WORKING FOR A HEALTHY FUTURE

HISTORICAL RESEARCH REPORT

Research Report TM/95/03
1995

A follow-up study of miners exposed to unusual concentrations of quartz

Miller BG, Hagen S, Love RG, Cowie HA, Kidd MW, Lorenzo S, Tielemans ELJP, Robertson A, Soutar CA

WORLD HEALTH ORGANISATION
COLLABORATING CENTRE
FOR OCCUPATIONAL HEALTH

RESEARCH CONSULTING SERVICES

Multi-disciplinary specialists in Occupational and Environmental Health and Hygiene

www.iom-world.org

A follow-up study of miners exposed to unusual concentrations of quartz

Miller BG, Hagen S, Love RG, Cowie HA, Kidd MW, Lorenzo S,
Tielemans ELJP, Robertson A, Soutar CA

The scanning of this and the other historical reports in the Research Reports series was funded by a grant from the Wellcome Trust. The IOM's research reports are freely available for download as PDF files from our web site: http://www.iom-world.org/research/libraryentry.php

INSTITUTE OF OCCUPATIONAL MEDICINE
Research Avenue North, Riccarton, Edinburgh, EH14 4AP
Tel: +44 (0)870 850 5131 Fax: +44 (0)870 850 5132
e-mail publications@iomhq.org.uk

Report No. TM/95/03

INSTITUTE OF OCCUPATIONAL MEDICINE

A follow-up study of miners exposed to unusual concentrations of quartz

by

BG Miller, S Hagen, RG Love, HA Cowie, MW Kidd, S Lorenzo,
ELJP Tielemans, A Robertson, CA Soutar

FINAL REPORT ON RESEARCH CONTRACT FOR BRITISH COAL

Institute of Occupational Medicine
8 Roxburgh Place
Edinburgh EH8 9SU

Tel: 0131 667 5131
Fax: 0131 667 0136

Price: £40.00 (UK)

This report is one of a series of Technical Memoranda (TM) distributed by the Institute of Occupational Medicine. Current and earlier lists of these reports and of other Institute publications are available from the Technical Information Officer/Librarian.

CONTENTS

Report No. TM/95/03

INSTITUTE OF OCCUPATIONAL MEDICINE

A follow-up study of miners exposed to unusual concentrations of quartz

by

BG Miller, S Hagen, RG Love, HA Cowie, MW Kidd, S Lorenzo,
ELJP Tielemans, A Robertson, CA Soutar

SUMMARY

Since the 1950s, British Coal's Pneumoconiosis Field Research (PFR) programme has been the principal source of epidemiological data on coalworkers' pneumoconiosis in the UK. Many analyses of PFR data have concluded that exposure to respirable mixed coalmine dust generally, rather than to its quartz content specifically, was the primary determinant of both incidence and prevalence of coalworkers' simple pneumoconiosis. Results on the specific role of quartz have been more equivocal, but the most detailed investigations have suggested that increasing the amount of quartz, mass for mass, in a specific dust increases the pneumoconiosis risk. However there has, until recently, been little information on the quantitative relationship between exposure to quartz and risks of pneumoconiosis, and associated lung function deficits.

In 1980 the IOM reported that quartz concentrations in certain faces of a Scottish colliery reached unusually high levels for a period in the 1970s, due to unusual geological conditions. In the main, Scottish collieries tended to experience less pneumoconiosis than some other regions in Britain, but by 1978, a number of men had developed signs of radiological progression. The epidemiological results, and data from animal inhalation experiments, suggested that the response to the dust was directly related to its quartz content.

This report describes a follow-up study of the population of men who worked and were surveyed by the PFR in this colliery during the 1970s. The study was undertaken to ascertain the current respiratory health status of these men, and to examine the quantitative relations between history of exposure to respirable quartz and risk of chest radiological and lung functional abnormality. The men were traced and invited to attend for an examination at which were taken a postero-anterior chest radiograph, a questionnaire on respiratory symptoms and smoking habits, a history of employment since leaving the colliery, and anthropometric and lung function measurements. A total of 551 men were seen between late 1990 and Spring 1991, representing 53% of the surviving population of men employed at this colliery in the 1970s.

Extensive data were available on these men's exposures to respirable dust and quartz throughout their work at the colliery. The assessment of exposures for the PFR was based on detailed and frequent measurements of dust concentrations in different occupational groups, and carefully maintained records of the times each man spent working in each of these groups. A wide range of quartz concentrations was observed, but for some periods, certain face occupations experienced concentrations of respirable quartz over 10 $mg.m^{-3}$.

For the present study, these concentration data were brought together, supplemented with data from the histories taken at the follow-up survey, and summarised as exposures to respirable dust and quartz in inter-survey periods of about four or five years in length, in order to permit some examination of temporal trends underlying any exposure-response relationships.

The chest radiographs were examined and classified according to the ILO (1980) scheme by three experienced readers. For analysis, profusions of small opacities were summarised by the median of the three readings. On this basis, the observed prevalence of small opacities 2/1 or greater was 8.6% overall, but reached 20 to 40% in the groups with the highest quartz exposures.

Logistic regression analyses of the profusion of small opacities recorded for the radiographs from the follow-up survey showed strong evidence of association between risks of displaying pneumoconiotic abnormalities and the exposures experienced during work at the colliery. The correlation between an individual's exposures in different inter-survey periods, induced by continuity of occupational group across time, requires some caution in interpreting regression results. Comparison of the estimated regression coefficients and their statistical significance from a large number of models suggested that the strongest association was with exposures in the periods 1970 through 1974 to 1978, followed by 1964 to 1970; and that the association was stronger with the estimated exposure to the quartz fraction of the respirable dust, than with its non-quartz component. The specific association with the periods in the 1970s, and the association with quartz in particular, showed most strongly in analyses where the response was a small opacities profusion of 2/1 or higher. There was no evidence of an association with exposures prior to the third PFR survey in early 1964, and little evidence for any association with coalmine exposures accumulated after 1978.

The results of these analyses have been used to calculate preliminary risk estimates, which give an approximate but useful indication of the magnitude of the risks involved. For example, a man aged 60 at survey and with fifteen years' exposure to an average quartz concentration of 0.1 $mg.m^{-3}$ is predicted to have a risk of approximately 3% of showing small opacities of category 2/1 or greater at follow-up. With fifteen years' exposure to 0.3 $mg.m^{-3}$, the prediction is a risk of 22%.

There was a strong association between radiological abnormalities at follow-up and time spent working in certain occupational groups known to have had very high concentrations of respirable quartz. It has not, however, been possible as yet to identify all of the occupational groups associated with increased risks of developing pneumoconiotic abnormalities, and further work is needed here.

The rapid progression observed in the radiological abnormalities, their relationship with quartz exposure estimates, and the strength of their relationship with lung function confirm suggestions that the effects of this unusual exposure are more similar to those of classical silicosis than to the patterns of pneumoconiosis observed in coalworkers. In turn, these findings are in line with two separate, though possibly complementary, theories: (1) that freshly fractured quartz may be much more aggressive in its effects than quartz whose surfaces are heavily contaminated with other ions; (2) that the unusual intensities (concentrations) of the quartz exposures experienced by some men induced proportionally higher risks in relation to exposure than those resulting from cumulative exposures at more usual quartz concentrations, conceivably by inducing a disproportionately severe and persisting inflammatory response.

Further work is needed to investigate in more detail the relationships between exposure, time and the development of pneumoconiosis. This work needs to identify and investigate the role of the specific occupational groups mentioned above; to explain and eliminate an unexplained (and possibly artefactual) relationship with age of subject at time of follow-up; and to look in detail at any evidence for disproportionate effects of very high concentrations, and evidence for health effects of very low concentrations, including the possibility of thresholds etc. The output from such work could be very influential in informing the setting of standards governing exposure to mixed dusts which contain respirable quartz. Until such further analyses have been carried out, the relationships and models presented in this report should not be used to predict risks at low mean concentrations of quartz in contexts, such as standard-setting, where precision of predictions is at a premium.

Logistic regression analyses of symptoms of chronic bronchitis showed relationships with age and smoking. In addition, there was evidence of an association with coalmine dust exposures, particularly with the period 1964 to 1970. There was little evidence to suggest a particular role for quartz.

Breathlessness as a symptom showed little evidence of association with dust exposure, except perhaps for a weak association with dust exposures in the period 1964 to 1970. Similarly, the symptom of wheezing showed little except perhaps a relatively weak dust effect in older men. Again, there was little evidence that quartz played any particular role in this.

There was evidence that, allowing for age, men with respiratory symptoms tended, after leaving the colliery, to stay unemployed, retired, or working in lighter jobs, while those who went on to further colliery or other heavy or dusty employment were less likely to be symptomatic. This has been interpreted as an employment selection effect.

Regression analyses of lung function variables showed the expected patterns of association with age and smoking, in that FEV_1 (and the ratio of FEV_1 to FVC) decreased with age, and showed an accelerated rate of loss in smokers. There was only weak evidence of any effect of dust or quartz exposures on FEV_1, and that only for the short period before the colliery closed 1978 to 1981. There was no strong evidence of a particular role for quartz. There was no evidence for a loss of FVC associated with dust or quartz exposures.

Additional analyses showed that reductions in FEV_1, FVC, and their ratio were associated with increasing category of small opacities. Adjusting for profusion category, there was no evidence of a residual association with dust or quartz exposures. Conversely, adjustment for dust exposures made negligible difference to the relationship with radiological category. This result is in contrast to the effects of more usual coal pneumoconiosis, where the presence of small rounded opacities has no influence on FEV_1 after the direct effects of exposure to coalmine dust have been taken into account.

Continued medical surveillance of this population is clearly required, and might usefully, in future, prioritise attempts to survey men who worked in the occupations which had the highest exposures to quartz. Further analysis of the data from the present study should concentrate on a detailed critique of the effects of the lower exposure ranges, and further investigation of the roles of peak concentrations in individuals' exposure histories. The results should provide valuable evidence towards setting limits for respirable quartz in mixed dust.

1. INTRODUCTION

1.1 Respirable coalmine dust and quartz in British epidemiological research

In the early 1950s the National Coal Board began the Pneumoconiosis Field Research (PFR) programme, and this has been the principal source of epidemiological data on coalworkers' pneumoconiosis in the UK. The programme of collection of research data lasted over thirty years, and was based on regular examinations of the workforce at selected collieries, detailed descriptions of the wide range of working environments within those collieries, with dust sampling and compositional analysis, and regular recording of the times each man spent working in those environments.

Many analyses of the extensive body of PFR data have concluded that exposure to respirable mixed coalmine dust generally, rather than to its quartz content specifically, was the primary determinant of both incidence and prevalence of simple coalworkers' pneumoconiosis (CWP) (Jacobsen *et al.*, 1971; Walton *et al.*, 1977; Hurley *et al.*, 1982), and of incidence of progressive massive fibrosis (PMF) (Hurley *et al.*, 1984; Maclaren *et al.*, 1989), for miners working in collieries where the quartz content of airborne dust was generally low (average 5%). Important unexplained differences in colliery-specific risks of developing CWP were not generally explicable in terms of average differences between the proportions of quartz in the dusts from different mines (Walton *et al.*, 1977; Hurley *et al.*, 1982). These findings led to extensive debate on the rôle of quartz in coalminers' pneumoconiosis. Walton *et al.* (1977) suggested that the presence of illite, a clay mineral, might explain the lower incidence of CWP at one high-quartz colliery in Nottinghamshire. Le Bouffant *et al.* (1977) hypothesised that the mechanism for such an effect could be that minerals such as illite released ions, perhaps of aluminium, which were adsorbed onto the surfaces of the quartz particles and interfered with their activity. Dodgson (1984), in reviewing these findings, noted the suggestion of Davis *et al.* (1983), that 'coalworkers pneumoconiosis should be regarded as a variable entity, the exact pattern of which depends on the composition of the dust retained in the lungs'.

More recent results have not all been consistent with the earlier findings, and have sometimes pointed to a more direct rôle for quartz. Jacobsen and colleagues carried out a case-control study of miners which showed that exposures to dust containing relatively high percentages of quartz (Jacobsen, 1980; Hurley *et al.*, 1982) were associated with 'rapid progression' of CWP and perhaps influenced the risks of developing PMF (Jacobsen and Maclaren, 1982). Robertson *et al.* (1987) extended these findings to the British coalfields generally. Cowie *et al.* (1990) later showed from PFR data that, for a given profusion of simple pneumoconiosis, men who had progressed rapidly to that profusion had doubled risks of progressing to PMF in a subsequent period, when compared to those whose simple pneumoconiosis had developed more slowly.

Soutar and Collins (1984) and Cowie *et al.* (1990) showed that one relatively rare type of PMF, described as consisting of conglomerations of small rounded opacities of type 'r', was associated with previous exposure to dust of a higher quartz content . These findings were supported by autopsy studies of the lungs of deceased miners for whom radiographs taken during life were available, and where the lesions in this particular type of PMF were found to be formed by aggregation of nodules, and to be associated with higher proportions of quartz in the dust retained in the coalworkers' lungs (Douglas *et al.*, 1988). Ruckley *et al.* (1989) reported that the rate of development of PMF lesions in life was associated with the amount of quartz recovered from the lungs at autopsy.

Taken together, these findings suggest that the answer to the quartz question in coal mines may not be simple. For example, they do not explain why the prevalence and incidence of both CWP and PMF were generally low at some collieries where percent quartz was high, notably one PFR research colliery in Nottinghamshire.

Data from Scotland, where the incidence of pneumoconiosis was generally low, but where unusual features in one colliery led for a time to high quartz content in respirable dust at some locations, added a new dimension to the discussion. Colliery P was the one Scottish colliery at which more than three PFR surveys took place. It received a total of six PFR surveys between 1954 and 1978. The prevalence of pneumoconiosis at this colliery since the research started was low, reflecting the Scottish experience generally. However, the medical officer who read and classified the radiographs taken at the 6th PFR survey in 1978 considered that 21 radiographs from the 623 taken showed unusually rapid progression of simple pneumoconiosis when compared with radiographs taken four years previously from the same men at the 5th survey.

This observation spurred a case-control study, of the 21 'rapid progressors' at this colliery (Seaton *et al.*, 1981), and 21 age-matched controls without pneumoconiosis. The results showed clear relationships of the progression of pneumoconiosis with exposure to respirable coal dust, and in particular to the quartz part of that dust; and it was suggested that the radiological appearances of the cases had, in many respects, the appearance of silicosis. Miller and Kinnear (1988), in a more extensive investigation of radiological evidence from this colliery, confirmed the results and demonstrated that the association was strongest with elevated quartz exposures experienced in the 1970s. The source of the quartz was sandstone strata between which the coal lay; and, for a time in the 1970s, incursions of the coal-getting machinery into these strata had been responsible for the emission of respirable quartz dust, and for adding it to the airborne burden of respirable coal dust.

1.2 Experimental studies on the inhalation of coalmine dust and quartz

Dust from workings in the Scottish coal seam associated with the rapid progression of pneumoconiosis was subjected to a programme of experiments to investigate its pathogenicity, reported by Robertson *et al.* (1984) and Davis *et al.* (1991). From an adjacent colliery working the same seam, two distinct samples were obtained in different working conditions: the first contained about 25% quartz by mass, and the second only about 7%. Groups of rats were exposed by inhalation to these high- and low-quartz dusts, at the same respirable mass concentration. At the end of the experiment, the rat lungs showed massive hypertrophy of the lymph nodes, and development of pulmonary fibrotic nodules, analogous to those found at autopsy in pneumoconiotic miners. There was a very clear relationship between the severity of these responses and the proportion of quartz in the dust. Comparisons were also made between a second high-quartz dust sample from this seam and a dust sample from a Nottinghamshire colliery where the risks of pneumoconiosis were low (Davis *et al.*, 1991). Table 1.1 summarises the compositions of the dusts collected for these studies, and shows that the later Scottish dust differed from the earlier samples in having a significant illite component.

All the dusts induced inflammatory responses and some interstitial fibrosis in the rat lungs. The principal difference was that both the high-quartz Scottish dusts induced profuse development of fibrotic nodules; the relatively high proportion of illite in the second high-quartz Scottish dust did not prevent the development of the fibrotic nodules. The Scottish dust with the lower quartz produced considerably fewer nodules than those with high quartz. The Nottinghamshire dust, in contrast, produced very few nodules in the rat lungs, but induced a widespread alveolar proteinosis and diffuse fibrosis, associated with large numbers of enlarged and activated macrophages.

Measurements were made of the thermo- and radio-luminescence properties of the second high-quartz Scottish dust and the Nottinghamshire dust. These properties are believed to relate to the free quartz surface area. The results showed that, although the Nottinghamshire dust was composed of smaller particles and thus had a greater surface area per mass, the Scottish dust had a free quartz surface area greater than the Nottinghamshire dust by a factor of around five.

Miller *et al.* (1993) discuss possible interpretations and explanations of these findings; the most plausible is that the quartz component of the fine respirable dust collected from the Scottish seam consisted of freshly fractured fragments of larger quartz grains, so that most of the surface of these respirable quartz particles would be free from contamination of any type at the time of their inhalation. In contrast, the quartz in the dust from Nottinghamshire was from ancient dirt bands. Its particles were inherently very small, and their surfaces are likely to have been worn and contaminated many millions of years ago. These suppositions are entirely consistent with the radio- and thermo-luminescence assessments of the free quartz surface area dusts, and they do not contradict experimental data showing that the presence of various ions in solution can affect the activity of quartz particles.

1.3 The need for a follow-up study at colliery P

Putting together the results from the epidemiological, autopsy, cell biology and animal inhalation studies, a picture emerges which is consistent with the following premise: while, in many coal seams, the risk of pneumoconiosis is influenced principally by exposure to respirable dust, and while differences in pneumoconiosis risks between collieries can not easily be explained in terms of dust composition, nevertheless differences in activity between dusts from the same seam can in some cases be related to the quartz content of the dusts.

Taking all the evidence together, our best understanding of the events at colliery P, and of the reasons for the rapid progression observed in some men there in the late 1970s, is that the conditions in some parts of that colliery led to men being exposed to respirable dust containing a proportion of very fresh quartz. This exposure, and in particular its quartz component, was very unusual in the PFR, and we therefore had little evidence as to what effects it might have in the long term. The questions were obvious: Would those in whom rapid radiological progression had been observed go on to progress further? Would there be any progression in men with similar exposures who had normal radiographs at 1978, or who were not examined then? And how did the risks of these events relate to the intensity and duration of exposures to dust and quartz experienced by the workers involved?

Answers to such questions could be obtained only by a follow-up study of the appropriate population. This report describes such a study, in which men who worked at colliery P during the 1970s were traced and invited to attend a survey similar to those of the PFR, in late 1990 and early 1991.

2. OBJECTIVES

The aims of the study were:

a) to determine the current respiratory health status of men exposed to unusually high concentrations of respirable quartz between about 1968 and 1980; and

b) to study the quantitative relations between history of exposure to respirable quartz in mixed coalmine dust and risk of chest radiographic and lung functional abnormality.

3. METHODS

3.1 Selection of study population

The programme of Pneumoconiosis Field Research (PFR) at Colliery P began in 1954 and continued until the Colliery closed in 1981. We refer throughout this report to PFR surveys and to the Inter-Survey Periods (ISPs) between them, during which data on exposures were collected. The approximate chronology of these was as follows (where the months given are those containing the majority of the several weeks which the surveys took to complete):

Month of Survey		**Begins**
(Prior to start of research)		ISP 0
02/54	PFR 1st survey	ISP 1 (~ 4 years)
04/58	PFR 2nd survey	ISP 2 (~ 6 years)
02/64	PFR 3rd survey	ISP 3 (~ 7 years)
12/70	PFR 4th survey	ISP 4 (~ 4 years)
10/74	PFR 5th survey	ISP 5 (~ 4 years)
11/78	PFR 6th survey	ISP 6 (~ 2 years)
		ISP 7 (four months)

The study of Miller and Kinnear (1988) was based on a detailed re-examination of the available chest radiographs for men who had attended any of the 4th, 5th and 6th PFR surveys at Colliery P, which took place in 1970, 1974 and 1978 respectively. This led to a study group of 1416 men, for whom a total of 2612 relevant radiographs were retrieved.

This group was adopted as the target group for the new follow-up study. It was therefore resolved to attempt to trace as many as possible of this group, and invite them to participate in a medical survey similar to those of the PFR.

3.2 Available data

The present study was a direct extension of that reported by Miller and Kinnear (1988), and the database constructed to contain all the relevant data for that earlier study became the starting point for the new follow-up study. This section describes the legacy of materials and data available from the earlier study.

3.2.1 Chest radiographs and radiological assessments

By definition, full-sized posterior-anterior chest radiographs were recorded as having been taken for at least one of the three qualifying surveys for each individual. Readings of the type and profusion of any pneumoconiotic abnormalities had been made at the time of the surveys. More recently, for the study reported by Miller and Kinnear (1988), these radiographs (except for a few which could not be included in the exercise) had been augmented by radiographs from a routine British Coal (then National Coal Board) radiological survey in 1980. All the radiographs had been organised into independent randomised batches, and classified by a panel of five readers with paramedical backgrounds but without medical qualifications, who had been self-trained (Copland *et al.*, 1981) to record their assessments of chest radiographs under the ILO (1980) classification scheme. In a separate reading exercise, three chest physicians with experience of the radiographic appearances of pneumoconiosis examined sets of radiographs for each man in a side-by-side viewing, to assess progression of small and large opacities. All of these existing and new assessments of radiographs had been stored in a database purpose-built for the project, as described in Miller and Kinnear (1988).

