoniosis in colliers of South Wales are analyzed from the point of view of anatomical changes in the lungs and their probable mode of development.

The primary dust-effect seen in the collier's lung is not a simple anthracosis as has been thought, but a mixed pneumokoniosis in which silica is always present, though its effect is possibly latent. The term "dust-reticulation" is suggested for it, instead of anthracosis.

Dust-reticulation may be defined as a dust-ridden state of the lungs corresponding to X-ray reticulation. It is characterized by a notable retention of silica as well as carbon, and the elaboration of reticular tissue throughout the interstitium of the lungs.

There is histological evidence that dust-reticulation tends to impair the function of the lung, by encroaching upon vital capacity and by interfering with the elasticity of the pulmonary tissues, thus contributing to the development of emphysema. Dust-reticulation is not necessarily progressive, but when the grosser indurations of anthraco-silicosis develop they do so on the basis of dust-reticulation.

Silica in excessive quantities has been demonstrated in every case of dust-reticulation, both by micro-incineration and by chemical analysis. It is intimately mixed with coal dust and has the same distribution. Qualitative analysis of the silica is the subject of another paper by King, Nagelschmidt and Belt which will show, amongst other things, that the greater part of the silica present is in the form of silicates.

Experimental and other evidence is presented to show that dust-reticulation is the effect more of siliceous dust than of coal and is produced by a twofold action: (1) relative immobilization of dust cells, so that they become trapped in the intra-pulmonary lymphatics, instead of being evacuated from the lungs; and (2) proliferation of reticulum fibres.

The accumulation of coal dust is apparently a fortuitous result of silica retention and not specially harmful.

Cases of classical silicotic nodulation tend to have a minimum of dust-reticulation and vice versa. The latter seems to be more the effect of certain silicates, the former of free silica.

The atypical quality of silicotic fibrosis in colliers may be attributable in part to the preponderance of silicates of the mica and clay types.

Dust-reticulation, whether due to free silica or silicates or both, is one form of silica effect, and silicotic fibrosis, whether typical or atypical, is another. The one is a reaction strictly proportional to the amount of dust, while the other is a redundant fibrosis. The former is due to dust alone, but there is reason to believe the latter to be a modified effect of silica, induced by an additional sporadic factor, possibly bacterial.

In anthraco-silicosis there are two types of lesion, nodulation and confluent fibrosis, each of which represents a mixture of dust-reticulation and atypical silicotic fibrosis.

Pulmonary tuberculosis tends to be so modified in colliers as to lose its identity and become merged with the pneumokoniosis. The combined effect constitutes a more or less separate and distinct disease. The term koniophthisis is suggested as a suitable name for it.

Koniophthisis, like the grosser forms of anthraco-silicosis, also develops on the basis of dust-reticulation. The lesions are not typically tuberculous but are predominantly of silicotic character, with a minimum of caseation.

Anthraco-silicotic lesions, even in cases not proven to be tuberculous, are often very similar to the lesions of koniophthisis, thus suggesting a hidden tuberculous element in a greater proportion of cases than is obviously koniophthisic.

## SHORT GLOSSARY OF TERMS WITH SPECIAL MEANING ADOPTED IN THIS REPORT

*Anthraco-silicosis* : An occupational disease affecting the lungs of colliers, characterized by a mixture of dust-reticulation and silicotic fibrosis. Lesions are either nodular or massive. (Dust-reticulation alone is not included under this term.) *Synonyms* : colliers' lung, colliers' pneumokoniosis, silico-anthracosis.

*Caseation* : A form of bland, granular, coagulation necrosis of cheesy consistency ; composed largely of amorphous, albuminous debris ; containing some lipid material and (in the case of colliers' lung) dust particles. *Synonym* : caseous necrosis.

*Confluent Fibrosis* : The confluent form of anthraco-silicotic lesion, comprising a mixture of dust-reticulation and silicotic fibrosis. *Synonyms* : massive fibrosis, cricket-ball mass, pseudo-tumoral mass.

*Dust-reticulation* : A dust-ridden state of the lungs corresponding to X-ray reticulation, characterized by accumulation of silica and concomitant elaboration of reticular tissue throughout the framework of the lungs. *Synonym* : anthracosis (unsuitable).

*Koniophage* : Large mononuclear phagocyte which appears in the pulmonary alveoli in response to the presence of foreign particles. *Synonyms* : dust-cell, macrophage.

*Koniophthisis* : Newly coined word (from *κόνις*, dust, and *phthisis*). A distinctive form of pulmonary tuberculosis modified by dust-reticulation ; lesions are not typically tuberculous but characterized by silicotic fibrosis, minimal caseation and wavy dust impregnation. *Examples* : Colliers' phthisis, silico-tuberculosis, tuberculo-silicosis.