3.2.2 Other data from PFR medical surveys

Miller and Kinnear (1988) also describe the extraction, checking and organisation into the project database of other relevant data for the study group. These included identification, National Insurance number and date of birth; and data from PFR medical surveys attended, including height, weight, lung function measurements and responses to a questionnaire on smoking habits and respiratory symptoms.

3.2.3 Data on respirable dust and quartz exposures

Respirable dust concentrations were measured at Colliery P from 1954 until the colliery's closure in 1981. Early measurements were made using the Standard Thermal Precipitator and particle counting. Subsequent measurements were made using the MRE 113A gravimetric dust sampler, and earlier data were converted to the gravimetric scale. Dust samples were analysed for quartz, kaolinite and illite/mica using infra-red spectrophotometry (Dodgson and Whittaker, 1973).

The respirable dust exposures experienced by each coalworker during his employment in coalmining was characterised by cumulating the products of concentrations typical of specific occupations and the time worked in those occupations (Hurley et al, 1979; 1982). By using the proportions of constituent fractions of the dust, notably ash and quartz, it was possible similarly to calculate estimates of cumulative exposures to these constituents.

For the study of Miller and Kinnear (1988), it was decided to retain separately the exposure data from inter-survey periods ISP 3 (between 3rd and 4th surveys), ISP 4 (between 4th and 5th), and ISP 5 (between 5th and 6th), and to form a cumulative total of any exposure from ISP 0, ISP 1 and ISP 2, that is up to the 3rd survey. All the relevant exposure data were extracted from computer files and loaded into the database. From ISP 3 onwards, a distinction was maintained between 'measured' exposures, based on information on the men's activities obtained from the colliery payroll systems, and 'unmeasured' exposures based on interview data on activities not captured by that system, and the measured and unmeasured components were stored separately. 'Measured' exposures were based on a substantially greater level of detail on underlying activities and their associated concentrations. 'Measured' exposure data were available for ISP 5 by individual quarter years, and this level of detail was retained in the database.

3.3 Tracing and inviting to survey

3.3.1 Routes of tracing

As described in 3.1, membership of the study population was defined by an individual having attended one of the routine PFR surveys in 1970, 1974 or 1978. Colliery P closed in 1981. The follow-up surveys were planned to take place in late 1990 to early 1991, and it was clear from the dates of birth available in the database that, while some men might still be in employment with British Coal, many men would be past retirement age by the time that the follow-up survey took place, and that some deaths were likely to have occurred among the population. In most past PFR work, the unique identification was by X-ray number; but men were unlikely to know their own X-ray number, and therefore exact identification of individuals would need to match name and date of birth. The PFR records included addresses, but many of them could also be out of date. There were several possibilities for confusion of identities, many of them intrinsic to traditional mining communities, such as similar names within families all of whom were mineworkers. All of these factors implied that the task of identifying and tracing individual men was likely to be difficult, and required great care.

A proportion of the men were also, by virtue of their attendance at the earliest round of PFR surveys, members of a cohort for the study of coalminers' mortality (Miller *et al.* 1981, Miller and Jacobsen 1985). Identification details of this cohort had been scrutinised in detail as part of the tracing procedures, and deaths among this sub-population could be readily identified from the mortality database files. It was considered highly desirable to eliminate other deceased men from the tracing exercise, both for efficiency and to avoid possible distress to surviving relatives.

Two routes were available which offered the possibility of contacting men who might have changed their addresses, while eliminating men who were deceased. The first was the letter-forwarding service offered by the Department of Social Security, and the second route was through British Coal's own pensions system. Under the Data Protection Act, neither system was permitted to relay to the IOM addresses which differed from the ones held in the PFR database, but both would forward contact letters to men directly.

Finally, the fact that colliery P was relatively local and at the heart of a community whose lifeblood had been coalmining could be used to advantage. It was realised that local contacts and knowledge could be extremely useful in tracing men not located by other more systematic methods. The following sections describe in some detail the tracing procedures employed, and how successful they were in action. Table 3.1 summarises the final achievement, both in tracing and in eventual attendance at the surveys.

3.3.2 Exclusion of those known to be deceased

A list of the PFR identity numbers of the men in the target population was prepared and matched against the mortality database entries for colliery P. This led to the identification of about 200 men as deceased. These were eliminated from further tracing efforts.

3.3.3 Letter forwarding

A letter describing the study and asking the individual to participate was constructed and printed. These were placed in addressed envelopes and sent to the DSS for forwarding. The forwarding system involves placing the envelope inside a larger envelope, with a note from the DSS explaining that they are acting simply as agents; that they have not revealed the individual's address; and that it would be entirely up to the individual whether or not he chose to contact the research team or participate in the study. This letter is reproduced as Exhibit A1.1 of Appendix A1.

Around the end of the first quarter of 1990, 1214 of these letters were sent to the DSS for forwarding. By the middle of June 1990, they had forwarded 1007. There were 164 men identified as already deceased (in addition to the previous 202), and 43 letters could not be forwarded because a current address could not be found. By September 1990, replies to this letter had been received from 580 men, of whom 466 had agreed to take part in the surveys.

As the replies came in, the identities were established of a group of men for whom DSS had been unable to forward a letter, or for whom no reply had been received. A second contact letter was created for these men, numbering 477. This letter is reproduced as Exhibit A1.2 of Appendix A1. The letters were passed to British Coal's Pensions and Insurance Department. Their success rate for tracing was rather poorer than that of the DSS, and they were able to forward only 196 letters. By November 1990, when the first phase of the survey started, 571 men had said they would take part.

3.3.4 Design of tracing control scheme

It was clear that the tracing exercise would be complex; that tracing would be achieved through different routes for different men; and that the exercise would take place over a period of time. It was therefore important to maintain good control procedures for keeping a record of the state of tracing for each individual at any time.

A computer file was constructed based on the identifying information initially available for each man. During the tracing exercise, this was regularly updated from the returns indicating vital status, whether a man had been traced and identified, and whether he had agreed to attend the survey. Provision was made for updates to identifying information, such as corrections to dates of birth, and for other corrections such as changes of address. Codes within the file recorded where any alterations had been made.

The return portion of letters of invitation was pre-printed only with the study number (PFR X-ray number), and the returned identifying information was carefully checked. Any apparent change was carefully scrutinised and checked against other men with the same surname to avoid confusion of identities. Alterations to names were accepted where difference was a plausible correction of spelling or a change to a second initial, but with the expected date of birth. There were some 13 returns which indicated a correction to date of birth which appeared plausible, in that it was confined to one of the elements day, month or year.

There were cases where the return contained alterations which were less plausible, and others which were clearly from the wrong individual. In these cases, efforts to trace the correct man were continued.

3.3.5 Advertisements, posters and publicity

Concerted efforts were made to create and sustain local awareness of the study's existence, of its purpose, and of the efforts being made to contact coalworkers who had been employed in Colliery P. Posters were printed, on fluorescent paper for visual impact, and distributed around the notice boards of miners' welfare and social clubs, of which there are many in the region surrounding colliery P.

In addition, a press release was prepared and sent out to all local media. The coverage achieved was good, and generated a few phone calls from ex-miners, adding to the number of successful contacts.

3.3.6 Local tracing

After the two letter-forwarding exercises were complete, the IOM sent recorded delivery letters to the last known addresses of 36 men which neither of the external systems had been able to trace. There remained some 375 potential subjects with whom IOM had had no contact, either because efforts to trace them had failed, or because they had not responded to letters sent to them. In order to try to reduce the size of this group, we employed the services of a retired NUM official from colliery P to attempt to contact individuals directly. His reports were used to update the tracing control file. By the end of the first phase of examinations, in January 1991, there were still 114 men not traced, and 238 men whose addresses were established but who had not replied to letters. Door-to-door visits obtained a reply from 190 men, of whom 124 agreed to attend.

3.3.7 Appointments made and kept

Once a man had replied to a letter or visit and agreed to participate, he was sent a second letter announcing that he would be contacted later for an appointment. The first appointments were made, for about 500 men, for the period between mid-November and Christmas, and 447 men were seen by the end of the year. A further week's surveys were scheduled for the third week of January 1991, and another 40 of these men were seen at this time. The second phase of surveys in April 1991 yielded another 63 attendances. One man of the target population was identified seriously ill in hospital, and a radiograph and questionnaire data were obtained, but he was not well enough to perform lung function manoeuvres. In total, the number of men surveyed, as shown in Table 3.1, was 551.

3.4 Survey methods

3.4.1 Location

Arrangements were made for the IOM's mobile survey units to be sited on land adjacent to the site of the former colliery P, with access to a water supply and a three-phase electrical power supply for the radiographic equipment. Arrangements were made where necessary to bring less able subjects to the site by car.

3.4.2 Radiography

The individual's name and identifying information were checked against the list of appointments, and the name and address of his GP were noted in case they were required for notification of clinical findings. A postero-anterior radiograph was then taken on 40 x 40 cm Agfa film, using a Siemens Polyphos generator with ruby screens. A moderately high kV technique (125kV) was used, with a moving grid. Films were processed immediately using a 3M XP510C automatic X-ray processor. A power supply failure on one evening session meant that it was not possible to take radiographs for two men, although the remainder of the examination was completed for them.

After a few weeks it was noticed that some of the films had begun to discolour, and brown stains appeared. This showed mainly on the clear parts of the radiograph, and so was worse over the mediastinum and subdiaphragmatic area, leaving the lung fields largely unaffected. The fault was ascribed to inadequate washing in the automatic processor. All films taken were checked and any with stains were collected together and put through a full wash cycle and dried again. While this did not clear the stains, it is expected to prevent further discolouring and deterioration of film quality.

3.4.3 Questionnaire

An experienced clerk applied a questionnaire, based on the Medical Research Council's respiratory symptoms questionnaire and very similar to those used in earlier PFR surveys. The survey recording forms are reproduced as Exhibit A1.3 of Appendix A1. Page 1 records identifying information, some of which was preprinted from PFR files. Page 2 recorded the man's occupational history (to the nearest month) since leaving the colliery. Pages 3 to 5 recorded the answers to the respiratory symptoms and smoking questionnaire, and page 7 provided for a short summary of selected aspects of the subject's health.

3.4.4 Lung function measurements

For consistency with lung function data from the PFR, lung function was measured at the follow-up survey using a modified Gaensler spirometer (Rogan *et al.*, 1973). For each inspiration, Forced Expiratory Volume in 1 second (FEV_1) and forced vital capacity (FVC) were recorded, the subject making three technically satisfactory forced expirations after a practice expiration.

3.4.5 Occupational History coding

The occupational history forms were passed to IOM staff with experience of coding occupations, who constructed a scheme for assigning an occupation code to each job described.

The final list of occupations was constructed on the principle that it is usually better to retain more distinctions, which can be pooled for analysis, than to group jobs too coarsely into broad categories which can then not be easily subdivided. The final list is shown as Exhibit A1.4 in Appendix A1.

3.5 Radiograph-reading exercises

3.5.1 Initial screening

Within a few days of each survey, an IOM physician screened each radiograph for pneumoconiotic abnormalities and for evidence of any other disease which might be present. All participants were sent a letter informing them of the result of this screening. In the cases where this yielded a positive finding, the letter advised the man to consult his GP; and, where pneumoconiosis was suspected, that he might be entitled to pursue a claim for compensation. In addition, where a man gave permission, contact was also made with his GP, advising him of the nature of the positive findings.

3.5.2 Design of epidemiological reading.

Many men in the study group had attended PFR radiological surveys on several occasions, in some cases back to the first round of surveys in the 1950s. Since there had been little progression before 1974, it was decided that the presence of pneumoconiotic abnormalities should be compared with that of radiographs taken in 1974 or 1978, but that comparison with earlier radiographs would not be necessary.

For each man, an envelope was prepared containing the radiograph taken at the follow-up survey in late 1990 or early 1991, plus any radiograph taken in the 1974 and/or 1978 surveys. This constituted about 1240 radiographs from 486 men. These were to be read under the ILO (1980) classification scheme. It was desired not only to obtain independent readings of each of the follow-up radiographs, but also to obtain readings in comparison with earlier radiographs. The reading protocol was designed so that both could be achieved efficiently. The written protocol and instructions to readers are reproduced as Exhibit A2.1 in Appendix A2. Three physicians with considerable experience of classifying pneumoconiotic abnormalities on chest radiographs were recruited as readers for the study. They were told the purpose of the study, and asked to read the protocol before proceeding to read. Standardised recording forms were prepared, with complete instructions for completing these. The instructions are reproduced as Exhibit A2.2, and the recording form as Exhibit A2.3, in Appendix A2.

The radiographs were organised in 13 batches. These were all of about 100 radiographs except the first, which was used as a trial batch. After completing this batch, the recording forms were checked for compliance with the recording instructions, and any variation in practice was standardised at that point.

In the last round of follow-up appointments, which took place in April 1991, 63 men were examined. Batches for these men, including a total of 155 radiographs, were read at a later date, by the same readers and under the same protocols.

3.6 Extraction of extra exposure data

All of the exposure data in the database constructed for the study reported by Miller and Kinnear (1988) (see 3.2.3 above) were available to the present study, and these covered the periods up to the 6th PFR survey in 1978. There were in existence additional data on dust concentrations and times worked for the time period from the 1978 surveys to the time when, prior to the colliery's closure, sampling was discontinued. These were extracted from records.

Because all exposure information for ISPs 3 and 4 was stored in a way which related to whole ISPs, no detail was directly available about exposures over shorter time periods within those ISPs. Reports on the environmental sampling contained additional information on the time periods during which specific occupational groups existed, and it was realised that this information made it possible to describe in more detail when specific components of these ISP exposures occurred. These dates were also extracted for loading to the database.

It was known that many men obtained work at other local collieries after they were laid off at colliery P. These collieries were not part of the PFR, but all relevant data from dust samples taken at the two nearest collieries were obtained from British Coal's Scientific Control department. In the event, these turned out not to be sufficiently detailed, particularly as regards quartz content, and no further use was made of them. The two principal collieries involved both closed within a few years of Colliery P.

3.7 Data recording, transfer, input and checking

Experienced staff were used for all tasks of data collection and recording, with explicit instructions and briefings. Recording forms were checked briefly by eye before being punched to data files by experienced punch operators.

Extensive checks were performed on the data, for adherence to prescribed coding schemes, completeness of data, and consistency between different data items from the follow-up examinations and earlier PFR data.

3.8 Database construction

The data from the study of Miller and Kinnear had been organised into a database using the facilities of the SIR database management system (Robinson *et al.*, 1980). Because of the close relationship between that study and the present follow-up, it was decided that all the new data should be added to the existing database.

3.9 Statistical analysis

Tabulations and summaries of the data, including those employed to check and validate the data after punching, used the tabulation and data plotting facilities available within the database management system SIR (Robinson *et al.*, 1980), and within the statistical packages BMDP (Dixon *et al.*, 1988) and Genstat (Genstat 5 Committee, 1987).

Investigation of relationships between health-related responses and exposure histories, adjusting for factors such as smoking habits, used the familiar epidemiological tools of regression analysis. Linear regression (Draper and Smith, 1981) was used to analyse responses measured on continuous scales, such as lung function measurements. Symptoms, and radiological attributes treated as present or absent, were analysed using logistic regression methods (Collett, 1991). All regression analyses were fitted using Genstat (Genstat 5 Committee, 1987).

Presentation graphics for this report were produced on an IBM-compatible personal computer using the graphics package Sigmaplot (Kuo *et al.*, 1992).

4. EXPOSURES TO DUST AND QUARTZ

4.1 Environmental conditions

One key aspect of the PFR research was the collection of frequent and detailed measurements of the environmental conditions in which men worked. Periodic summaries of these data allowed an overview to be taken. Exhibit A3.1 in Appendix A3 contains reproductions of tables of results from the summary reports on environmental conditions at the colliery, covering the time period 1964-1974; similar data from 1975-1981 are Exhibit A3.2. These data as summarised are specific to particular Occupational Group Serial Numbers (OGSNs). A casual glance identifies, for example, high dust and quartz levels at Face OGSNs 514, 532, 551 and several others. However, the large number of OGSNs and the lack of structure in the tables makes it hard to obtain an overall picture from these alone.

Figure 4.1 shows the length of time for which each OGSN existed, from the dates in the tables of Appendix A3. Typically, an OGSN referred to a specific occupation on a particular face worked within a seam. Thus the OGSNs from the same seam are grouped together in Figure 4.1.

Although these data in Appendix A3 are mean concentrations for the whole life of each Occupational Group, the computer data files retained individual quarterly means for each OGSN from 1969 onwards. Figures 4.2 to 4.10 summarise these quarterly values.

Figures 4.2 to 4.4 show the quarterly mean respirable dust concentrations in a variety of underground occupations, for the three main seams worked at colliery P (Parrot, Kailblades and Splint), wherever there were more than 10 samples taken in a quarter. It should be noted that these occupations do not correspond exactly with OGSNs, because they are not specific to faces worked. However, since in each seam there was usually only one face being worked at a time, the amount of overlap is in fact very small. This is illustrated in Figure 4.2, where the duration of the life of each face is indicated by the horizontal dotted lines superimposed on the graph, each of which is labelled with the identity of the face. This graph demonstrates that there were occupations associated with the Parrot seam where respirable dust concentrations exceeded 5 $mg.m^{-3}$ for considerable lengths of time, and shorter periods when higher levels were recorded. The corresponding graphs of Figures 4.3 and 4.4, for Kailblades and Splint seams, also have a proportion of values above 5 $mg.m^{-3}$, but without such excursions as in the Parrot seam. In general, the occupations with the highest concentrations were those associated with the return end of the face, as would be expected. The maximum mean dust concentration of any OGSN for any of the quarters at the Parrot seam was 22.32 $mg.m^{-3}$ for the occupation of return stableman. In the Kailblades and Splint seams the highest values were 7.51 and 12.77 $mg.m^{-3}$ respectively.

Table 4.1 identifies the specific OGSNs at the Parrot seam with mean respirable dust concentrations greater than 5 $mg.m^{-3}$ for one or more quarter, or mean respirable quartz concentrations greater than 1 $mg.m^{-3}$ in a quarter. Generally, high values for the two variables tend to occur together. Comparatively high values appear for return stablemen and the power loading team at the P.03 face.

Eight OGSNs at Kailblades had associated concentrations greater than 5 $mg.m^{-3}$ (most exceeding this only slightly); most were return stablemen or rippers. At Splint three OGSNs exceeded 5 $mg.m^{-3}$; face team (No.2 face), return stablemen (No.2 face) and return ripper (Sp.03 face). Again, none of the means was excessively high. Looking at quartz values, for the Kailblades seam, over the same period, there were no mean quartz concentrations exceeding 1 $mg.m^{-3}$; one mean concentration of 1.57 $mg.m^{-3}$ was recorded for return rippers at the Splint seam during the quarter from April 1979.

Figures 4.5 to 4.7 are similar to those for respirable dust, but summarise the proportion of quartz measured in the dust samples. In general, these are not means, but are based on at most a single value per quarter, because it was necessary to bulk individual samples for compositional analysis. In fact, this was often done over more than one quarter within an OGSN, and the effect of this is clearly seen in the many places where adjacent quarters share the same concentration estimate. Again, the contrast between the patterns for the different seams is very marked. In the Parrot seam, there were many bulked samples returning values of more than 20% quartz, and some in excess of 50%. There is a clear correspondence between the highest values and the life of particular faces within the seam. The values from the other two seams hardly ever exceeded 15%, and never reached 20%.

An estimate of the concentration of quartz in each respirable sample can be obtained by multiplication of the mass concentration by the quartz proportion. The latter, as mentioned above, is an average over many samples, and this may smooth out some variation between the true quartz concentration in individual samples. The quartz concentrations so estimated are also summarised by OGSN in the tables in Appendix A3.

Figures 4.8 to 4.10 summarise the estimated average quartz concentrations for each quarter for each of the three seams. In this series, the contrast between the three seams is even more marked than before. In the Parrot seam, the combination of high dust levels and high proportions of quartz yields some very high estimates for concentrations of respirable quartz, some exceeding 10 $mg.m^{-3}$. In the other two seams, the corresponding values were almost without exception below 1 $mg.m^{-3}$.

In summary, some workers in the Parrot seam at Colliery P experienced, during the mid 1970s, much higher concentrations of respirable dust and quartz than workers in other seams. The jobs associated with these exposures were situated at the return ends of faces, particularly stablemen, rippers and coalface workers. There were several periods of very high concentrations between mid 1972 and mid 1973 on the P.03 face, but there were also unusually high concentrations, particularly of quartz, throughout the period from 1972 to 1977.

The coal measures in faces P.03, P.04 and P.27 were thinner than in earlier Parrot seam faces, and the roof and floor of each face were sandstone. The mining method employed at P.03 in 1972 and 1973 (fixed drum shearer and hydraulic props with a minimum height greater than the seam thickness) made it necessary to cut into the sandstone roof and/or floor, causing the very high dust and quartz concentrations. Even after improvements had been made to the mining methods, the thin seams in faces P.03, P.04 and P.27 made excursions into the sandstone strata, and consequently high quartz concentrations, inevitable. Quartz concentrations were controlled to lower levels from 1977 on.

4.2 Measures of individuals' exposures

Section 3.2.3 above describes the methods used to characterise exposures experienced by the coalworkers in the PFR studies. The data used here had been extensively reworked for the study of Miller and Kinnear (1988), which retained separately the exposure data from inter-survey period (ISP) 3 (between 3rd and 4th surveys), ISP 4 (between 4th and 5th), and ISP 5 (between 5th and 6th), and used a cumulative total of any exposure from ISP 0, ISP 1 and ISP 2, that is up to the 3rd survey. All the relevant exposure data were extracted from computer files and loaded to the database.

Within the present study, some small corrections were made to individual erroneous items of data discovered during data screening. Data for the periods designated ISP 6 (from around the 6th survey in 1978 to October 1980), and ISP 7 (from October 1980 to February 1981) were added to the database. Then programs written in the database retrieval language were run to combine data on times worked with concentration data, to calculate exposures to respirable dust and to respirable quartz in the separate periods up to 3rd survey (ISP 0,1,2), ISP3, ISP 4, ISP 5, ISP6 and ISP 7. During these calculations, the 'measured' and 'unmeasured' components (see 3.2.3) were combined. The 'unmeasured' were in most cases much smaller than the 'measured'. The more detailed data on quarterly exposure were retained in the main database for further inspection if required.

Table 4.2 summarises the exposures calculated for the individuals in the study population, which were then used in the analyses of exposure-response relationships described in Chapter 6. Many men had sizeable exposures prior to 3rd survey. Exposures in later ISPs were far from negligible for many individuals. Table 4.3 summarises the proportions of quartz in the summary exposures, calculated as the ratio of the estimated quartz exposure to the estimated dust exposure. Notable here is that the minimum, mean and maximum values for percentage quartz all reached a peak around ISPs 4 and 5, and that in those periods the maximum increased by a greater factor than did the mean. This is in line with the observation made in 4.1 above, of unusually high quartz concentrations and percentages in some occupations during this period. Because some men worked in dusty jobs in more than one ISP, and because high quartz concentrations tended to occur with generally high levels of dust, the measures of exposure are not independent within an individual, and this has important consequences for the interpretation of statistical analyses. Table 4.4 contains the correlations between the different exposure variables used in later analyses.

4.3 Occupational exposure after leaving the colliery

4.3.1 Description of the data

Men attending the follow-up survey were asked for an occupational history to cover the time after they left Colliery P. These data, as recorded on the form on page 2 of the survey recording form (Exhibit A1.3, Appendix A1), comprised dates of leaving and entering different occupations or periods of unemployment, and the job involved. A total of 1479 periods of occupation were reported by the 549 men surveyed.

The dates reported by the men were checked to ensure that they formed a complete coverage of the follow-up period, and in addition were checked against the dates at which men were known, by the date of the radiograph, to have attended a PFR survey. As expected with dates obtained from memory, there was considerable evidence of confusion over exact dates in occupational histories. There were, however, only five cases in which dates of leaving were flatly contradicted by dates of existing radiographs. Further examination of other data files, including data on times worked, suggested that it was the men's memories which were inaccurate, so processing of the occupational history date assumed the recorded date of the radiograph as the date of leaving. It was not possible to obtain any independent verification of any of the other reported dates.

4.3.2 Time spent at other collieries

Three hundred and thirty seven men spent time in other collieries after leaving Colliery P. The number of colliery jobs a man had after Colliery P ranged from one to seven, with most having only one (Table 4.6). The amount of time spent working in other collieries ranged from 2 months to 26 years 7 months with a mean of 5 years and 4 months. These durations are summarised in Figure 4.11.

Most of this time was attributed to work in one or other of the two collieries which still existed in the area after the closure of Colliery P. Respectively, 33% and 24% of the follow-up population worked at each of these collieries. In both of the other collieries, the average time spent was five years. There were a few individuals who moved to training, workshop or Headquarters jobs within the mining industry.

4.3.3 Time spent in non-colliery occupations

All but two men had some time in occupations or activities other than in coalmining. The total of such times for each individual ranged from only 7 months to 27 years and 2 months, with mean 8 years 7 months.

The specific occupations are detailed in Table 4.5. Many men had periods of unemployment, strikes and/or ill health after leaving Colliery P, and by the time of the follow-up a large number had retired from employment. The most common occupations encountered were of the type which we have chosen to categorise as 'non-industrial' or 'industrial (non noxious)'. This is not surprising, since there is little heavy industry in the region of Colliery P. While only small numbers of individuals had worked in each of the other occupations, the amount of time was often non-trivial.

4.3.4 Quantifying exposures after leaving Colliery P

It was clear that there was no way in which exposure to respirable hazards could be estimated reliably for these occupational spells, since there were no data on concentrations available of any form for the non-colliery jobs, and, except for routine contol point measurements, very little data even on conditions within the adjacent collieries. However, the descriptions of jobs made it possible to distinguish, for instance, between dustier colliery jobs such as those involved in face development and coal getting, and other colliery occupations. Any set of grouped occupations is in some sense arbitrary, but the aim should always be to maintain distinctions considered important, while avoiding unnecessary or irrelevant detail. In this instance, where the prime interest was in colliery exposures, it was decided to summarise, for each man, the amounts of time spent in the following categories of occupation:

- Coal mining in the adjacent colliery 1 (face and development);
- Coal mining in the adjacent colliery 1 (other occupations);
- Coal mining in the adjacent colliery 2 (face and development);
- Coal mining in the adjacent colliery 2 (other occupations);
- Coal mining in other collieries (face and development);
- Coal mining in other collieries (other occupations);
- Other industrial (dusty or noxious);
- Other industrial (non-dusty);
- Non-industrial;
- Unemployed, retired, etc.

Variables summarising the times spent by each man in each of these categories were calculated and stored with the information on Colliery P exposures.

5. SURVEY RESULTS

5.1 Characteristics of the population surveyed

5.1.1 Characteristics at time of follow-up survey

The follow-up survey was conducted in three waves, over a period from late 1990 to April 1991. A total of 550 men were examined. An additional man was seen in hospital, bringing the total surveyed to 551. As described in chapter 3, it was intended to interpret the follow-up survey results in the light of the data held for these individuals in the PFR database, and there was extensive checking to ensure that the two datasets were consistent. These checks revealed discrepancies in the height data held for two individuals, which could not be easily explained either by measurement error or by simple recording error. These and other data suggested the strong possibility that some confusion of identity for two members of the target population had occurred at some point, and the survey results from these two individuals were excluded from all the analyses reported in the following sections. This exclusion reduced the population surveyed to 549 men. Inspection of the radiological data for these men showed that both had low profusions of small opacities, so that it is unlikely that these omissions could have had any serious distorting effect on regression analyses of the health response.

A few men had some individual items of data missing, and therefore the numbers available for a full analysis are in some cases were slightly reduced. Notably, it was not possible to obtain radiographs for two individuals, and all analyses relating to radiology were based on a total of 547 men.

The ages of the 549 men surveyed ranged from 29 to 85 years, the mean age being 59 years. The majority of men (371; 68%) were aged 55 years or older at the time of follow-up survey (Table 5.1).

Forty-six percent (251) of the population were smokers, 38% (210) were ex-smokers and 16% (88) non-smokers (Table 5.1). The younger men, under 35 years, had a relatively high proportion of non-smokers (38%). The 45-54 age group had the highest proportion of smokers (59%), and the group of men aged over 75 contained most ex-smokers (53%). None of these results is surprising

The men's heights (excluding 6 missing values) ranged from 144 to 192 cm; the mean height was 171 cm (standard deviation 6.54). Individual weights (excluding 4 missing values) ranged from 48 to 150 kg, the average being 80 kg (standard deviation 12.88).

5.1.2 Comparison of responders with non-responders

The 549 who attended the follow-up survey arose from the target population of 1416. Of the remainder, 384 were known to have died by the time of the follow-up study in 1990-91. The remaining 483 men either had not been traced, *or* had refused to attend, *or* had not kept appointments to attend.

In any study where there is sizeable non-response, it is appropriate to ask how representative of the target population are those who responded. One way of addressing this question is to compare the groups in terms of available information, and in this case, by definition, we have the data from the PFR surveys attended in the 1970s. We have therefore compared the attenders and the non-attenders, after excluding those known to have died, in terms of their ages and smoking habits at the PFR surveys.

For both attenders and non-attenders at the follow-up, the range of age at the last attended of the 4th, 5th and 6th PFR survey was 15-69 years, with mean 45 years. Table 5.2 compares the ages by 10-year intervals.

It is clear by inspection of Table 5.2 that the proportion of non-attenders decreased with age: among younger men (<35 years) less than a third attended the follow-up survey, while among older men (45-54 years) more than two thirds attended. Anecdotal evidence suggests that many younger men moved away to find work after the colliery was closed, so this pattern is plausible.

Classifying attenders and non-attenders by their smoking habit at last survey (Table 5.3) shows that the proportion of men attending follow-up survey was similar for each smoking group (52% to 56%). Thus there is little evidence for a bias in the follow-up study population with regards to smoking habit.

More extensive tables (not shown here) were produced to examine the attendance rates by age and smoking simultaneously, but these demonstrated that the age-dependence of the response rates was similar in all the smoking groups. Other tabulations demonstrated that these patterns did not depend on which PFR survey the individual was last seen at, and again these extensive tables are not shown here

5.2 Initial clinical screening of radiographs

Within a few days of being taken, each radiograph was examined by an occupational physician. His remit was to pass clinical judgement on any visible feature which might have clinical significance, including the presence of pneumoconiotic abnormalities.

While this clinical screening was not intended to be accompanied by a full classification of abnormalities under the ILO (1980) scheme, the results for pneumoconiotic abnormalities were recorded as profusion on the 12-point scale, plus a note of the shape and size of the opacities observed. A recorded profusion of 1/1 or greater was considered to justify alerting the individual to the presence of some pneumoconiosis, and letters to that effect were sent to 90 men satisfying this criterion. Table 5.4 shows the range of profusions recorded for these individuals. Large opacities suggestive of PMF were evident in 19 of these 90 cases with pneumoconiotic abnormalities, and seven of these were referred for further tests to exclude the diagnosis of apical tuberculosis.

Comparison with earlier radiographs for these men showed that 17 subjects had evidence of previous pneumoconiosis. All 17 showed progression at the follow-up survey. Of those men identified by Seaton *et al.* (1981) as rapid progressors, 13 attended the follow-up, and all were judged to have shown further progression.

In addition, other non-pneumoconiotic abnormalities were observed on 23 radiographs. In all of these cases, both the worker and his general practitioner were advised of the nature of the abnormality. The distribution of these abnormalities was as follows:

Cardiomegaly and/or left ventricular failure	10
Gross emphysema	2
Previous lobectomy	1
Apical lesion suspicious of tuberculosis	7
Hilar enlargement with lymphadenopathy	1
Pleural reaction or effusion	1
Straight left heart border	1

5.3 Epidemiological classifications of radiographs

This section describes the epidemiological classifications made by the the three readers in the reading exercises which followed the surveys. Throughout, the epidemiological readers are identified by the code numbers 002, 013, 015.

5.3.1 The nature and extent of radiological re-classifications

Under the protocol for the epidemiological reading exercise, each reader first classified the radiograph taken during the follow-up survey, and then was permitted to record an amended classification after examination side-by-side with earlier radiographs from the same man.

The readings for this study cover 547 follow-up radiographs which were read by three readers, resulting in 1641 classifications. Only 36 (2%) of these classifications were revised. One of these re-classifications involved a film subsequently being coded as of unacceptable quality, thus a revised reading was not given. The remaining 35 re-classifications related to 35 different individuals, that is no two readers re-classified the same film. The distribution of numbers of re-classifications across readers 002, 013 and 015 was 12, 5 and 18 respectively. Table 5.5 shows the number of changes arising from the re-classifications in each of the sections of the ILO Classification, for each reader.

Re-classification of profusion of small opacities was most common; profusion was changed on 27 occasions, zone on 20 occasions, and shape and size on 30 occasions. Re-classification of profusion, zone, and shape and size were not independent; for example on 14 occasions films which had previously been classified as having no small opacities (0/0) were re-classified as 0/1 or greater, necessitating a change in both zone and shape and size.

Reader 015, on four occasions, re-classified a film in terms of technical quality; each change implied that the film quality was poorer than previously thought (in addition this reader re-classified one film as unacceptable as noted above).

There were a few changes made in the assessment of other pleural abnormalities. Reader 002 made two alterations to classifications of costophrenic angle obliteration; once deciding, on reconsideration, that such an abnormality was present and once deciding that, in fact, it was not. Reader 015 also made one such change of the latter type. Reader 002 made a change to one classification indicating that diffuse pleural thickening was, on revision, apparent.

Reader 015, on re-classifying two films, noted 'other abnormalities' which had not previously been recorded. The presence of a comment in a revised classification, when none had been made previously, was common mostly in reader 015's revisions. The main comment made on revision was that the abnormalities on the follow-up film were exaggerated by radiographic technique and that as a result the film had been over-read. There were also comments suggesting that on some occasions film technique had been over-compensated for on the first reading causing under-reading. It was also commented that on some occasions an abnormality on the '91 film had not been noticed until the whole series of films had been read.

Table 5.6 shows the detail of the profusion categories for radiographs for which some reclassification was recorded. Readers 002 and 013 had a tendency to re-classify films to a higher profusion, whereas reader 015 reclassified more films to a lower profusion category. In all 67% (18) of changes to profusion were to a higher point on the 12 point scale, 14 of these from 0/0 to a profusion 0/1 or greater; there were eight, three and three such changes for readers 002, 013 and 015 respectively. The largest increase in profusion was from 0/0 to 1/2, recorded by reader 015. There were only four re-classifications to a revised profusion category of 0/0, 3 of these from 0/1.

The ILO (1980) classification describes the shape and size of small opacities by the code letters P, Q, R for increasing sizes of rounded opacities, and S, T, U for increasing sizes of irregularly-shaped opacities. In 16 cases (46%), re-classification implied no change in the coding for the predominant shape and size. Distinguishing rounded (P,Q,R) and irregular (S,T,U) and ignoring size, most re-classifications of shape arose from films which on first reading had no small opacities but subsequently were classified as having predominantly rounded small opacities; six, one and three such changes were made by readers 002, 013 and 015 respectively. Less frequent were re-classifications from no small opacities to predominantly small irregular opacities; two such changes were made by reader 002, two by reader 013 and none by reader 015.

Summarising, it is clear that revision of classification was rare, and that almost all of the re-classifications were in the nature of fine-tuning, rather than radically altering, the recorded classification. In what follows, therefore, the revised classifications are always used.

5.3.2 Technical quality of radiographs

Table 5.7 shows the recorded classifications of radiograph quality by each of the three readers. All three readers thought the majority of radiographs were of 'good' or 'acceptable' quality. Only reader 015 considered any radiograph unacceptable, and classified three as such. This resulted in no readings for these radiographs from reader 015; missing values are indicated in the relevant tables. Reader 002 thought all three of these radiographs were of poor quality; reader 013 classified two as poor and the remaining radiograph acceptable.

5.3.3 Profusion of small opacities

Profusion of small opacities was recorded on the ILO (1980) 12 point scale. Table 5.8 summarises the distribution of classifications for the three readers. No reader used the category 0/- or 3/+. For readers 002 and 015 a large proportion of radiographs were classified 0/0; 66% and 68% respectively. Reader 013 put a smaller proportion of radiographs (34%) in this category and a larger proportion into category 0/1. If we consider categories 1/0+, which indicate more significant abnormality, the proportions are more comparable; 27%, 36% and 30% respectively for readers 002, 013 and 015.

In order to assess the extent of agreement between readers, consistency coefficients were calculated as the percentage of all classifications on which the readers recorded the same profusion, missing classifications excluded. Agreement between readers is summarised in Table 5.9, on the ILO 12 point scale. Readers 002 and 015 had the best agreement; 59% of their classifications of small opacities coincided, of which 92% were category 0/0. Agreement between these two readers and reader 013 on this scale was poorer, mainly because reader 013 classified a large number of radiographs 0/1 which readers 002 and 015 classified 0/0. Table 5.10 shows the same data summarised to the four principal categories of profusion. With the reduced number of categories, discrepancies are reduced, and the consistency coefficients for all pairs of readers are therefore higher than on the 12-point scale.

For further analysis, the opinions of the three readers on each radiograph were summarised by the median value; that is, the middle value in increasing order of profusion. The median of three readings has the advantages that where two or three readers record the same category, then the median is the majority consensus view; and in the situation where all three readers record different values, the median is the middle value, and (unlike the mean) always represents a category actually recorded by one reader.

There were, as noted above, three radiographs which reader 015 considered of unacceptable technical quality, and so did not classify. This raised some potential difficulty in defining a median. In one of the three radiographs, the other two readers both recorded 0/0, so that the absence of 015's reading did not affect the median. In the other two cases, however, the readings by 002 and 013 were the pairs (0/0, 0/1) and (0/0, 1/1). In neither case is there an obvious definition of a median, so arbitrary action was necessary. Because 015's general level of reading of profusion was nearer 013's than 002's, the higher value recorded by reader 013 was taken in both cases, and the medians were set at 0/1 and 1/1. It is noted and accepted that this is but one of a number of possible actions, but that in practice conclusions were likely to be similar whichever was adopted. The last line of Table 5.8 shows the complete distribution of median profusion categories.

Analyses to relate the radiological results of individual coalminers to their histories of exposure to respirable dust and quartz are reported in Chapter 6. These analyses are complex, principally because they look in some depth at the different patterns of exposures and when they occurred. In such circumstances, simple tabulations can be misleading or just uninformative. In this case, however, we have used the results of the later analyses to aid choice and design of tables which, at the risk of some over-simplification, will summarise the most important facets of the underlying relationships.

Tables 4.2 and 4.3, and Figures 4.5 to 4.7, demonstrated that the proportion of quartz in some men's respirable dust exposures increased dramatically during ISP 3, and that high values were common through the following ISPs. We have therefore chosen, for the purpose of illustration, to tabulate the occurrence of small opacities at follow-up by an exposure variable representing the estimated total exposure to respirable quartz cumulated during the period ISP 3 to ISP 7 inclusive.

Table 5.11 shows the distribution of the population for whom follow-up radiographs were available, grouped by age at follow-up and by ISP 3-7 exposure to respirable quartz. The age groupings are the usual 10-year bands, but those for the quartz exposure have been defined by calculating the *quintiles* of that variable's distribution, that is the cutpoints which divide the ordered distribution into five groups of equal sizes (to within the limits of rounding to whole numbers). The entries in each cell of Table 5.11 show the number of men in that cell, and the arithmetic mean of their quartz exposures.

Table 5.12 shows, for the same groupings, the number of men in each cell whose follow-up radiograph was assigned a median reading of 1/0 or greater. The percentage which this number represents of the men in that cell is shown in italics. Table 5.12 shows a clear trend of increasing prevalence of small opacities with increasing ISP 3-7 quartz exposure, and also with increasing age. The trends are reasonably consistent across the tables.

Table 5.13 shows the same breakdown of numbers and percentages, for men whose small opacities were considered sufficiently advanced to produce a median profusion reading of at least 2/1. The trend with increasing exposure is particularly marked in this table, with 31 of the 47 cases concentrated amongst the highest 20% of the exposures.

5.3.4 Large opacities

Table 5.14 shows agreement between readers in classifying large opacities. In general agreement between the readers was good, mainly because few radiographs were thought to have large opacities and were thus coded 0. There was a noticeable disagreement between reader 002 and the other readers. On twenty occasions reader 002 coded radiographs 0 while reader 013 recorded large opacities as being present; with reader 015 there were ten such disagreements.

Table 5.15 summarises the recordings of large opacities made by all of the readers, and in addition shows the profusion category recorded for small opacities on the same radiograph.

5.3.5 Shape and size of small opacities

Shape and size of small opacities is classified by two letters; the first representing the predominant shape/size of small opacities present and the second the shape/size of any less frequently occurring opacities. Two methods are adopted here to examine shape/size; (1) considering only the predominant shape and (2) combining both letters to form the categories 'all rounded', 'predominantly rounded', 'predominantly irregular' and 'all irregular'.

Table 5.16 summarises the numbers of radiographs where the small opacities were classified as All Rounded, Predominantly Rounded, Predominantly Irregular, and All Irregular. Radiographs classified as profusion category 0/0 do not not have a shape/size category, so the number of classifications of shape and size varies between readers. Noticeably, reader 015 classified a relatively small proportion of radiographs as being predominantly or all irregular in shape.

Table 5.17 classifies each reading by profusion category and by predominant shape and size. Readers 002 and 013 both classified approximately equal numbers of predominantly rounded and irregular opacities within the profusion category 0/1. Reader 015 saw only rounded opacities on radiographs in this category. Of radiographs in the higher profusion categories, 2/1+, each of the readers classified a much higher proportion as predominantly rounded than predominantly irregular; 80%, 70% and 81% for readers 002, 013 and 015 respectively.

5.3.6 Progression since last attendance at a PFR survey

Each member of the study population had, by definition, attended at least one of the three PFR surveys between 1970 and 1978. In the exercise in which the follow-up radiograph was read and classified, a reading was also made of the 1974 and/or 1978 radiograph where available, or the 1970 radiograph otherwise. Thus the reading exercise involved the classification of a series of radiographs for each individual (except in seven cases where previous films could not be found). Comparisons were made between the readings of each individual's follow-up radiograph and most recent previous radiograph to assess changes between the two time points. The availability of radiographs from the previous PFR surveys is summarised in Table 5.18. For a large proportion of the men there was a gap of approximately 13 years between last and follow-up radiograph.