*Mixed Nodule* : The nodular form of anthraco-silicotic lesion combining dust-reticulation with atypical silicotic fibrosis. Sometimes has "Medusa-head" contour. *Synonym* : anthraco-silicotic nodule.

*Pneumokoniosis* (abbreviated from *pneumonokoniosis* : Any dust-ridden state of the lungs severe enough to impair health.

*Redundant Fibrosis* : Fibrous reaction out of proportion to amount of dust ; collagenous fibrosis containing minimal amounts of dust. *Example* : silicotic fibrosis.

*Reticular Tissue* : Loose form of specialized connective tissue, as defined by Maximow and Bloom (*Textbook of Histology*, 3rd ed., 1938, p. 66), composed of fixed macrophages which elaborate argentophil fibres ; histological basis of dust-reticulation.

*Silica* : Term used loosely to include silicates as well as silicon dioxide, in the same sense that chemists use the term "total silica" when they estimate silica content of lungs without distinguishing between free and combined forms. Sometimes used interchangeably with term "siliceous dust". (Uncombined silica is designated as free silica or as quartz.)

*Silicotic Fibrosis* : Acellular collagenous fibrosis in form of silicotic nodules as in classical silicosis, or irregular collagenous deposits as in anthraco-silicosis ; characterized by distinctive ash pattern containing fine film of silica, by dust-free (redundant) parts, by tendency towards encapsulation and by drifting of dust at periphery of individual lesions ; always in contact with silica but not proportional in amount.

## REFERENCES

- BADHAM, C., and TAYLOR, H. B. (1936) Extract from *Ann. Rep. Dep. Publ. Hlth., N.S.W. Studies in Industrial Hygiene*, No. 19, p. 100.
- BELT, T. H. (1929) *Canad. J. Publ. Hlth.*, 20, 495.
- (1939) *J. Path. Bact.*, 49, 39.
- , FERRIS, A. A., and KING, E. J. (1940) *J. Path. Bact.*, 51, 263.
- , IRWIN D., and KING, E. J. (1936) *Canad. med. Ass. J.*, 34, 125.
- , KING, E. J., and FERRIS, A. A. Experimental lesions produced by various dusts from South Wales collieries (to be published).
- BÖHME, A. (1934) *Ergebn. ges. Med.*, 19, 489.
- CHRISTIE, R. V. (1934) *J. clin. Invest.*, 13, 295.
- COHEN, A. C. (1939) *Arch. intern. Med.*, 63, 1117.
- COOKE, W. E. (1932) *Practitioner*, 129, 483.
- CUMMINS, S. L. (1935) *Brit. med. J.*, 2, 287.
- and SLADDEN, A. F. (1930) *J. Path. Bact.*, 33, 1095.
- and WEATHERALL, C. (1931) *J. Hyg., Camb.*, 31, 464.
- GARDNER, L. U. (1933) *U.S. Publ. Hlth. Bull.*, No. 208, p. 16.
- GOUGH, J. (1940) *J. Path. Bact.*, 51, 277.
- IRWIN, D. A. (1934) *Canad. med. Ass. J.*, 31, 135.
- JONES, W. R. (1933) *J. Hyg., Camb.*, 33, 307.
- KING, E. J., NAGELSCHMIDT, G., and BELT, T. H. Mineral content of coalminers' lungs (to be published).
- KLOTZ, O. (1914) *Amer. J. Publ. Hlth.*, 4, 887.
- LAUCHE, A. (1931) *Verh. dtsch. path. Ges.*, p. 107.
- MAVROGORDATO, A. (1922) *Publ. S. Afr. Inst. med. Res.*, No. 15, p. 112.
- (1926) *Ibid.*, 3, No. 19, 1.
- MIDDLETON, E. L. (1940) *Proc. Internat. Conf. Silicosis, Geneva* (International Labour Office; Studies and Reports, Series F, No. 17).
- MILLER, J. W. (1935) *U.S. Publ. Hlth. Bull.*, No. 221, p. 69.
- MILLER, W. S. (1937) *The Lung*, London (Baillière, Tindall & Cox).
- NICAUD, M. P. (1938) *Bull. Soc. méd. Hôp. Paris*, 54, 250.
- POLICARD, A. (1933) *Presse méd.*, 41, 89.
- and DOUBROW, S. (1929) *Presse méd.*, 37, 905.
- SCHNURER, L., and HAYTHORN, S. R. (1937) *Amer. J. Path.*, 13, 799.
- SOKOLOFF, M. J. (1936) *Amer. Rev. Tuberc.*, 34, 700.
- STRATTON, T. M. L. (1838) *Edin. Med. Surg. J.*, 49, 490.
- TATTERSALL, N. (1926) *J. Industr. Hyg.*, 8, 466.
- WATKINS-PITCHFORD, W. (1927) *J. Industr. Hyg.*, 9, 109.

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