The median of the three readers' classification of profusion of small opacities for the follow-up radiograph was compared with that for the most recent previous radiograph in order to assess progression. Table 5.19 summarises the comparisons with previous films without distinguishing the survey at which they were taken, and Table 5.20 presents a breakdown of these separately for each previous PFR survey.

In all but one case the median reading for profusion of small opacities at follow-up was the same or higher than for the last previous radiograph. The single exception was an apparent change from profusion 1/0 to 0/1. In 62% (336) of cases the median reading was the same for both radiographs; in 38% (203) the median was higher.

Table 5.21 summarises the comparison between the median of the three readers' classifications of large opacities at the follow-up with that for the last previous PFR survey. Fourteen individuals' follow-up radiographs had a median reading which indicated the presence of large opacities. For three of these the median for the last previous radiograph also identified large opacities; in the case of one, both radiographs were classified as A, while for the other two the earlier radiograph was category A and the later category B. The remaining 11 had category 0 medians associated with their last radiograph; eight progressed to category A and three to category B. All but one of the progressions observed occurred between a radiograph from the 1978 PFR survey and the follow-up radiograph.

Table 5.22 summarises the previous and follow-up radiograph medians, for small and large opacities, for those cases in which large opacities were noted at follow-up.

It would seem that progression has occurred both for those who previously had little or no abnormality as well as for those who had already developed pneumoconiosis by the time of leaving the colliery. In addition, in most of these cases, progression of small and large opacities has occurred simultaneously.

5.4 Respiratory symptoms

A medical questionnaire on respiratory symptoms had been administered to all of the 549 men surveyed in the follow-up.

5.4.1 Symptoms of chronic bronchitis; persistent cough and phlegm

Questions Q1 to Q4a of the medical questionnaire concern persistent cough and persistent phlegm production, and are designed to detect symptoms considered typical of chronic bronchitis. The answers to these eight questions were summarised as follows: presence of cough was taken as a positive response to either of questions Q1 and Q2 and this was further classified as persistent by a positive answer to Q1a or Q2a. In the same way, presence of phlegm was taken as a positive answer to Q3 or Q4 and a positive answer to questions Q3a or Q4a indicated persistent phlegm.

Table 5.23 shows the numbers of men reporting different combinations of presence and persistence of symptoms (non-present, non-persistent, persistent). One man did not answer Q2a, and so has been omitted from this table. As can be seen, 198 (36%) of the men reported neither cough nor phlegm while 155 (28%) reported both persistent cough and persistent phlegm.

For further analysis, these 155 men with persistent cough and persistent phlegm were defined as having the symptoms of chronic bronchitis, while the remainder were defined as non-bronchitic. (Note, however, that these definitions refer to combinations of questionnaire responses, and are *not* clinical diagnoses.) The distribution of bronchitic symptoms by age and smoking habit (numbers and percentages) is shown in Table 5.24. As expected, there were marked differences by smoking habit. Overall, the proportion of men with symptoms increased with age, men older than 64 having a prevalence twice that of men under 45. This trend was observed for smokers and ex-smokers while in non-smokers the prevalence increased up to 55 years old. There were fewer non-smokers, so the pattern in this group is not so clearly defined.

5.4.2 Breathlessness

Table 5.25 shows numbers and percentages of men reporting breathlessness (walking on level ground) in response to question Q6. Overall, the prevalence of this symptom increased with age within each smoking category, and, despite some sampling variation, the increased prevalence in smokers is apparent in most age groups.

5.4.3 Wheezing

Table 5.26 shows numbers and percentages of men reporting wheezing in the chest as a response to question Q7. There was no clear evidence of a trend with age, but there was a clear distinction between the smoking groups; the prevalence of wheezing in smokers was much higher in smokers than in non-smokers, with the ex-smokers intermediate.

5.4.4 Interrelation between breathlessness and wheezing

Table 5.27 shows the joint occurrence in the surveyed population of breathlessness and wheezing. Although there was clearly some association between these symptoms, there was a considerable proportion of the population who had one symptom but not the other.

5.4.5 History of chest illness

Table 5.28 shows numbers and percentages of men reporting, in reply to question Q8, that they had had a chest illness in the past three years. (For one man, the answer to this question was not recorded, so this table is based on only 548 men.)

For this question, comparisons between age-groups differed slightly within smoking category, with older ex-smokers and non-smokers showing a clearer trend with age than smokers. Smoking did not show any regular pattern of influence in the frequency of chest illness within age intervals.

5.5 Lung function

5.5.1 Distribution of lung function within population surveyed

Lung function tests were scheduled for all individuals attending the follow-up surveys. It was aimed to obtain three measurements of FEV_1 and three of FVC for each individual. For six of the men no lung function measurements were collected, and a further five and eight men had two and one measurements respectively. For the purposes of the analysis the maximum of the available measurements of FEV_1 and FVC for each individual were used. The ratio of FEV_1/FVC% was also calculated from the maximum values.

The mean FEV_1 was 2.67 litres, with individual values ranging from 0.2 to 5.15 litres. The mean FVC was 3.92 litres ranging from 1.3 to over 6.5 litres, and the mean FEV_1/FVC% was 66.7, ranging from 15.4 to 88.0. Tables 5.29 to 5.31 show the mean FEV_1, FVC and FEV_1/FVC% for the study population divided by age and smoking group. These have not been adjusted for heights of individual men.

As expected, both FEV_1 and FVC decreased with increasing age in all smoking groups. Levels for non-smokers were higher than those for current smokers at all ages except under 35. Current smokers experienced a sharper rate of decrease with increasing age, particularly in men aged 65 or more. Levels for ex-smokers tended to fall between those for non and current smokers, and their rate of decline with age was most similar to that of current smokers. For all smoking groups FEV_1/FVC% decreased as age increased. The rate of decline varied considerably between smoking groups, with a very slow decrease for non-smokers (with mean levels ranging only from 75.5% to 67.9% across age groups) and much steeper slopes for ex-smokers and particularly current smokers.

5.5.2 Comparison with predicted values

Predicted lung function values based on age and height were calculated for each individual using the standard European prediction equations (Quanjer, 1983):

Predicted FEV_1 = 4.30*height (m) - 0.029*age (yrs) - 2.49

Predicted FVC = 5.76*height (m) - 0.026*age (yrs) - 4.34

Predicted FEV_1/FVC% = -0.18*age (yrs) + 87.21

Mean predicted FEV_1 was 3.13 litres with a range of 1.50 to 4.64 litres. Predicted FVC had a mean of 3.96 litres ranging from 2.02 to 5.63 litres and predicted FEV_1/FVC% had a mean of 76.5 ranging from 71.9 to 82.0. The prediction equations were based on a non-smoking, non-dust exposed population and, as expected, the mean predicted value for each of the lung function variables was higher than the mean value observed in the study population.

A direct comparison between observed and predicted lung function values for each individual can be quantified by calculating the %predicted value (equal to the observed value/predicted value times 100). The mean value of %predicted FEV_1 was 84% ranging from 13% to 129%. The mean %predicted FVC was 98% ranging from 50% to 142% and the mean %predicted FEV_1/FVC% was 87% ranging from 21% to 110%.

One hundred and thirty-one individuals (24% of the study population) had %predicted FEV_1 of over 100% and 120 (22%) had %predicted FEV_1 of less than 70%. As expected, proportionally more non-smokers had %predicted FEV_1 greater than 100% compared to current and ex-smokers, and proportionally fewer non-smokers had %predicted FEV_1 of less than 70%. By contrast almost half of the study population (257 men, 48%) had %predicted FVC greater than 100% and only 31 men (6%) had %predicted FVC less than 70%. For %predicted FEV_1/FVC% 69 men (13%) had values greater than 100% and 62 men (11%) had values less than 70%. Patterns with smoking habit for %predicted FVC and FEV_1/FVC% were similar to those seen for %predicted FEV_1.

Tables 5.32 to 5.34 show the mean %predicted FEV_1, FVC and FEV_1/FVC% by age and smoking group. For all three variables, levels for non-smokers tended to be higher than for current smokers and there was a clear decline with age for current smokers which is not evident for non-smokers. Levels for ex-smokers tended to lie between those for non and current smokers and there was evidence of declining levels with increasing age among men aged 45 or more.

6. RELATIONSHIPS OF RESPONSES WITH EXPOSURE TO DUST AND QUARTZ

6.1 Relationships of radiology with exposures

6.1.1 Form and presentation of the analyses

Analyses of the relationships between exposure to respirable dust and quartz and the radiological abnormalities observed at the follow-up surveys were all carried out using similar statistical methods. The basic structure was that of regression analysis. As described earlier, the consensus of the three readers' observations of the profusion of small opacities was summarised by the median of their readings. This yielded a value which, like the readings themselves, lay on the ILO (1980) 12-point scale of profusion. For simplicity of analyses, response variables were formed by splitting the response at chosen points on this scale. Because it is known that readers can differ considerably in the relative frequency with which they assign readings to the the detailed profusion categories within the four main divisions 0, 1, 2, 3, the splitting points were chosen at the boundaries of the major categories. Thus, one response variable was formed in which a positive response was defined as the median profusion 1/0 or higher (designated 1/0+), and a second in which a positive response was a median profusion 2/1 or higher (2/1+). These responses were analysed using the technique of logistic regression (Collett, 1991), which relates the probability (or risk) that a symptom or condition will be present in an individual to an equation predicting the response as a (logistic) function of a linear combination of explanatory variables. The resulting equation predicts the risk probability on a scale lying between 0 and 1. Logistic analyses were performed separately for each of the two response variables. No direct allowance was made for the fact that men with median readings of 1/0, 1/1 and 1/2 were treated as having positive responses in the first set of analyses (1/0+), but as negative for the second set (2/1+).

For each response, the strategy for the model-fitting was to fit baseline models containing confounding variables such as age and smoking habits, and then to assess the additional predictive usefulness of including variables for exposure to dust and quartz. In these models, because of the specific interest in quartz, the dust variable was that representing the exposure to non-quartz dust, obtained by subtracting quartz exposure estimates from respirable dust estimates. Variables summarising times in occupations after leaving Colliery P were also considered for inclusion in the models.

The results tabulated in Tables 6.1 to 6.11 are arranged so that comparisons may be readily made between models containing different combinations of variables. Each column is a single model, and the estimated regression coefficients which are present (i.e. not blank) show which variables were fitted in that model. The usefulness of adding a term to the model may be judged by the difference in the deviance between the two models with and without the term. This difference is distributed as chi-square, with degrees of freedom (d.f.) calculated as the difference in d.f. between the two models.

6.1.2 Results of regression analyses

Table 6.1 shows selected results from logistic regression analyses of the 1/0+ response. The columns are labelled with a combination of 1+ for the response, F for Follow-Up, and a sequential number for each model. Model 1+/F/01 is the baseline model, with a term only for age. Smoking habit was modelled as a distinction between current smokers, ex-smokers and lifelong non-smokers, but in none of the models fitted was there a significant effect of smoking habit, nor was there any evidence of any difference between smoking groups in their relationship of response with age. None of the models shown here contains terms for smoking effects. The remaining models in this Table show the effects of adding to this baseline single and separate terms for exposures to respirable quartz in different periods. The first period represents the cumulative lifetime exposure up to PFR survey 3, that is ISPs 0+1+2. ISPs 3, 4 and 5 were added individually, and ISP7, which was a single quarter, has been included with the two years of ISP 6, and labelled ISP 6+7.

For the period ISP 0+1+2, there was no evidence of any exposure-response relationship with the probability of a median reading of 1/0+. The later ISPs, however, showed a very different pattern. There were highly significant effects for quartz exposures in each of ISPs 3, 4, 5 and, to a lesser extent, ISP 6+7. The magnitude and significance of the age coefficient fluctuated somewhat, depending on which exposure variables were in the models.

Table 6.2 shows a similar set of models, from analyses of the more advanced profusion response 2/1+. The labelling of the columns of this and the following tables is an obvious extension of that for Table 6.1. The patterns in this Table are very similar to those in Table 6.1, with highly significant individual terms for quartz exposures in ISPs 3, 4, 5 and, to a lesser extent, ISP 6+7, but no significance for exposure prior to PFR 3rd survey.

For completeness, Tables 6.3 and 6.4 show similar analyses for the 1/0+ and 2/1+ responses, but focussing on the effects of the respirable (non-quartz) dust exposures. These gave very similar results to the quartz exposures, but the terms for ISP 3, 4 and 5 dust exposures were all marginally less significant than the corresponding exposures to quartz, at both levels of response. This suggests that the quartz may have a stronger role than the other components of the respirable dust, in the genesis of the radiological abnormalities observed in these men, and is consistent with the results of Miller and Kinnear (1988) for earlier stages of the men's radiological development. By contrast, the ISP 6+7 exposures gave a more significant association with dust than with quartz.

Tables 6.5 and 6.6 extend the results in Tables 6.1 and 6.2. They show additional models which include selected combinations of quartz exposures in different ISPs. Comparison and interpretation of these models must be carried out with care. For example, when two exposure terms are fitted simultaneously, each must be interpreted as the effect of that exposure adjusted for the effect of the other. These may differ considerably from the effects fitted individually, particularly if there is sizeable correlation between the two exposure variables. This effect is clearly seen in the present analyses, where the correlation between exposures (see Table 4.4) reflects the fact that men in dustier jobs in one ISP tended to continue in similar jobs in other ISPs. Thus, as can be seen for example in Table 6.5, the coefficient for dust exposure in one ISP can change radically in either magnitude or statistical significance, or both, when exposure from another ISP enters the model.

For both 1/0+ and 2/1+ responses, the term for exposure in ISP 6+7 disappeared in the presence of any of the exposure variables for ISP 3, 4 or 5. The terms for quartz exposure in ISPs 4 and 5 remained significant in the presence of each other, but that for ISP 3 was considerably diminished in the presence of ISP 4 exposure alone, or with ISP 5 included also, even to the extent of appearing not significant in the models of Table 6.6. Similar findings were obtained in similar models with non-quartz dust exposures replacing the quartz, and again the significance of almost all of the terms was slightly lower for dust than for quartz. By the same token, the quartz models showed better goodness of fit, as measured by the residual deviance, than did the corresponding models with dust exposures. These models are shown in Tables 6.7 and 6.8.

Taken together, the models in Tables 6.1 to 6.8, and the comparisons between them, give very strong hints that the assessment of the role of these different exposures must be undertaken with care. In addition, the role of age needs clarification. While it is true that some heavy smokers may develop low profusions of largely irregular opacities as they age, it is not generally expected that men who are not exposed to respirable dust will develop advanced pneumoconiotic abnormalities as they age. Thus a highly significant coefficient for age in a response of, say, profusion category 2/1 or greater may well be a surrogate for some aspect of exposure which is related to age, but which is not well represented by the exposures in the models presented so far. Further, the relative roles of the quartz and non-quartz fractions of the respirable dust have been touched on only indirectly.

Several additional series of models were fitted in efforts to address some of these additional points. Table 6.9 shows models where, in each ISP, both the quartz and the non-quartz dust exposures were fitted simultaneously. For both levels of response, it was clear that the effect of dust after allowing for quartz was not significant, but that after allowing for dust there was still a highly significant contribution from the quartz. This suggests that, indeed, the quartz fraction of the dust was the better, and perhaps more relevant, predictor of the response than the dust; and, moreover, that the observed dust effects were likely to be interpretable more through their correlation with quartz exposure levels than in their own right. A similar effect is visible in models 1+/F/29 and 2+/F/29, where the effects of several ISPs are fitted simultaneously.

Because of these findings, the remainder of the models in Tables 6.10 to 6.12 show the effects only of quartz exposures.

The models in Table 6.10 attempt to investigate further the extent to which the radiological abnormalities were associated with work in the very worst conditions. Table 4.1 identified the OGSNs in the Parrot seam which had particularly high concentrations of dust and quartz. Here, the occupation of return stableman was singled out as particularly heavily exposed, and two faces, P.03 and P.27, as associated with generally high levels of dust and quartz. Table 6.10 shows models which included separate terms for time in OGSNs 514 (Return stableman, P.03 face), which existed during ISP 4, and 553 (Return stableman, P.27 face), which had most of its existence during ISP 5. The results are very interesting. Model 1+/F/31 for response 1/0+ showed that the inclusion of time spent in OGSN 514 was significant, and almost eliminated the term for quartz exposure in ISP 4. For the 2/1+ response, a similar effect was observed, but here time in OGSN 514 was even more strongly significant, while having a slightly smaller effect on the ISP 4 quartz exposure term. The time in OGSN 553 also proved significant, particularly for the 2/1+ response, but had less effect on the significance of the ISP 5 quartz variable.

These results suggest that during ISP 4, most of the exposure which increased the risk of a radiological response was experienced by men working in OGSN 514; but this does not explain all the abnormalities observed at follow-up. Nevertheless, the results were interesting enough to prompt some further modelling. The study population was split into two groups:

the first, 118 men who were recorded as having spent some time in OGSNs 514 or 553; and the remaining 429 men, who had no time recorded in either OGSN. Table 6.11 shows the results in these groups of fitting, for the response 1/0+, models containing different combinations of ISP quartz exposures. The results showed, in the men with time in OGSNs 514 and 553, significant contributions from quartz exposures in ISPs 4 and 5, but a smaller (and not statistically significant) effect for ISP 3 quartz. In the second group, without time spent in either 514 or 553, the ISP4 quartz exposure effect was negligible, although there were significant contributions from the ISP 3 and ISP 5 quartz exposures. Very similar results obtained in the same way for the response 2/0+ are shown in Table 6.13.

Thus, while the demonstrable influence of ISP 4 quartz exposures on risks can be ascribed to the exposures of some men to very extreme levels of respirable quartz in a few occupational groups, we have not demonstrated a similar effect for the risks related to the ISP 3 and ISP 5 exposures. There is scope for further more detailed study of the influence of time spent in other occupational groups with relatively high quartz exposure levels. Such analyses would simultaneously help to answer the question of whether there are risks which can be attributed to exposure to lower levels of quartz exposure, and indeed whether there exists a threshold for the effects of quartz on health.

Further models were fitted, including variables quantifying the times spent in other occupations after leaving Colliery P. In models which already contained quartz or dust exposures for ISPs 3, 4 and 5 none of the variables for occupations after leaving Colliery P gave a significant improvement to the model fit; but with a baseline model containing only age, there was, for both 1/0+ and 2/0+ responses, a significant contribution for time spent in facework in one of the adjacent collieries. It is possible that some men may have experienced some further quartz or dust exposure, thus adding to their pneumoconiosis risk, after transferring to the neighbouring colliery; it is also possible that men who accumulated risk in face jobs in Colliery P were more likely to occupy face jobs on transfer to other collieries, and that the association is a spurious one caused by the confounding that this would introduce into the data set. The latter seems more consistent with the pattern of the results. Since detailed and differential data on exposures at other collieries were not available, it has not been possible to investigate these findings further

6.1.3 Summary of results on radiology

Logistic regression analyses of the profusion of small opacities recorded for the radiographs from the follow-up survey showed strong evidence of association between risks of displaying pneumoconiotic abnormalities and the exposures experienced during work at Colliery P. The correlation between an individual's exposures in different ISPs, induced by continuity of occupational group across ISPs, requires some caution in interpreting regression results. Comparison of the estimated regression coefficients and their statistical significance from a large number of models suggested that the strongest association was with exposures in ISPs 4 & 5, followed by ISP 3; and that the association was stronger with the estimated exposure to the quartz fraction of the respirable dust, than with its non-quartz component. The specific association with ISPs 4 & 5, and the association with quartz in particular, showed most strongly in analyses where the response was a small opacities profusions 2/1 or higher. There was no evidence of an association with exposures prior to the third PFR survey, and little evidence for any association with coalmine exposures accumulated after 1978.

There was a strong association between radiological abnormalities at follow-up and time spent working in certain occupational groups known to have had very high concentrations. It has not, however, been possible as yet to identify all of the OGSNs associated with increased risks of developing pneumoconiotic abnormalities.

Comparison of the magnitudes of the regression coefficients for the influence of quartz exposures on pneumoconiosis suggested an ordering ISP 5 > ISP 4 > ISP 3. Consideration of the possible significance of this observation is deferred to the discussion in Chapter 7.

6.2 Relationships of respiratory symptoms with exposures

6.2.1 Form and presentation of the analyses

The analyses of the relationship between exposure to respirable dust and quartz and the respiratory symptoms recorded during the survey interview were all carried out using similar methods. The basic structure was that of regression analysis, but because the response in each case was the presence or absence of a particular symptom (or set of symptoms), the technique of logistic regression (Collett, 1991) was employed. This relates the probability (or risk) that a symptom will be present in an individual, to an equation predicting the response as a (logistic) function of a linear combination of explanatory variables. The resulting equation predicts the risk probability on a scale lying between 0 and 1.

For each response, the strategy for the model-fitting was to fit baseline models containing confounding variables such as age and smoking habits, and then to assess the additional predictive usefulness of including variables for exposure to dust and quartz. In these models, because of the specific interest in quartz, the dust variable was that representing the exposure to non-quartz dust, got by subtracting quartz exposure estimates from respirable dust estimates. Variables summarising times in occupations after leaving Colliery P were also considered for inclusion in the models.

The results tabulated in Tables 6.13 to 6.15 are arranged so that comparisons may be readily made between models containing different combinations of variables. Each column is a single model, and the estimated regression coefficients which are present (i.e. not blank) show which variables were fitted in that model. The usefulness of adding a term to the model may be judged by the difference in the deviance between the two models with and without the term. This difference is distributed as chi-square, with degrees of freedom (d.f.) calculated as the difference in d.f. between the two models.

6.2.2 Results from analyses of symptoms of chronic bronchitis

For the presence at survey of chronic bronchitis, we have chosen to analyse a response indicating the presence of persistent cough and phlegm (see section 5.4.1). There were 155 men who satisfied this definition, and who were therefore treated as positive for chronic bronchitis.

Table 6.13 shows selected results from the logistic regression analyses. The columns are labelled with a combination of CB for Chronic Bronchitis, F for Follow-Up, and a sequential number for each model. Model CB/F/1 is the baseline model, with the terms for only age and the differences between the three smoking habit groups; both of these terms were significant in the absence of any exposure terms, and their directions were as would be expected: the risk of chronic bronchitis was higher in older men, and higher in current smokers than in lifelong non-smokers, with the ex-smokers occupying an intermediate position.

Models CB/F/2 to /7 show the effects of adding to this baseline separate terms for respirable (non-quartz) dust exposure in each of the ISPs, and finally a term representing the entire cumulative exposure to dust at Colliery P. The age and smoking coefficients were little changed by the inclusion of these exposure terms. The term for exposure before 3rd survey (ISP 0+1+2) was not significant. The terms for exposures in the periods ISP 3 to 5 were all individually significant, and had similar coefficients. The term for dust in ISP 6+7, on the other hand, failed to reach significance, although the magnitude of its estimated coefficient was over twice that of the other terms; this combination implies that the standard error associated with estimating this term is much greater than for the earlier ISPs. The impression from this table is that there is definite evidence of a dose-response effect of dust on the risk of reporting chronic bronchitis at follow-up; and the pattern of the coefficients' increase over the follow-up period seems notable.

Table 6.14 shows the baseline model again (for ease of comparison) and models containing mixtures of exposures from the individual ISPs. Comparison of these models must be carried out with care. For example, when two exposure terms are fitted simultaneously, each must be interpreted as the effect of that exposure adjusted for the effect of the other. These may differ considerably from the effects fitted individually, particularly if there is sizeable correlation between the two exposure variables. This effect is clearly seen in the present analyses, where the correlation between exposures (see Table 4.4) reflects the fact that men in dustier jobs in one ISP tended to continue in similar jobs in other ISPs. Thus when the model contains the dust exposure from any one of the ISPs, then the addition of any of the others does not give a significantly improved fit.

Similar models were fitted using the using the quartz in place of the dust exposure variables. These produced very similar results, and in almost all cases the significance of the quartz effect was marginally less than that of the corresponding dust effect, so they are not shown here. In addition, all models were fitted using the logarithms of the exposures, which again did not improve the fit. Interaction terms representing the possibility that the age effect might differ between smoking groups were also not significant, and again these models have not been shown.

Finally, the importance of occupational exposure after leaving Colliery P was assessed by adding to the models each of the exposure variables described in section 4.3. In general, these produced no interesting results except that chronic bronchitis appeared more common in individuals with longer time in non-dusty industries and in non-employed periods. It is difficult to interpret these results as indicating some hazard associated with these non-specific and probably diffuse occupational groups. There is another, possibly more plausible, explanation, in that men who were experiencing chest problems may have been less likely to take on further heavy or dusty work, either by personal choice or by employment selection. If this is the case, it would be inappropriate to use employment in these occupations as a predictor, when in fact it is a consequence of the response. We prefer this explanation for the observed effect, and do not show here any of the models which suggested its presence.

6.2.3 Results from analyses of breathlessness

The symptom of breathlessness was taken as a positive response to question 6, 'Do you have to walk slower than other people on level ground because of your chest?'. A total of 169 men gave a positive answer to this question. The statistical methods and strategy of analysis were the same as described for the analysis of the symptoms of chronic bronchitis.

Table 6.15 shows selected results from these analyses. The models shown are labelled as before, with BR for breathlessness. The risk of being breathless increased strongly with age. The difference between the smoking groups did not reach statistical significance, but the magnitudes of the estimated coefficients had the expected directions. The only exposure variable which produced a significant improvement in model fit was that for ISP3.

Various alternative exposures and interaction terms were tried but, as for chronic bronchitis, none of these improved the fit, and they are not shown here. The same association was observed between increased risk of breathlessness and time either in on-dusty industry or not employed. Again, this is taken to reflect a consequence of the response rather than a cause.

6.2.4 Results from analyses of wheezing

The symptom of wheezing was taken as a positive response to question 7, 'Do you ever have wheezing or whistling in your chest? – I don't mean only when you have a cold.' A total of 203 men gave a positive answer to this question. The statistical methods and strategy of analysis were the same as described for the analysis of the symptoms of chronic bronchitis.

Table 6.15 shows selected results from these analyses. The models shown are labelled as before, with WH for wheezing. The risk of having wheezing showed little evidence of an association with age, but there were highly significant differences between the smoking groups, and the pattern was as expected, with ex-smokers intermediate between non-smokers and current smokers. No exposure variable produced a significant improvement in model fit, and the only one shown is the total cumulative exposure to non-quartz dust, which almost reached the 5% significance level. Overall, then, there was little evidence for an association between wheezing and exposure to non-quartz dust.

The effects of various alternative exposures and interaction terms were examined but, as for chronic bronchitis, none of these materially improved the fit, and they are not shown here. There was, however, one interesting observation. The effect of quartz exposure over the working lifetime at Colliery P, although not significant on its own, showed a significant interaction with age. This was investigated further, by splitting the population arbitrarily at age 45 and fitting the models separately to each part of the group. The results showed an increased risk of wheezing with increased exposure to quartz in the older men (model WH/F/02 in Table 6.15), but an association in the opposite direction for the younger men. It seems plausible that this could be a mixture of two phenomema: an occupational hazard in the older men, and a tendency for younger men with wheeze, who may be asthmatic, to avoid dustier occupations.

The same association was observed between increased risk of wheezing and time either in non-dusty industry or not employed. Again, this is taken to reflect a consequence of the response rather than a cause.

6.2.5 Results from analyses of past chest illness

In question Q8, each man was asked ' In the last three years have you had a chest illness that has kept you from your usual activities for more than a week?'. There were 124 positive responses to this question, of which four were ascribed to asthma, one to a combination of asthma and bronchitis, 18 to bronchitis, 32 to colds and flu, and 67 to other miscellaneous causes including non-respiratory ailments. The probability of a positive response was found to be increased in older men. But, as might be expected with a such a non-specific question, there was no relationship with any of the dust exposure variables in any of the analyses, nor with smoking habits. The presence of chest illness in the previous 3 years to the study, examined similarly, was found to be related only to age and to time spent unemployed. Neither smoking nor dust or quartz exposures showed any relationship with this response. None of the models fitted is shown here.

6.2.6 Summary of results on respiratory symptoms.

Logistic regression analyses of symptoms of chronic bronchitis showed relationships very much as expected with age and smoking. In addition, there was evidence of an association with coalmine exposures, particularly with ISP 3. There was little evidence to suggest a particular role for quartz.

Breathlessness as a symptom showed little evidence of association with dust exposure, except perhaps for a weak association with dust exposures in ISP 3. Similarly, the symptom of wheezing showed little except perhaps a relatively weak dust effect in older men. Again, there was little evidence that quartz played any particular role in this.

There was evidence that, allowing for age, men with respiratory symptoms tended, after leaving Colliery P, to stay unemployed, retired, or working in lighter jobs, while those who went on to further colliery or other heavy or dusty employment were less likely to be symptomatic. This has been interpreted as an employment selection effect.

6.3 Relationships of lung function with exposures

6.3.1 Form and presentation of the analyses

The analyses of the relationship between exposure to respirable dust and quartz and the measurements of lung function taken during the survey interview were all carried out using similar methods. The responses were the Forced Expiratory Volume in one second (FEV_1), the Forced Vital Capacity (FVC), both in litres, averaged over a maximum of three technically satisfactory expirations, and their ratio expressed as a percentage, $FEV_1/FVC\%$.

The basic structure was that of linear regression analysis (Draper and Smith, 1981). For each response, the strategy for the model-fitting was to fit baseline models containing confounding variables such as age and smoking habits, and then to assess the additional predictive usefulness of including variables for exposure to dust and quartz. In these models, because of the specific interest in quartz, the dust variable was that representing the exposure to non-quartz dust, obtained by subtracting quartz exposure estimates from respirable dust estimates. Variables summarising times in occupations after leaving Colliery P were also considered for inclusion in the models. Five hundred and forty-nine workers were surveyed at the follow-up survey. However, eight workers were excluded from the analysis due to missing values, and the analyses were performed on five hundred and forty-one workers.

The results tabulated in Tables 6.16 to 6.21 are arranged so that comparisons may be readily made between models containing different combinations of variables. Each column is a single model, and the estimated regression coefficients which are present (i.e. not blank) show which variables were fitted in that model. The usefulness of adding a term to the model may be judged by the difference in the residual sum of squares between the two models with and without the term. This difference may be divided by its degrees of freedom (d.f.), calculated as the difference in d.f. between the two models; the ratio of this mean square to the residual mean square from an adequately fitting model can be tested as an F-statistic.

6.3.2 Results from analyses of FEV_1

Table 6.16 shows results from the linear regression analysis of FEV_1. The columns are labelled with a combination of FEV, F for follow-up, and a sequential model number for each model. Model FEV/F/01 is the baseline model, with terms for height and separate relationships with age for each of the three smoking groups. The pattern of these is as expected, in that the current smokers are losing FEV_1 faster with age than are the non-smokers, with the ex-smokers intermediate between the two.

Models FEV/F/02 to /06 show the effects of adding to this baseline separate terms for respirable (non-quartz) dust exposure in each of the ISPs. The height, age and smoking terms were little changed by the inclusion of any of these terms. The coefficient for exposure prior to 3rd PFR survey was negligible. The coefficients for the later ISPs were larger, and of broadly similar magnitudes, but only that for ISP 6+7 achieved statistical significance at the 5% level.

Relationships with quartz exposure variables were less significant than those for the non-quartz dust, and have not been shown here. A number of additional models were fitted to test aspects of the models. Number of cigarettes smoked was not significant, and neither the inclusion of weight nor the addition of quadratic terms in height or age improved the model fit. Fitting the model using the logarithms of the exposure variables likewise gave no improvement.

6.3.3 Results from analyses of FVC

Table 6.17 shows results from the linear regression analysis of FVC. The columns are labelled with a combination of FVC, F for follow-up, and a sequential model number for each model. Model FVC/F/01 is the baseline model, with term for height, weight, age and differences between the three smoking groups. Unlike the models for FEV_1, there was little evidence for a different rate of FVC loss with age in the three smoking groups.

Models FVC/F/02 to /06 show the effects of adding to this baseline separate terms for respirable (non-quartz) dust exposure in each of the ISPs. The height, weight, age and smoking terms were little changed by the inclusion of any of these exposure terms. None of the exposure terms approached conventional statistical significance levels.

Relationships with quartz exposure variables were even less significant than those for the non-quartz dust, and have not been shown here. As for FEV_1, none of several alternative and augmented models gave improved fits.

6.3.4 Results from analyses of the ratio of FEV_1 to FVC

Table 6.18 presents results from analyses of the ratio of FEV_1 to FVC. The baseline model included age, height and weight as explanatory variables, and in addition the age and weight coefficients were found to differ between the three smoking groups. As with FEV_1 and FVC, estimates of baseline variables did not alter much when adding the different exposure variables. The ratio decreased by about 0.18 percentage points per year, and about 0.17 percentage points per centimetre of height.

None of the exposure variables showed a statistically significant association with the ratio. As with FEV_1 and FVC, various supplementary analyses were performed with other combinations of variables, but none of these gave any evidence of a dose-response relationship of FEV_1/FVC ratio with exposure, and the results are not presented here.

6.3.5 Relationships with exposures after leaving Colliery P

Regression analyses of lung function (FEV_1, FVC and ratio) and data describing the occupational histories of employees after leaving Colliery P were also performed. The variables used were those described in 4.3, including number of years spent in other collieries, years in non dusty industries, years in dusty industries, years in non-industrial occupations and years unemployed. Although of varying statistical significance, the estimates of occupational history variables save years unemployed were all positive, which echoes the results found in the analyses of respiratory symptoms. Again, the most likely explanation for this effect is some form of selection process, with employees who worked in other occupations tending to be healthier than those who remained unemployed after leaving Colliery P. Since this relationship is not causal on lung function as a response, the results from these models are not shown here.

6.3.6 Lung function and profusion of small and large opacities

There has long been controversy as to whether the presence of small opacities is associated with any clinically significant loss of lung function. In this study, we have performed additional analyses to investigate this question, by adding an explanatory variable representing radiological status to the regression models for lung function variables. The same baseline models were used as before. However, the estimates were slightly different due to the exclusion of two employees for whom radiographs had not been obtained. A variable was constructed dividing the workers into five groups according to the median readings of small and large opacities. The constructed groupings were as follows:

0 – no opacities 0/-, 0/0, 0/1 (n=388);
1 – small opacities 1/0, 1/1, 1/2 (n=109);
2 – small opacities 2/1, 2/2, 2/3 (n=32);
3 – small opacities 3/2, 3/3, 3/+ (n=4);
L – large opacities present (n=14).

Table 6.19 presents some results from the linear regression analyses of FEV_1. The variable distinguishing groups by radiological status is labelled 'opacities', and estimated effects are shown as differences from the large group without abnormality, 'opacities 0'. The models shown include the baseline, with the addition of opacities, the dust exposures for ISP 6+7, and the Total dust exposure, i.e. the sum over all the ISPs. The estimates of the baseline variables varied little as profusion rate and exposure variables were included. However, the inclusion of the opacities variable gave a statistically significant association. The magnitudes and directions of the estimated effects showed an interesting pattern: the average loss of lung function was marked in men with large opacities, but also increased with severity of small opacities. In addition, neither of the exposure terms was statistically significant in the presence of the opacities variable. These findings suggest that there was at least partial association between FEV_1 and profusion rating, even in men with what would normally be considered minor or early signs of pneumoconiotic disease. Results for quartz exposures were similar, and are not shown.

Table 6.20 shows similar regression analyses of FVC. As with FEV_1, inclusion of coefficients representing the five opacities groups was statistically significant and showed a very convincing pattern indicating a loss of lung function with increasing level of radiological abnormality. The exposure variables were not significant predictors of FVC when included simultaneously with the variable for profusion rating.

Table 6.21 presents results of analyses of the ratio of FEV_1 to FVC. As with FEV_1 and FVC individually, the estimates of the effect of the opacities showed a negative relationship with the ratio which was very consistent. Again, exposure estimates were not statistically significant when fitted simultaneously with the opacities variable.

Supplementary analyses were performed to investigate any possible interaction between opacities and exposure. However, these interaction terms did not gave any improvement to the fit, and the results are not shown here.

6.3.7 Summary of results on lung function

Regression analyses of lung function variables showed the expected patterns of association with age and smoking, in that FEV_1 (and the ratio of FEV_1 to FVC) decreased with age, and showed an accelerated rate of loss in smokers. There was only weak evidence of any effect of dust or quartz exposures on FEV_1, and that only for ISP 6+7. There was no strong evidence of a particular role for quartz. There was no evidence for a loss of FVC associated with dust or quartz exposures.

Additional analyses showed that reductions in FEV_1, FVC, and their ratio were associated with increasing category of pneumoconiotic abnormality. Adjusting for profusion category, there was no evidence of a residual association with dust or quartz exposures. Conversely, adjustment for dust exposures made negligible difference to the relationship with radiological category.

7. DISCUSSION

7.1 Introductory remarks

This research project had a number of features by which it differed from much of the previous epidemiological research of the PFR. Firstly, the PFR studies, with the exception of one major follow-up study which included ex-workers (Soutar *et al.*, 1982), were of miners who were still working at the time of survey. Thus, the PFR has provided only limited information on the patterns of health and disease to be expected in miners past normal retirement age. Secondly, the high dust and quartz concentrations in one seam during the 1970s arose from an unusual combination of circumstances, namely the inability of the coal-getting machinery to adjust to the varying height of a narrowing coal measure between sandstone strata. Thus, the present study deals with quartz exposures which were quite untypical of those to which coalminers in Britain are usually exposed. Thirdly, the statistical analyses of the present study have been carried out using exposure data characterised in greater detail than has been common in the past, both because the form of storage of data from the last years of the PFR permitted this, and specifically because the relationships of respiratory hazard with the accumulation of exposure to quartz were expected to differ from those previously observed in response to exposure to dusts containing little quartz. The results have been both informative and instructive.

7.2 Summary of principal findings (from Chapter 6)

Logistic regression analyses of the profusion of small opacities recorded for the radiographs from the follow-up survey showed strong evidence of association between risks of displaying pneumoconiotic abnormalities and the exposures experienced during work at Colliery P. The correlation between an individual's exposures in different ISPs, induced by continuity of occupational group across ISPs, requires some caution in interpreting regression results. Comparison of the estimated regression coefficients and their statistical significance from a large number of models suggested that the strongest association was with exposures in ISPs 4 & 5, followed by ISP 3; and that the association was stronger with the estimated exposure to the quartz fraction of the respirable dust, than with its non-quartz component. The specific association with ISPs 4 & 5, and the association with quartz in particular, showed most strongly in analyses where the response was a small opacities profusion 2/1 or higher. There was no evidence of an association with exposures prior to the third PFR survey, and little evidence for any association with coalmine exposures accumulated after 1978.

There was a strong association between radiological abnormalities at follow-up and time spent working in certain occupational groups known to have had very high concentrations of respirable quartz. It has not, however, been possible as yet to identify all of the OGSNs associated with increased risks of developing pneumoconiotic abnormalities.

Logistic regression analyses of symptoms of chronic bronchitis showed relationships very much as expected with age and smoking. In addition, there was evidence of an association with coalmine exposures, particularly with ISP 3. There was little evidence to suggest a particular role for quartz.

Breathlessness as a symptom showed little evidence of association with dust exposure, except perhaps for a weak association with dust exposures in ISP 3. Similarly, the symptom of wheezing showed little except perhaps a relatively weak dust effect in older men. Again, there was little evidence that quartz played any particular role in this.

There was evidence that, allowing for age, men with respiratory symptoms tended, after leaving Colliery P, to stay unemployed, retired, or working in lighter jobs, while those who went on to further colliery or other heavy or dusty employment were less likely to be symptomatic. This has been interpreted as an employment selection effect.

Regression analyses of lung function variables showed the expected patterns of association with age and smoking, in that FEV_1 (and the ratio of FEV_1 to FVC) decreased with age, and showed an accelerated rate of loss in smokers. There was only weak evidence of any effect of dust or quartz exposures on FEV_1, and that only for ISP 6+7. There was no strong evidence of a particular role for quartz. There was no evidence for a loss of FVC associated with dust or quartz exposures.

Additional analyses showed that reductions in FEV_1, FVC, and their ratio were associated with increasing category of pneumoconiotic abnormality. Adjusting for profusion category, there was no evidence of a residual association with dust or quartz exposures. Conversely, adjustment for dust exposures made negligible difference to the relationship with radiological category.

7.3 Reliability of principal findings

The observed association of radiological response with quartz exposures is very plausible, but it is necessary to consider whether any other explanations of the observed patterns are equally, or perhaps even more, plausible. No study is perfect, and there are always more potential factors than can be measured. It is therefore both necessary and appropriate that the findings of any study should be subjected to detailed scrutiny and criticism.

We consider first non-response. Colliery P was an ageing colliery, experiencing increasing difficulty in extracting coal from old, well-worked seams. Its problems were shared with several other collieries in the area, which was in decline (and in which the coal industry now consists of a single, privately owned, deep mine). Through the 1970s, the employed population declined through natural wastage, and there was little fresh recruitment. As a result, the working population was composed of increasing proportions of older men. The time which elapsed between the geological difficulties of the 1970s and the follow-up surveys was between fifteen and twenty years, and it was thus inevitable that some of the older members of the workforce would have died over that period. This implies an inevitable degree of non-response, and possibly amongst those with the most severe response to their occupational exposures. More than half of the study population were, at the time of tracing for the follow-up study, already members of the cohort maintained for the study of PFR coalworkers' mortality; and an expansion of the cohort, as part of a further British Coal/CEC study, will have the effect of including the entire target population of 1416 men. Thus, when tracing is complete for the cohort, it will be possible to investigate the pattern of mortality within Colliery P in relation to exposures, and for specific causes of death. We note here simply that any deaths as a result of exposure to dust or quartz would be unlikely to bias the study in a direction to produce spurious associations of radiological abnormality with exposure, but would be more likely to lead to an underestimation of the extent of health problems. The likely extent of this will be more readily assessed once the mortality studies are complete.

At the end of the tracing exercise, 384 men were known or believed on good evidence to be already deceased. There were 111 men untraced or believed or known to be abroad. From the target population of 1416 men, there remained 924 men who were believed traced, although a few of the 44 who never replied to any contact might have been deceased. Of the 876 who replied to the tracing attempts, 165 refused to participate, and a further 160 either did not turn up for appointments, or could not be contacted to make an appointment. In such a complex situation, there a number of ways to express a response rate. There were questions about the identities of two men surveyed, so that on the most pessimistic rendering, the follow-up saw 549/1416 = 39% of men who worked at Colliery P during the 1970s; more realistically, perhaps, those surveyed were 549/924 = 59% of those believed to have been traced. While the level of non-response was not trivial, nevertheless the survey was a considerable achievement. Direct comparisons with other studies are not easy to make. The major twenty-year follow-up study of men who had been surveyed in the first round of the PFR was selective towards men with radiological abnormalities, and included both ex-miners and men still in the industry. That study saw 60% of those still alive (Soutar *et al.*, 1982). It is not possible from the published reports of this study to distinguish between the part of the target population who were still employed in collieries and those who had left the industry; but response rates of between 80% and 100% were common in PFR colliery populations, and simple arithmetic suggests that the response rate amongst ex-miners must have been less than 60% in that study.

It is necessary to ask, then, whether the results of the present study may be seriously in error because of the level of non-response. One insight into this can be gained through the comparisons of section 5.1.2, where non-responders (excluding the deceased) and responders were compared in terms of the data obtained from them at the PFR surveys of the 1970s. These comparisons suggested that the responders and non-responders differed little in smoking habits; but that the response rates were poorest in men under the age of 35 years. This response pattern can be explained by the greater likelihood of younger men migrating from the area to find work when there was little chance of colliery work in their home region; it is unlikely to represent a strongly health-based selection effect.

To the extent that non-response always leads to the absence of the data which would be necessary to quantify its effect, we cannot be certain that the results of this study are not in some way distorted. It is possible, however, to appeal to results such of those of Gauld *et al.* (1988), which showed for one group of coalworkers surveyed on several occasions that, while those not responding were on average less healthy than the responders, there was no evidence that they were atypical in their relationship between exposure and response. In principle, it would be possible to perform further detailed analyses of this sort on the PFR survey data for responders and non-responders in the present follow-up. In practice, since most of the radiological progression occurred after the PFR surveys, such analyses would provide very little useful information. However, there seems little evidence in the observed patterns of response to suggest that those surveyed would provide a biased view of the exposure-response relationships.

Another important consideration for the reliability of the results is in the reliability of the explanatory variables fitted in the various regression models. It has long been known that measurement errors in the explanatory variables introduce biases (known as the *attenuation effect*, see for example Snedecor and Cochran, 1980) into the estimates of regression coefficients , such as are used to quantify dose-response relationships. Heederik and Miller (1988) demonstrated this effect in a subset of PFR data, and showed how an extension of linear regression methods could adjust for this, where the response variable was measured on a continuous scale. Similar effects occur in logistic regression modelling, but methods for adjusting logistic regression analyses are not at present readily available.

In the present study, we note simply that the exposure information available in the PFR is almost unparalleled for the length of time over which direct observations of environmental conditions were taken, and for the detail in which they were stored; and the analyses here used exposure variables summarised over periods of only about five years in length. Other variables such as age were known exactly. We believe, therefore, that the impact of exposure assessment errors must have been well below that experienced in many other epidemiological studies.

7.4 Radiological results: prevalence and progression of disease

The most important of the results have been in relation to the radiological status of the subjects. The clinical and epidemiological readings of the radiographs collected at the follow-up survey have demonstrated progression both in men who had experienced radiological change by the 6th PFR survey in 1978, and in men who had no previous evidence of radiological change. While the numbers of such progressors might not have been remarkable in some areas of the UK in the first half of this century, they formed a pattern less typical of the better regulated conditions of the more recent decades, and unusual for the Scottish coalfields, where pneumoconiosis risks have traditionally remained lower than in areas such as the anthracite coalfields of Wales.

The respiratory abnormalities demonstrated in these miners are likely to represent true silicosis, resulting from exposure to mixed dust containing high concentrations of quartz, and are different from the coal pneumoconiosis usually seen in coalminers in that: the frequency and progression of radiological abnormalities are much greater than would be expected for these levels of exposure to dust if they had not contained large amounts of quartz (Hurley *et al.*, 1979); in the progression of radiological appearances after the main exposure ceased, a feature of silicosis (Westerholm, 1980); and in the association of radiological category of simple pneumoconiosis with lung function, even after allowing for dust exposure. Notably the mean lifetime mixed dust exposure of the present population was 57 ghm^{-3}, well below the 167 ghm^{-3} mean experienced by a population of men with category 0/0 small opacities from collieries with lower quartz concentrations, described previously (Collins *et al.*, 1988).

Some qualifications should be expressed about the associations with lung function. Rogan *et al.* (1973) showed that in coalface workers from collieries where concentrations of quartz in the dusts were below 10%, that cumulative exposure to respirable dust was inversely related to lung function, and that the presence of the small rounded opacities of simple pneumoconiosis was not associated with functional deficits on average after the influence of life-time exposure to mixed dust had been taken into account. At that time the presence of small irregular opacities was not recorded. Subsequently Collins *et al.* (1988), analysing radiographic readings in which irregular as well as rounded opacities were recorded, confirmed the observations of Rogan *et al.* for rounded opacities, and showed that irregular opacities were both associated with dust exposure and with functional deficits after adjusting for dust exposure. In the present work the presence of both rounded and irregular opacities were recorded, but because of our interest in all possible effects of dust containing high concentrations of quartz, rounded and irregular opacities have been studied together. There is, incidentally, invariably rather poor inter-reader agreement on shape of small opacities, and given that both are related to dust exposure, separation of rounded and irregular opacities may be unreliable, and possibly misleading under some circumstances. Subject, therefore, to any influence (not examined) of the methodological differences between the previous and present work, the observation of a progressive reduction in FEV_1 associated with increase in category of simple pneumoconiosis), even after allowing for dust exposure, suggests that silicosis resulting from mixed dust with a high quartz content affects lung function at an earlier stage in the development of radiological abnormality than is the case with low quartz coalmine dusts.

We did not study whether the functional abnormalities predated the early estimated radiological abnormalities, but the direct relationship between dust or quartz exposure and lung function was weak in this population. For surveillance purposes both chest radiographs and lung function tests would be advisable for silica exposed workers.

7.5 Radiological results: exposure-response relationships

Statistical analyses of these radiological responses have pointed to a role for the unusually high concentrations of quartz experienced by some workers, and particularly those working at or near the return ends of certain faces within the Parrot seam at Colliery P. These faces were known to be difficult to work, because they fluctuated in thickness; and because they often became narrower than the fixed range of the drum shearer cutting the coal, it was inevitable that some of the sandstone roof and floor would be cut with the coal, resulting in increased dust containing a higher proportion than usual of quartz. The hypothesis that it was specifically this source of quartz which has induced the disturbingly high prevalences of radiological abnormality at follow-up is strengthened by the absence of a relationship with quartz exposures experienced before the mechanisation of coal-getting in this colliery.

Regression models such as those reported in chapter 6 can be used to yield various predictions of the risk of pneumoconiosis associated with different values of the explanatory variables. These predictions can be used to summarise the trends found within the data sets, or (with greater uncertainty) to extrapolate to other values. An example of such calculations is given in Figure 7.1. Model 2+/F/17 of Table 6.6 was used to predict the risk that the radiograph of a man appearing at follow-up would produce a median reading of 2/1 or greater, as a function of quartz exposure and age at follow-up. The exposure calculation assumed that the man was exposed to a constant concentration of respirable quartz throughout ISPs 3, 4 and 5, and the predicted risks are tabulated against these average concentrations. A correspondence can be drawn between these and the men's cumulative exposures by noting that the three ISPs covered about 15 years, and that a year is assumed to include 1740 working hours. To convert from concentration in $mg.m^{-3}$ to exposure in ghm^{-3} we therefore multiply by the factor $15 \times 1.74 = 26$.

The predicted risks are graphed, for men aged 50, 60, 70 and 80 at follow-up, at average quartz concentrations up to 0.5 $mg.m^{-3}$. The predicted risks are very high at the highest range. To place this in the context of the available data, the upper quintile of the exposure distribution of Table 5.11 was 5.7, equivalent to a concentration of 0.22; and the mean exposure of that group corresponded to a concentration of 0.3. The observed prevalences in this highest exposed group, at around 20 - 40%, accord well with the magnitude of the predictions at this level.

The fitted exposure-response relationships provide a very interesting comparison with those reported by Miller and Kinnear (1988) from analyses of the PFR survey data from the same population. As in that report, the present study has demonstrated no relationship with exposures before the 3rd PFR survey. There have been many other reports from different groups of PFR subjects in whom radiological abnormalities have been related to estimates of exposures during this early period. More than half of the men had non-zero ISP 0+1+2 exposures, and these had a range of over 130 ghm^{-3}, implying that the failure to observe a similar relationship here is not simply a function of very low dust exposures. Table 4.3 suggests a possible explanation, in that it was only after 3rd survey, in ISP 3, that the average proportion of quartz in the respirable dust concentrations began to rise above 5%. This coincided with a complete change in the working methods used in Colliery P, from a fairly large number of hand-got faces in 1954 to a very small number of mechanised faces by 1967, so that ISP 0+1+2 represented dust exposure from a period when the coal was almost entirely hand-got. Hand-getting caused little disturbance of the strata surrounding the coal measure, and it is thus very plausible that sandstone roofs and floors played little part in the generation of respirable dust throughout the period prior to 3rd survey.

While exposures prior to 3rd survey have not been shown to relate to pneumoconiosis risk at follow-up, there were clear effects of later exposures. We have noted the caution required in interpreting the effects of exposures correlated over time, but have fitted a number of models with combinations of exposure terms in an attempt to understand these here. We have found that radiological abnormalities related somewhat better to quartz exposures than to the non-quartz fraction, and this finding is similar to that of Miller and Kinnear (1988) for results from the PFR surveys. There are some detailed differences between two sets of results. The earlier work showed stronger associations with the 1/0+ response than with the 2/1+ response, but the number of responses at the higher level was very limited. In the present study, with rather more abnormality, the analyses of the follow-up data have greater power to distinguish between possible alternative models for the more advanced response.

A further similarity with the earlier results is in the comparison between the regression coefficients for the exposures during the different ISPs; whether fitted singly or several at a time, the coefficients for the effect of quartz exposure in ISP 3 are smaller than those in ISPs 4 and 5. For example, in model 2+/F/17 of Table 6.6, the three coefficients are 0.207, 0.525 and 0.652 respectively. The statistical significance of the ISP 3 coefficient in the presence of the others is dubious, but, whether or not it is important, it is significantly less than the ISP 4 and 5 effects. Although the ISP 5 coefficient is larger than that for ISP 4, the difference is not statistically significant, since each of the three coefficients has a standard error of around 0.15.

This pattern may tell us something about the shape of the exposure-response relationship for the men from this colliery. Research results on coalworkers' pneumoconiosis have suggested that the total cumulative exposure to respirable dust was the exposure variable which gave the best fitting association with the risk of developing pneumoconiosis. Knowledge of the elapsed time since exposure was experienced did not, in the main, materially improve the prediction of risk. An association with total cumulative exposure, regardless of time, can be shown to arise from an exposure whose effects take place relatively soon after the exposure is experienced, as with, for example, radiation exposures with short half-lives. The findings of the early research also suggested that, on average, pneumoconiosis risks changed little after cessation of exposure. Subsequent PFR results have suggested that this model may have been over-simplistic, and that progression after cessation of exposure does occur in some men, particularly those who have already shown a rapid progression in response to their occupational exposure. It is not yet clear whether residence time of the dust deposited in the lungs, or individual differences in susceptibility to disease following exposure, is the more important factor here.

Different dosimetric assumptions can lead to different relationships, in which some quantity other than total cumulative exposure may be a better indicator of exposure-related risk. For example, epidemiological evidence from occupations with exposure to relatively pure quartz dust, such as hardrock metal mining, granite quarrying and masonry, suggests that the silicosis observed in those industries is a much more aggressive disease than coalworkers' pneumoconiosis, and with a much greater likelihood of progression after exposure ceases. Such alternative risk scenarios can often be investigated by fitting separately exposures experienced in different periods, and comparing the magnitude of the estimated coefficients, and the modelling strategies employed here are designed from this viewpoint. But the model under which quartz remains active within the lung and continues to add to the probability of progression would be expected to show higher risks, and thus higher coefficients, for exposures experienced in earlier periods, which is not what we observe here. On the other hand, the amount of progression which occurred between the colliery's closure and the follow-up surveys appears consistent with the pattern expected for quartz exposures.

It is possible that the smaller coefficient for the ISP 3 quartz exposure represents a transition, in 1964 - 70, between the almost non-noxious exposures of the period before PFR 3rd survey and the damaging exposures of ISPs 4 and 5. All of the face occupations in the tables reproduced in Appendix A3 had quartz concentrations associated with them, but their magnitudes differed considerably. Inspection of these tables shows that even before 1966 there were occasional instances of much higher exposures to dust and quartz in particular occupations, and that in most cases these were associated with coal getting machinery or work at the return end of mechanised faces. Thus both the contribution of these quartz exposure to eventual pneumoconiosis risk, and the dilution of this effect by other smaller and possibly less direct quartz exposures, are plausible given the documented patterns of exposure in ISP3. The similarity of the magnitudes of the ISP 4 and ISP 5 exposure effects does not necessarily argue against the importance of the quartz; Figure 4.8 demonstrates that the most serious quartz exposures occurred over a relatively short space of time, occupying only part of ISP 4 and ISP 5, so again there may have been some dilution of the exposure effect by less damaging quartz exposures at lower concentrations.

This raises the question of whether there is a threshold for health effects from quartz exposures: that is, is there an amount of exposure to respirable quartz which can be tolerated and which does not carry an increased risk of radiological progression? The observations of the preceding paragraphs suggest that it may be necessary, before attempting to answer this question, to distinguish between types of quartz exposures. As we have observed, there is strong evidence for the role of the quartz produced by mechanised coal-getting in a difficult seam in sandstone, and at least in ISP 4 almost no quartz effect remained after allowing for time worked in the excessive concentrations of particular occupational groups in 1971 and 1972. Attempts to explain the effects of ISP 5 exposures in terms of a single occupation were much less successful. What is needed here is careful modelling which distinguishes between quartz exposures typical of those experienced up to ISP 3, and low-level exposures to the quartz produced by the mechanised working in, particularly, the Parrot seam. Given the size of the study population and the fact that many men worked in many OGSNs over their working lives, the results of such modelling may be difficult to interpret in detail; but the careful work done so far to retain the separate components of an individual's occupational exposure offers many opportunities for such investigations. It is possible, in addition, that detailed modelling might help to explain the apparently anomalous relationship of radiological response with age.

Taking the statistical models at face value permits the estimation of health risks over a range of low exposures relevant to the debate on control limits, and, as we have seen, these turn out to suggest significant risks at quite low average concentrations of quartz. However it is possible that the unusual intensity (concentrations) of the quartz exposures experienced by some men induced proportionately higher risks in relation to exposure than those resulting from exposures at more usual quartz concentrations, conceivably by toxic overload of the lung defence mechanisms. As an explanation for the higher estimates of risk during ISPs 3 and 4 than ISPs 0, 1 and 2, this would be an alternative or complementary hypothesis to the suggestion that the freshly cut nature of the quartz during the later periods caused a more intense biological response. The statistical models described in this report summarise the exposure response relationships over the whole range of exposures within each ISP, and assume that the quartz concentration has no influence in excess of its incremental effect on cumulative exposure.

Indeed, the complexity of the subject implies that there may be additional dangers in simply extrapolating predictions to lower doses or to other collieries. The models presented, though perfectly satisfactory for summarising the general pattern of exposure-response across the whole range of exposure, must be approached with caution at the extremes of the exposure range. Attempts to estimate directly from statistical models the health risks over the low range of quartz concentrations, say below 1 $mg.m^{-3}$, should be cautious, and some additional analysis of the fit of the model at low exposures, and the influence on the exposure response relationship of experience of unusually high concentrations, would be highly desirable. The exposure data, and the exposure experience of this population would be highly suitable for determining risks at low exposures, if these considerations are taken into account.

7.6 Lung function and respiratory symptoms

As might have been expected, the results of analyses of lung function and respiratory symptoms were much less directly associated with exposure variables. There was some evidence of an association of symptoms of chronic bronchitis with dust exposures, but other symptoms showed little evidence of any such relationship. Evidence for a link between FEV_1 and occupational exposure was weak, but there was evidence for a relationship between loss of FEV_1 and development of radiological abnormalities even at the lower profusion levels. This is an uncommon finding for the coal industry, in which previous work has generally failed to identify detectable respiratory signs or symptoms in simple pneumoconiosis. Again, if these are health effects associated with quartz exposures, it is understandable that they may behave differently from the effects of respirable coal dust.

The lung function measurements were taken using the now obsolete Gaensler spirometer, so that they would be directly comparable with measurements from the PFR. No direct use has been made in this study of this inbuilt comparability, but we note that recent IOM work on the analysis of longitudinal lung function data (Maclaren *et al.*, 1994) has identified modelling techniques which might be employed to analyse these data as a whole.

7.7 Concluding remarks

It is clear from previous publications and from the data and results presented in this report that the events of the 1970s in Colliery P led to a number of men experiencing unusually and undesirably high exposures to quartz-laden dust. This had produced by 1991 an amount of radiological abnormality which was atypical certainly of the Scottish coalfields, and probably of the industry in general. The unusual nature of the exposures, and of the responses they have induced, suggest that the medical surveillance of the population should be continued if at all possible. Such surveillance might usefully prioritise attempts to examine men who worked in occupations where the quartz concentrations were highest.

The study has produced information on responses to quartz in respirable coalmine dust which are probably unequalled in reliability and in detail, particularly in the exposure data. Further analyses of these data could shed light on the shape of the exposure-response curve at lower exposure levels, which would be relevant to the setting of standards; and would allow the investigation of functional questions such as the presence or absence of low-level threshold effect, or of exaggerated responses to high concentration peaks.

8. ACKNOWLEDGEMENTS

Many colleagues, past and present, have contributed to the work of the Pneumoconiosis Field Research since it began some forty years ago. It is impossible to name them individually, but the range and quality of data available for study are a tribute to the efforts of all of them.

The local knowledge and innumerable contacts of past and present British Coal employees, and particularly of Mr P Hogg, one-time NUM official at Colliery P, were invaluable in identifying and tracing ex-workers from that colliery.

The new data from the follow-up surveys were collected by a team supervised by radiographers Mrs B Hamilton and Ms J Jeffryes and including Mr J Allan, Mr P Johnston, Mr T Campbelton and Mr W Scott.

The radiographs were read clinically by Drs ER Waclawski and CA Soutar, and the panel for the epidemiological reading exercise was Dr A Rickards, Prof A Seaton and Dr J Bennett. Data were entered to computer by Ms Margaret Burnett and Ms Mags Parker.

The manuscript was prepared by the authors, with secretarial help from Miss A McCarron and Mrs E Macrae. Mr B Turner assisted in the production of some of the graphs.

The authors gratefully acknowledge the assistance given by those mentioned above both explicitly and by implication, without which the completion of this investigation would not have been possible.

We gratefully acknowledge the financial support of British Coal.

9. REFERENCES

Collett D. (1991). Modelling binary data. London: Chapman and Hall.

Collins HPR, Dick JA, Bennett JG, Pern PO, Rickards MA, Thomas DJ, Washington JS, Jacobsen M. (1988). Irregularly shaped small shadows on chest radiographs, dust exposure and lung functions in coal-workers' pneumoconiosis. British Journal of Industrial Medicine; 45: 43-55.

Copland L, Burns J, Jacobsen M. (1981) Classification of chest radiographs for epidemiological purposes by people not experienced in the radiology of pneumoconiosis. British Journal of Industrial Medicine; 38: 254-261.

Cowie HA, Hurley JF, Hutchison PA, Pern PO, Soutar CA. (1990). Factors influencing the occurrence of progressive massive fibrosis of various types. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/90/13/041).

Davis JMG, Chapman J, Collings P, Douglas AN, Fernie JM, Lamb D, Ruckley VA. (1983). Variations in the histological patterns of the lesions of coalworkers' pneumoconiosis in Britain and their relationship to lung dust content. American Review of Respiratory Disease; 128: 118-124.

Davis JMG, Addison J, Brown GM, Jones AD, McIntosh C, Miller BG, Whittington M. (1991). Further studies on the importance of quartz in the development of coalworkers' pneumoconiosis. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/91/05).

Dixon WH, Brown MB, Engelman L, Hill MA, Jennrich RI eds. (1988). BMDP statistical software manual. Berkeley (Ca): University of California Press.

Dodgson J. (1984). Dust composition and coal workers pneumoconiosis. In: Bergbau-Berufsgenossenschaft. (1984). International Pneumoconiosis Conference 1983, Bochum. Vol. 3. Geneva: International Labour Organisation: 1609-1624.

Dodgson J, Whittaker W. (1973). The determination of quartz in respirable dust samples by infrared spectrophotometry, II. Annals of Occupational Hygiene; 16: 389-395.

Douglas AN, Collins HPR, Fernie JM, Soutar CA. (1988). The relationship between radiographic and pathological appearances of progressive massive fibrosis. In: Dodgson J, McCallum RI, Bailey MR, Fisher DR, eds. Inhaled Particles VI. Oxford: Pergamon Press: 561-566.

Draper NR, Smith H. (1981). Applied regression analysis. 2nd ed.. New York: John Wiley.

Gauld SJ, Hurley JF, Miller BG. (1988). Differences between long-term participants and non-responders in a study of coalminers' respiratory health and exposure to dust. In: Dodgson J, McCallum RI, Bailey MR, Fisher DR, eds. Inhaled Particles VI. Oxford: Pergamon Press: 545-551.

Genstat 5 Committee. (1987). Genstat 5 reference manual. Oxford: Clarendon Press.

Heederik DJ, Miller BG. (1988). Weak associations in epidemiology: adjustment for exposure estimation error. International Journal of Epidemiology; 17: 970-974.

Hurley JF, Copland L, Dodgson J, Jacobsen M. (1979). Simple pneumoconiosis and exposure to respirable dust: relationships from twenty-five years' research at ten British coalmines. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/79/13).

Hurley JF, Burns J, Copland L, Dodgson J, Jacobsen M. (1982). Coalworkers' simple pneumoconiosis and exposure to dust at 10 British coalmines. British Journal of Industrial Medicine; 39: 120-127.

Hurley JF, Maclaren WM, Alexander WP, Cowie AJ, Collins HPR, Ewing A, Hazledine DJ, Jacobsen M, Munro L, Soutar CA. (1984). Factors influencing the occurrence of progressive massive fibrosis in British coalminers. Final report on CEC contract 7256-34/016/08. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/84/02).

ILO. (1980). Guidelines for the use of ILO International Classification of Radiographs of Pneumoconiosis. Geneva: International Labour Organisation. (ILO Occupational Safety and Health Series No.22 (rev.80)).

Jacobsen M. (1980). New data on the relationship between simple pneumoconiosis and exposure to coal mine dust. Chest; 78 (2:suppl).

Jacobsen M, Rae S, Walton WH, Rogan JM. (1971). The relation between pneumoconiosis and dust exposure in British coal mines. In: Walton WH, ed. Inhaled Particles III. Proceedings of an international symposium organised by the British Occupational Hygiene Society in London, 14-23 September 1970. Vol 2. Old Woking (Surrey): Unwin Bros: 903-919.

Jacobsen M, Maclaren WM. (1982). Unusual observations and exposure to coalmine dust: A case-control study. In: Walton WH, ed. Inhaled particles V. Proceedings of an international symposium organized by the British Occupational Hygiene Society. Cardiff, 8-12 September 1980. Oxford: Pergamon Press: 753-765 (Annals of Ocupational Hygiene; 26).

Jacobsen M, Smith TA, Hurley JF, Robertson A, Roscrow R. (1988). Respiratory infections in coal miners exposed to nitrogen oxides. Cambridge (MA): Health Effects Institute. (HEI Research Report No.18).

Kuo J, McDonald J, Fox E. (1992). Sigmaplot users manual (DOS Version). Erkrath: Jandel Scientific.

Le Bouffant L, Daniel H, Martin JC. (1977). Quartz as a causative factor in pneumoconiotic lesions in coalminers. Luxembourg: Commission of the European Communities. (ECSC Industrial Health and Medicine Series No.19).

Maclaren WM, Hurley JF, Collins HPR, Cowie AJ. (1989). Factors associated with the development of progressive massive fibrosis in British coalminers: a case-control study. British Journal of Industrial Medicine; 46: 597-607.

Maclaren WM, Miller BG, Hurley JF, Love RG. (1994). Reference values for lung function decline in working coalminers. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/94/08).

Miller BG, Jacobsen M, Steele RC. (1981). Coalminers' mortality in relation to radiological category, lung function and exposure to airborne dust. Final report on CEC Contract 7246-16/8/001. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/81/10).

Miller BG, Jacobsen M. (1985). Dust exposure, pneumoconiosis and coalminers' mortality. British Journal of Industrial Medicine; 42: 723-733.

Miller BG, Kinnear AG. (1988). Pneumoconiosis in coalminers and exposure to dust of variable quartz content. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/88/17).

Miller BG, Addison J, Brown GM, Donaldson K, Hurley JF, Robertson A. (1993). Effects of quartz in coalmine dust - a synthesis of results from research in the British coal industry. In: Hurych J, Lesage M, David A, eds. Eighth international conference on occupational lung diseases, 14-17 September 1992, Prague, Czechoslovakia. Proceedings. Vols. 1-3. Geneva: International Labour Office: 594-602.

Quanjer PH, ed. (1983). Standardisation of lung function tests. Report of working party. Bulletin Européen de Physiopathologie Respiratoire: 19 (Supplement 5). Luxembourg: Commission of the European Communities.

Robertson A, Bolton RE, Chapman JS, Davis JMG, Dodgson J, Gormley IP, Jones AD, Miller BG. (1984). Animal inhalation experiments to investigate the significance of high and low percentage concentrations of quartz in coalmine dusts in relation to epidemiology and other biological tests. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/84/5).

Robertson A, Hurley JF, Brown PW, Collins HPR, Dodgson J, Maclaren WM. (1987). A case-control study of reasons for unusual radiological changes of pneumoconiosis among individual mineworkers. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/87/11).

Robinson BN, Anderson GD, Cohen E, Gdzik WF, Karpel LC, Miller AH, Stein JR. (1980). SIR scientific information retrieval. Users' manual version 2. Evanston (Ill): SIR Inc.

Rogan JM, Attfield MD, Jacobsen M, Rae S, Walker DD, Walton WH. (1973) Role of dust in the working environment in development of chronic bronchitis in British coal miners. British Journal of Industrial Medicine; 30: 217-226.

Ruckley VA, Fernie JM, Campbell SJ, Cowie HA. (1989). Causes of disability in coalminers: a clinico-pathological study of emphysema, airways obstruction and massive fibrosis. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/89/05).

Seaton A, Dick JA, Dodgson J, Jacobsen M. (1981). Quartz and pneumoconiosis in coal miners. Lancet; ii: 1272-1275. (Correspondence: 1982; i: 45-46).

Snedecor GD, Cochrane WG. (1980). Statistical methods. Seventh edition. Iowa: State University Press.

Soutar CA, Maclaren W, Hurley F, Murdoch R, Hadden G, Love R. (1982). Pneumoconiosis, lung function and exposure to airborne dust: epidemiological research to compare responses of working coalminers with responses of ex-miners: Part II. Final report on CEC Contract 7246-16/8/002. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/82/05).

Soutar CA, Collins HPR. (1984). Classification of progressive massive fibrosis of coalminers by type of radiographic appearance. British Journal of Industrial Medicine; 41: 334-339.

Walton WH, Dodgson J, Hadden GG, Jacobsen M. (1977). The effects of quartz and other non-coal dusts in coalworkers' pneumoconiosis. In: Walton WH, ed. Inhaled Particles IV. Vol 2. Oxford: Pergamon Press: 669-690.

Westerholm P. (1980) Observations on a case register. Scandinavian Journal of Work, Environment and Health; 6, Supplement 2: 1-86.

Table 1.1 Comparisons of compositional analyses of coalmine dusts used in two series of animal inhalation experiments.

Dust	%Coal	%Ash	%Quartz	%Kaolinite	%Illite
Scottish High Quartz[+]	45.4	54.6	24.5	23.8	2.4
Scottish Low Quartz[+]	70.5	29.5	6.8	15.3	4.3
Scottish High Quartz II*	24.2	75.5	18.4	25.5	17.0
Nottinghamshire*	13.6	86.3	15.7	18.6	32.3

[+] Robertson *et al.*, 1984 * Davis *et al.*, 1991

Table 3.1 Summary of tracing and survey attendance

Tracing result	No of men
Dead	384
Untraced or abroad	111
Traced, no reply	45
Traced, replied `No'	165
Traced, replied `Yes'	711
Total	1416
Attended survey	551

Table 4.1 Parrot seam: OGSNs and associated quarters for which mean quartz concentration >1 mg.m^{-3} or mean respirable dust concentration >5 mg.m^{-3}

OGSN	Job Title	Parrot Face	Quarter	Concs. (mg.m^{-3}) Quartz	Resp. dust
F488	Return Brusher	No.2 West	Oct 69	1.244	5.536
			Jan 70	1.232	5.483
			Apr 70	1.126	9.910
			Jul 70	1.547	5.166
F490	Return Stablemen	No.2 West	Oct 69	1.3877	6.173
			Jan 70	1.0880	-
			Apr 70	-	5.680
			Jul 70	-	5.155
F503	P/L team	No.5 south	Jan 71	-	5.980
F512	Intake/return Ripper	P.03 face	Apr 72	1.052	-
			Jul 72	3.070	7.293
			Oct 72	1.751	-
			Jan 73	2.020	-
F514	Return Stablemen	P.03 face	Apr 71	-	6.11
			Jul 71	-	7.46
			Oct 71	-	5.62
			Jan 72	2.486	-
			Apr 72	10.729	18.31
			Jul 72	6.068	12.52
			Oct 72	*	*
			Jan 73	10.822	22.32
			Apr 73	2.167	-
F515	P/L team	P.03 face	Apr 72	3.206	6.697
			Jul 72	2.280	-
			Jan 73	3.856	-
			Apr 73	7.296	7.620
			Jul 73	-	14.417
F534	Return Stablemen	P.04 face	Apr 74	-	5.482
			Oct 75	-	8.370
			Jul 76	1.3027	5.433
			Oct 76	-	5.400
F535	Face team	P.04 face	Jul 76	1.0681	-
F543	Return Ripper	P.04 face	Apr 73	-	7.555
			Jul 73	-	5.433
			Apr 74	-	5.385
			Jan 75	-	5.195
			Jul 76	1.389	5.110

Table 4.1 (contd).

OGSN	Job Title	Parrot Face	Quarter	Concs. (mg.m^{-3})	
				Quartz	Resp. dust
F551	Return Ripper	P.27 face	Oct 73	1.767	9.940
			Jan 74	1.209	6.805
			Apr 74	1.420	7.988
			Jul 74	2.028	6.268
			Oct 74	1.909	5.900
			Jan 75	1.175	7.322
			Apr 75	1.107	6.898
			Jul 75	*	5.100
			Oct 75	1.836	-
			Jan 76	3.724	9.207
			Apr 76	1.325	-
			Jul 76	2.136	5.137
			Jul 76	-	5.100
F553	Return Stablemen	P.27 face	Oct 73	1.635	11.007
			Jan 74	1.116	7.513
			Apr 74	1.015	6.832
			Jul 74	2.191	7.257
			Oct 74	1.191	-
			Jan 75	-	5.677
			Apr 75	-	5.151
			Jul 75	2.424	7.210
			Oct 75	1.350	-
			Jan 76	1.935	5.756
			Apr 76	1.540	-
			Jul 76	2.432	-
			Oct 76	-	5.000
F554	Face team	P.27 face	Jul 74	1.8391	6.006
			Oct 74	1.3893	-
F566	Return Ripper	P.05 face	Jan 77	1.1174	5.966
			Jul 77	-	5.267
			Oct 77	-	6.137
F578	Return Stablemen	P.05 face	Apr 77	-	5.006
			Jul 77	-	6.868
			Oct 77	-	6.285
			Jul 78	-	6.910
F578	Return Ripper	P.11 face	Apr 78	-	6.087
			Jan 79	-	5.270
F580	Return Stablemen	P.11 face	Jan 78	-	5.160
			Apr 78	-	5.710
			Oct 78	-	5.505
F604	Return Ripper	P.07 face	Apr 80	1.0212	5.196
			Jul 80	-	5.940
			Oct 80	-	5.130
F607	Face team	P.07 face	Jul 80	-	5.718

* indicates non-existence of data within a period where other quarters have concentrations >1 mg.m^{-3} (dust) or >5 mg.m^{-3} (quartz).

- indicates a quarter where the mean dust (quartz) concentration does not meet the criterion for inclusion, but the corresponding quartz (dust) concentration does.

Table 4.2 Summary of data on exposures to the non-quartz and quartz fractions of respirable dust for all 549 men in study population. Tabulated are the mean and maximum values, and the number of non-zero values, for each variable.

	Non-quartz dust exposure (ghm^{-3})			Quartz dust exposure (ghm^{-3})		
Period	Mean	Max.	No. > 0.0	Mean	Max.	No. > 0.0
ISP 0+1+2	26.35	128.54	304	1.33	7.00	304
ISP 3	13.31	35.14	502	1.37	5.79	502
ISP 4	7.03	27.80	519	0.95	7.89	519
ISP 5	5.13	21.74	442	0.69	4.73	442
ISP 6	0.86	9.74	372	0.09	1.26	370
ISP 7	0.26	3.05	272	0.03	0.39	265

Table 4.3 Summary of data on proportion of quartz (in non-zero exposures) to total respirable dust. Tabulated are the minimum, mean and maximum values of the proportion, presented as a percentage, and the number of values over which they were calculated.

	Percentage quartz in respirable dust			
Period	Min	Mean	Max.	No. of values
ISP 0+1+2	0.36	4.80	7.58	304
ISP 3	1.82	7.70	17.54	502
ISP 4	2.40	8.64	29.36	519
ISP 5	1.59	9.10	26.65	442
ISP 6	0.00	7.12	16.13	372
ISP 7	0.00	8.06	16.73	272

Table 4.4. Matrix of correlations between exposures of 549 follow-up survey attenders of to respirable quartz and non-quartz dust in various ISPs.

	Age at Survey	Quartz ISP 0+1+2	Quartz ISP 3	Quartz ISP 4	Quartz ISP 5	Quartz ISP 6+7	Dust ISP 0+1+2	Dust ISP 3	Dust ISP 4	Dust ISP 5
Quartz ISP 0+1+2	0.664									
Quartz ISP 3	0.338	0.223								
Quartz ISP 4	0.095	-0.029	0.633							
Quartz ISP 5	-0.124	-0.187	0.346	0.554						
Quartz ISP 6+7	-0.059	-0.095	0.307	0.377	0.520					
Dust ISP 0+1+2	0.677	0.973	0.201	-0.029	-0.188	-0.084				
Dust ISP 3	0.442	0.286	0.902	0.569	0.357	0.288	0.269			
Dust ISP 4	0.142	0.018	0.648	0.865	0.643	0.461	0.012	0.683		
Dust ISP 5	-0.071	-0.116	0.398	0.548	0.889	0.587	-0.123	0.423	0.721	
Dust ISP 6+7	-0.058	-0.089	0.340	0.393	0.512	0.957	-0.079	0.316	0.498	0.615

Table 4.5 Summary of time spent in non-coalmining occupations after leaving Colliery P

Occupation	Time spent (yrs)			
	Min.	Mean	Max.	No. of men
Other mining (surface)	6,417	6.417	6.417	1
Brickworks general	1.750	2.000	2.250	2
Construction (other)	0.250	3.783	14.333	28
Demolition	0.167	4.167	11.167	3
Quarry (General)	0.333	0.333	0.333	1
Quarry (dusty)	1.667	1.833	2.000	2
Agricultural/farming	0.250	1.083	1.833	3
Other industrial (nox/dust)	0.500	2.917	7.750	14
Other industrial (not nox)	0.250	5.058	18.833	72
Other non-industrial	0.083	4.370	19.917	91
Armed services	0.250	3.479	8.500	4
Ill health	0.167	4.914	14.083	33
Redundant/unemployed	0.000	2.106	14.083	123
Strike	0.167	0.744	1.083	125
Retired	0.250	9.016	21.167	350
Coalmining	0.167	5.230	18.500	337

Table 4.6 Distribution of number of colliery jobs held after leaving Colliery P

No. of colliery jobs held after P	No. of men
0	212
1	185
2	129
3	16
4	5
5	1
6	0
7	1
Total	549

Table 5.1 Number of men surveyed by 10-year age group and smoking habit.

Age (yrs)	Smoking habit			Total
	Non	Current	Ex	
<35	9	12	3	24
35-44	16	33	11	60
45-54	20	55	19	94
55-64	20	68	60	148
65-74	16	63	86	165
75+	7	20	31	58
Total	88	251	210	549

Table 5.2 Attendance at follow-up survey by age at last PFR survey attended. Numbers of men (and % of row total).

Age Group	Attendance		Total
	Attenders	Non-attenders	
15-24	64 (32)	137 (68)	201
25-34	47 (32)	100 (68)	147
35-44	109 (60)	72 (40)	181
45-54	182 (71)	76 (29)	258
55-64	145 (61)	93 (39)	238
65+	2 (40)	3 (60)	5
Total	549 (53)	481 (47)	1030

Table 5.3 Attendance at follow-up survey by smoking habit at last PFR survey attended. Numbers of men (and % of row total).

Smoking category	Attendance		Total
	Attenders	Non-attenders	
Non-smoker	96 (52)	87 (48)	183
Smoker	344 (53)	308 (47)	652
ex-smoker	107 (56)	84 (44)	191
Total	547 (53)	479 (47)	1026

Table 5.4 Distribution of radiological abnormalities (small and large opacities) identified at initial screening of radiographs.

Small Opacities	Profusion							
Shape and size	1/1	1/2	2/1	2/2	2/3	3/2	3/3	Total
p/p	21	1		6			1	29
p/q	5	2		2			2	11
p/r		1		1				2
q/q	3	1	1	10	3		1	19
q/p	3	1	1	1				6
q/r				3	1		1	5
r/r	3			2		1	1	7
r/p							1	1
r/q	1			1				2
Others	2	1	1	3			1	8
Total	38	7	3	29	4	1	8	90
Large Opacities								
A	4			4		1	2	11
B	1			4			2	7
C				1				1

Table 5.5 Number of changes made to the 35 original classifications of follow-up radiographs, by the main sections of the ILO (1980) Classification.

Section of classification	Number of changes: Reader 002	013	015	Total
Technical quality	0	0	4	4
Small opacities:				
profusion	11	4	12	27
zone	9	4	7	20
shape and size	10	5	5	20
Category of large opacities	0	0	1	1
Pleural thickening:				
plaques	0	0	0	0
diffuse	1	0	0	1
diaphragm	0	0	0	0
cpa obliteration	2	1	0	3
Pleural calcification	0	0	0	0
Other abnormalities	0	0	2	2
Comments	1	0	12	13
Total	34	14	43	91

Table 5.6 Comparison of profusion of small opacities from first and revised readings of follow-up survey radiographs.

Reader 002		Profusion on 2nd reading 0/0	0/1	1/0	1/1	Total
Profusion on 1st reading	0/0	0	3	5	0	8
	0/1	1	1	1	0	3
	1/0	0	0	0	1	1
Total		1	4	6	1	12

Reader 013		Profusion on 2nd reading 0/0	0/1	1/0	Total
Profusion on 1st reading	0/0	0	3	0	3
	0/1	1	0	0	1
	1/0	0	0	1	1
Total		1	3	1	5

Reader 015		Profusion on 2nd reading 0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	Total
Profusion at 1st reading	0/0	3	0	2	0	1	0	0	0	6
	0/1	1	0	1	0	0	0	0	0	2
	1/0	0	0	1	0	0	0	0	0	1
	1/1	0	0	1	0	0	0	0	0	1
	1/2	1	0	0	1	0	0	0	0	2
	2/1	0	0	0	2	0	0	0	0	2
	2/2	0	0	0	0	0	0	2	1	3
	2/3	0	0	0	0	0	1	0	0	1
Total		5	0	5	3	1	1	2	1	18

Table 5.7 Assessment of technical quality of follow-up survey radiographs.

	Reader		
Quality	002	013	015
Good	327	368	385
Acceptable	190	164	116
Poor	30	15	43
Unacceptable	0	0	3
Total	547	547	547

Table 5.8 Distribution of films to profusion categories assigned by individual readers; plus summary median reading.

	Profusion											
Reader	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	Miss -ing	Total
002	361	38	66	43	14	7	8	6	3	1	0	547
013	188	163	68	57	11	18	27	11	4	0	0	547
015	373	12	38	30	23	17	27	14	5	5	3	547
Median	322	67	55	41	15	14	19	10	3	1		547

Table 5.9 Agreement between pairs of readers on profusion of small opacities on ILO (1980) 12 point scale (* = assessment not made).

Profusion	Reader 013											Total
	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	*	
0/0	178	128	37	13	3	0	1	1	0	0	0	361
0/1	5	12	13	7	0	1	0	0	0	0	0	38
1/0	4	19	14	19	5	3	1	1	0	0	0	66
1/1	0	3	2	14	2	10	9	2	1	0	0	43
Reader 1/2	1	1	2	4	1	1	4	1	0	0	0	14
002 2/1	0	0	0	0	0	0	6	1	0	0	0	7
2/2	0	0	1	0	0	1	4	2	0	0	0	8
2/3	0	0	0	0	0	2	2	1	1	0	0	6
3/2	0	0	0	0	0	0	0	1	2	0	0	3
3/3	0	0	0	0	0	0	0	1	0	0	0	1
*	0	0	0	0	0	0	0	0	0	0	0	0
Total	188	163	68	57	11	18	27	11	4	0	0	547

CONSISTENCY COEFFICIENT = 41.3%

Profusion	Reader 015											Total
	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	*	
0/0	300	10	22	14	4	3	4	1	0	0	3	361
0/1	24	2	4	0	4	2	2	0	0	0	0	38
1/0	35	0	11	10	6	1	2	0	1	0	0	66
1/1	11	0	1	3	8	6	8	5	0	1	0	43
Reader 1/2	2	0	0	2	0	3	4	3	0	0	0	14
002 2/1	0	0	0	0	0	2	3	2	0	0	0	7
2/2	0	0	0	1	1	0	3	1	2	0	0	8
2/3	1	0	0	0	0	0	0	2	1	2	0	6
3/2	0	0	0	0	0	0	1	0	1	1	0	3
3/3	0	0	0	0	0	0	0	0	0	1	0	1
*	0	0	0	0	0	0	0	0	0	0	0	0
Total	373	12	38	30	23	17	27	14	5	5	3	547

CONSISTENCY COEFFICIENT = 59.4%

Profusion	Reader 015											Total
	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	*	
0/0	176	2	5	4	0	0	0	0	0	0	1	188
0/1	124	8	16	10	2	1	1	1	0	0	0	163
1/0	45	2	10	6	3	0	1	0	0	0	1	68
1/1	18	0	4	8	10	6	8	1	0	1	1	57
Reader 1/2	5	0	2	0	1	2	0	1	0	0	0	11
013 2/1	3	0	1	1	4	2	5	2	0	0	0	18
2/2	2	0	0	1	3	4	9	6	2	0	0	27
2/3	0	0	0	0	0	2	2	3	2	2	0	11
3/2	0	0	0	0	0	0	1	0	1	2	0	4
3/3	0	0	0	0	0	0	0	0	0	0	0	0
*	0	0	0	0	0	0	0	0	0	0	0	0
Total	373	12	38	30	23	17	27	14	5	5	3	547

CONSISTENCY COEFFICIENT = 39.8%

Table 5.10 Agreement between pairs of readers on profusion of small opacities on a 4 point scale of major profusion categories (* = assessment not made).

	Reader 013					
Profusion	0	1	2	3	*	Total
0	323	73	3	0	0	399
Reader 1	28	62	32	1	0	123
002 2	0	1	19	1	0	21
3	0	0	2	2	0	4
*	0	0	0	0	0	0
Total	351	136	56	4	0	547

CONSISTENCY COEFFICIENT = 74.2%

	Reader 015					
Profusion	0	1	2	3	*	Total
0	336	48	12	0	3	399
Reader 1	48	41	32	2	0	123
002 2	1	2	13	5	0	21
3	0	0	1	3	0	4
*	0	0	0	0	0	0
Total	385	91	58	10	3	547

CONSISTENCY COEFFICIENT = 71.8%

	Reader 015					
Profusion	0	1	2	3	*	Total
0	310	37	3	0	1	351
Reader 1	70	44	19	1	2	136
013 2	5	10	35	6	0	56
3	0	0	1	3	0	4
*	0	0	0	0	0	0
Total	385	91	58	10	3	547

CONSISTENCY COEFFICIENT = 71.7%

Table 5.11. Distribution of population with follow-up radiographs, by age and quintiles of exposure to respirable quartz in ISP 3-7. Table contains numbers of men and mean exposure.

Age at follow-up	Exposure to respirable quartz cumulated in ISP 3-7 (ghm^{-3})											
	0 - 0.37		0.37 - 1.46		1.46 - 3.18		3.18 - 5.70		over 5.70		All exps	
	No.	*Exp*	No.	*Exp*	No.	*Exp*	No.	*Exp*	No.	*Exp*	No.	*Exp*
≤ 34	18	*0.11*	4	*0.52*	0	*	0	*	0	*	22	*0.18*
35-44	21	*0.12*	19	*0.89*	8	*1.93*	10	*4.69*	2	*6.73*	60	*1.59*
45-54	14	*0.18*	16	*0.95*	23	*2.42*	20	*4.31*	21	*8.17*	94	*3.52*
55-64	14	*0.15*	28	*0.88*	26	*2.44*	30	*4.69*	50	*7.78*	148	*4.19*
65-74	28	*0.28*	25	*0.77*	36	*2.14*	40	*4.60*	36	*7.90*	165	*3.47*
≥ 75	14	*0.22*	18	*0.90*	16	*2.08*	10	*4.44*	0	*	58	*1.67*
All ages	109	*0.18*	110	*0.86*	109	*2.25*	110	*4.57*	109	*7.88*	547	*3.15*

Table 5.12. Numbers of men with radiographs classified as 1/0 or greater (median reading). Percentages of Table 5.11 are shown in italics.

Age at follow-up	Exposure to respirable quartz cumulated in ISP 3-7 (ghm^{-3})											
	0 - 0.37		0.37 -1.46		1.46 - 3.18		3.18 - 5.70		over 5.70		All exps	
	No.	*%*	No.	*%*	No.	*%*	No.	*%*	No.	*%*	No.	*%*
≤ 34	0	*0*	0	*0*	*	*	*	*	*	*	0	*0*
35-44	1	*5*	1	*5*	1	*13*	2	*20*	0	*0*	5	*8*
45-54	2	*14*	2	*13*	4	*17*	6	*30*	15	*71*	29	*31*
55-64	1	*7*	2	*7*	2	*8*	7	*23*	30	*60*	42	*28*
65-74	4	*14*	8	*32*	11	*31*	16	*40*	20	*56*	59	*36*
≥ 75	4	*29*	5	*28*	9	*56*	5	*50*	*	*	23	*40*
All ages	12	*11*	18	*16*	27	*25*	36	*33*	65	*60*	158	*29*

Table 5.13. Numbers of men with radiographs classified as 2/1 or greater (median reading). Percentages of Table 5.11 are shown in italics.

Age at follow-up	Exposure to respirable quartz cumulated in ISP 3-7 (ghm^{-3})											
	0 - 0.37		0.37 -1.46		1.46 - 3.18		3.18 - 5.70		over 5.70		All exps	
	No.	*%*	No.	*%*	No.	*%*	No.	*%*	No.	*%*	No.	*%*
≤ 34	0	*0*	0	*0*	*	*	*	*	*	*	0	*0*
35-44	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
45-54	0	*0*	0	*0*	0	*0*	2	*10*	9	*43*	11	*12*
55-64	0	*0*	0	*0*	2	*8*	2	*7*	10	*20*	14	*9*
65-74	0	*0*	1	*4*	1	*3*	2	*5*	12	*33*	16	*10*
≥ 75	1	*7*	2	*11*	2	*13*	1	*10*	*	*	6	*10*
All ages	1	*1*	3	*3*	5	*5*	7	*6*	31	*28*	47	*9*

Table 5.14 Agreement between pairs of readers on the presence and size of large opacities (* = assessment not made)

Large Opacities		Reader 013 0	A	B	C	*	Total
Reader 002	0	520	17	3	0	0	540
	A	1	2	2	0	0	5
	B	0	0	2	0	0	2
	C	0	0	0	0	0	0
	*	0	0	0	0	0	0
Total		521	136	7	0	0	547

CONSISTENCY COEFFICIENT = 95.8%

Large Opacities		Reader 015 0	A	B	C	*	Total
Reader 002	0	527	9	1	0	3	540
	A	0	4	1	0	0	5
	B	0	0	2	0	0	2
	C	0	0	0	0	0	0
	*	0	0	0	0	0	0
Total		527	13	4	0	3	547

CONSISTENCY COEFFICIENT = 97.4%

Large Opacities		Reader 015 0	A	B	C	*	Total
Reader 013	0	514	5	0	0	2	521
	A	12	7	0	0	0	19
	B	1	1	4	0	1	7
	C	0	0	0	0	0	0
	*	0	0	0	0	0	0
Total		527	13	4	0	3	547

CONSISTENCY COEFFICIENT = 96.0%

Table 5.15 Radiological classifications for the 31 radiographs where at least one reader identified a large opacity

Small & large opacity readings						Large opacities
Reader						
002		013		015		Median
1/1	0	2/3	A	2/3	0	0
0/0	0	0/1	0	0/1	A	0
0/0	0	0/1	A	0/0	0	0
1/0	0	1/2	0	0/0	A	0
0/1	0	1/1	A	2/2	0	0
0/1	0	0/1	A	0/0	0	0
2/3	0	3/2	B	3/3	0	0
0/0	0	1/1	A	1/2	0	0
1/0	0	1/2	A	1/2	0	0
2/3	0	2/1	A	0/0	0	0
1/2	0	1/1	A	1/1	0	0
2/2	0	2/2	A	2/3	0	0
1/1	0	2/1	A	2/2	0	0
1/0	0	2/1	A	1/2	A	0
0/0	0	1/0	A	0/0	0	0
1/0	0	0/0	0	0/0	A	0
1/0	0	2/2	A	0/0	0	0
2/3	0	2/2	A	2/3	A	A
1/0	A	1/2	A	0/0	A	A
1/0	A	2/1	B	2/2	A	A
0/0	0	1/0	A	0/0	A	A
1/1	0	3/2	A	2/2	A	A
1/1	0	2/1	A	2/2	A	A
1/0	0	2/3	A	3/2	A	A
1/2	A	2/3	A	2/3	A	A
1/1	A	2/2	0	2/2	A	A
1/1	B	2/2	B	2/3	B	B
2/2	A	2/3	B	2/2	B	B
2/2	B	2/1	B	2/2	B	B
0/0	0	1/1	B	*/*	*	B
1/1	0	2/1	B	2/2	B	B

Table 5.16 Distribution of shape category for the 3 readers; number (percentage)

Shape	Reader 002	Reader 013	Reader 015
All rounded	69 (37)	120 (33)	104 (61)
Predom. rounded	57 (31)	105 (29)	35 (20)
Predom. irregular	7 (4)	51 (14)	11 (6)
All irregular	53 (28)	83 (23)	21 (12)
Total	186	359	171

Table 5.17 Distribution of readings by profusion and predominant shape/size. (* = assessment not made)

Reader 002

Profusion (12 pt)	Predominant shape/size p	q	r	s	t	u	None	*	Total
0/0	0	0	0	0	0	0	361	0	361
0/1	9	11	0	13	5	0	0	0	38
1/0	30	12	3	13	8	0	0	0	66
1/1	13	15	2	10	3	0	0	0	43
1/2	2	7	2	2	1	0	0	0	14
2/1	1	6	0	0	0	0	0	0	7
2/2	0	4	1	1	2	0	0	0	8
2/3	0	3	1	2	0	0	0	0	6
3/2	0	3	0	0	0	0	0	0	3
3/3	0	1	0	0	0	0	0	0	1
*	0	0	0	0	0	0	0	0	0
Total	55	62	9	41	19	0	361	0	547

Table 5.17 (contd)

Reader 013

Profusion (12 pt)	p	q	r	s	t	u	None	*	Total
	Predominant shape/size								
0/0	0	0	0	0	0	0	188	0	188
0/1	70	13	3	71	6	0	0	0	163
1/0	38	5	0	20	5	0	0	0	68
1/1	35	8	5	7	2	0	0	0	57
1/2	4	1	1	4	1	0	0	0	11
2/1	7	1	5	4	1	0	0	0	18
2/2	2	6	10	7	2	0	0	0	27
2/3	2	3	3	0	1	2	0	0	11
3/2	0	2	1	0	0	1	0	0	4
3/3	0	0	0	0	0	0	0	0	0
*	0	0	0	0	0	0	0	0	0
Total	158	39	28	113	18	3	188	0	547

Reader 015

Profusion (12 pt)	p	q	r	s	t	u	None	*	Total
	Predominant shape/size								
0/0	0	0	0	0	0	0	373	0	373
0/1	2	10	0	0	0	0	0	0	12
1/0	8	23	4	0	3	0	0	0	38
1/1	4	13	2	0	10	1	0	0	30
1/2	3	10	5	0	5	0	0	0	23
2/1	4	4	3	0	6	0	0	0	17
2/2	0	15	7	0	5	0	0	0	27
2/3	2	3	7	0	2	0	0	0	14
3/2	0	1	4	0	0	0	0	0	5
3/3	1	2	2	0	0	0	0	0	5
*	0	0	0	0	0	0	0	3	3
Total	24	81	34	0	31	1	373	3	547

Table 5.18 Availability for comparison of radiographs from previous PFR survey attendances.

Year of last PFR survey	Years between last PFR survey and follow-up	No. of men
1970	21	97 (18%)
1974	16	116 (21%)
1978/79	13	327 (61%)
All years		540 (100%)

Table 5.19 Comparison of median profusion for follow-up radiograph with median for last previous radiograph.

Last radiograph	Follow-up radiograph										Total
	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	
0/0	317	54	40	25	4	4	4	3	2	1	454
0/1	.	11	12	12	4	4	4	2	1	.	50
1/0	.	1	3	3	2	5	5	2	.	.	21
1/1	.	.	.	1	3	1	1	2	.	.	8
1/2	.	.	.	.	2	.	.	.	.	.	2
2/1	.	.	.	.	.	.	3	.	.	.	3
2/2	.	.	.	.	.	.	2	.	.	.	2
2/3	.	.	.	.	.	.	.	.	.	.	.
3/2	.	.	.	.	.	.	.	.	.	.	.
3/3	.	.	.	.	.	.	.	.	.	.	.
3/+	.	.	.	.	.	.	.	.	.	.	.
Total	317	66	55	41	15	14	19	9	3	1	540

Table 5.20 Comparison of median profusion for follow-up radiograph with median for last previous radiograph.

1970 Radiograph	Follow-up radiograph										Total
	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	
0/0	58	13	3	3	2	2	.	.	.	1	82
0/1	.	1	6	2	.	.	.	.	.	.	9
1/0	.	.	2	.	.	1	.	1	.	.	4
1/1	.	.	.	.	1	.	.	.	.	.	1
1/2	.	.	.	.	1	.	.	.	.	.	1
2/1	.	.	.	.	.	.	.	.	.	.	.
2/2	.	.	.	.	.	.	.	.	.	.	.
2/3	.	.	.	.	.	.	.	.	.	.	.
3/2	.	.	.	.	.	.	.	.	.	.	.
3/3	.	.	.	.	.	.	.	.	.	.	.
3/+	.	.	.	.	.	.	.	.	.	.	.
Total	58	14	11	5	4	3	.	1	.	1	97

1974 Radiograph	Follow-up radiograph										Total
	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	
0/0	63	13	12	6	1	.	.	.	1	.	96
0/1	.	4	3	4	.	.	2	2	.	.	15
1/0	.	.	.	1	.	2	.	.	.	.	3
1/1	.	.	.	.	1	.	.	.	.	.	1
1/2	.	.	.	.	.	.	.	.	.	.	.
2/1	.	.	.	.	.	.	.	.	.	.	.
2/2	.	.	.	.	.	.	1	.	.	.	1
2/3	.	.	.	.	.	.	.	.	.	.	.
3/2	.	.	.	.	.	.	.	.	.	.	.
3/3	.	.	.	.	.	.	.	.	.	.	.
3/+	.	.	.	.	.	.	.	.	.	.	.
Total	63	17	15	11	2	2	3	2	1	.	116

Table 5.20. (contd)

1978/79 Radiograph	Follow-up radiograph										Total
	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	
0/0	196	28	25	16	1	2	4	3	1	.	276
0/1	.	6	3	6	4	4	2	.	1	.	26
1/0	.	1	1	2	2	2	5	1	.	.	14
1/1	.	.	.	1	1	1	1	2	.	.	6
1/2	.	.	.	.	1	.	.	.	.	.	1
2/1	.	.	.	.	.	.	3	.	.	.	3
2/2	.	.	.	.	.	.	1	.	.	.	1
2/3	.	.	.	.	.	.	.	.	.	.	.
3/2	.	.	.	.	.	.	.	.	.	.	.
3/3	.	.	.	.	.	.	.	.	.	.	.
3/+	.	.	.	.	.	.	.	.	.	.	.
Total	196	35	29	25	9	9	16	6	2	.	327

Table 5.21 Comparisons of median profusion of large opacities for follow-up radiograph with median for last previous radiograph.

Last Radiograph	Follow-up radiograph 0	A	B	C	Total
0	526	8	3	0	537
A	0	1	2	0	3
B	0	0	0	0	0
C	0	0	0	0	0
Total	526	9	5	0	540

Table 5.22 Summary of change in median profusion of small opacities from last PFR radiograph to follow-up for those men with large opacities present at follow-up.

Large opacities		Small opacities	
follow-up	last PFR	follow-up	last PFR
A	0	2/3	1/0
A	0	1/0	0/0
A	0	2/1	0/1
B	0	2/2	2/2
A	0	0/0	0/0
A	A	2/2	2/1
A	0	2/1	1/0
B	0	2/2	2/1
A	0	2/3	1/1
B	A	2/2	1/1
B	0	1/1	0/1
B	A	2/1	0/1
A	0	2/3	0/0
A	0	2/2	1/0

Table 5.23 Number (and percentage of total) of men reporting cough and phlegm at follow-up survey.

Cough	Phlegm: None	Phlegm: Not persistent	Phlegm: Persistent	Total
none	198 (36)	34 (6)	27 (5)	259 (47)
not persistent	23 (4)	46 (8)	21 (4)	90 (16)
persistent	24 (4)	20 (4)	155 (28)	199 (36)
Total	245 (45)	100 (18)	203 (37)	548

Table 5.24 Number (and percentage of Table 5.1) of men with symptoms of chronic bronchitis (persistent cough and phlegm) at follow-up survey, by age and smoking habit.

Age (yrs)	Smoking habit: non	Smoking habit: current	Smoking habit: ex	Total (Margin)
<35	0 (0)	3 (25)	0 (0)	3 (13)
35-44	1 (6)	8 (24)	2 (18)	11 (18)
45-54	4 (20)	17 (31)	2 (11)	23 (24)
55-64	2 (10)	25 (37)	16 (27)	43 (29)
65-74	2 (13)	23 (37)	25 (29)	50 (30)
75+	0 (0)	13 (65)	12 (39)	25 (43)
Total (Margin)	9 (10)	89 (35)	57 (27)	155 (28)

Table 5.25 Number (and percentage of Table 5.1) of men reporting breathlessness at follow-up survey, by age and smoking habit.

Age (yrs)	Smoking habit: non	Smoking habit: current	Smoking habit: ex	Total (Margin)
<35	0 (0)	1 (8)	0 (0)	1 (4)
35-44	1 (6)	3 (9)	0 (0)	4 (7)
45-54	5 (25)	14 (25)	2 (11)	21 (22)
55-64	4 (20)	19 (28)	20 (33)	43 (29)
65-74	4 (25)	31 (49)	36 (42)	71 (43)
75+	3 (43)	13 (65)	13 (42)	29 (50)
Total (Margin)	17 (19)	81 (32)	71 (34)	169 (31)

Table 5.26 Number (and percentage of Table 5.1) of men reporting wheezing at follow-up survey, by age and smoking habit.

Age (yrs)	Smoking habit			Total (Margin)
	non	current	ex	
<35	2 (22)	6 (50)	1 (33)	9 (38)
35-44	1 (6)	9 (27)	2 (18)	12 (20)
45-54	8 (40)	28 (51)	6 (32)	42 (45)
55-64	1 (5)	29 (43)	18 (30)	48 (32)
65-74	3 (19)	29 (46)	33 (38)	65 (39)
75+	2 (29)	11 (55)	14 (45)	27 (47)
Total (Margin)	17 (19)	112 (45)	74 (35)	203 (37)

Table 5.27 Number (and percentage of total) of men reporting combinations of breathlessness and wheezing at follow-up survey.

Breathlessness	Wheezing		
	No	Yes	Total(Margin)
No	287 (52)	93 (17)	380 (69)
Yes	59 (11)	110 (20)	169 (31)
Total (Margin)	346 (63)	203 (37)	549

Table 5.28 Number (and percentage of Table 5.1) of men reporting past chest illnesses at follow-up survey, by age and smoking habit.

Age (yrs)	Smoking habit			Total (Margin)
	non	current	ex	
<35	2 (22)	1 (8)	0 (0)	3 (13)
35-44	2 (13)	8 (24)	1 (9)	11 (18)
45-54	3 (15)	13 (24)	2 (11)	18 (19)
55-64	3 (15)	11 (16)	18 (30)	32 (22)
65-74	4 (25)	10 (16)	26 (30)	40 (24)
75+	3 (43)	7 (35)	10 (32)	20 (34)
Total (Margin)	17 (19)	50 (20)	57 (27)	124 (23)

Table 5.29 Mean FEV_1 (litres) by age and smoking group

Age (yrs)	Smoking Group			All
	non	current	ex	
<35	3.89	3.96	3.82	3.92
35-44	3.91	3.60	3.70	3.70
45-54	3.28	2.99	3.29	3.12
55-64	2.80	2.52	2.59	2.59
65-74	2.72	2.03	2.23	2.20
75+	2.31	1.53	1.91	1.84
All	3.17	2.64	2.48	2.67

Table 5.30 Mean FVC (litres) by age and smoking group

Age (yrs)	Smoking Group non	current	ex	All
<35	5.20	5.11	4.98	5.13
35-44	5.17	4.78	4.97	4.92
45-54	4.51	4.26	4.38	4.34
55-64	4.04	3.85	3.82	3.87
65-74	3.76	3.35	3.48	3.46
75+	3.41	2.87	3.13	3.08
All	4.37	3.93	3.71	3.92

Table 5.31 Mean $FEV_1/FVC\%$ by age and smoking group

Age (yrs)	Smoking Group non	current	ex	All
<35	74.53	77.67	76.58	76.35
35-44	75.48	75.08	75.07	75.18
45-54	72.73	69.95	74.77	71.52
55-64	69.23	64.59	67.45	66.38
65-74	72.25	59.49	63.16	62.63
75+	67.87	51.29	59.68	58.01
All	72.14	65.55	65.75	66.69

Table 5.32 Mean percent predicted FEV_1 by age and smoking group

Age (yrs)	Smoking Group non	current	ex	All
<35	93.60	97.31	90.49	95.07
35-44	98.65	92.95	95.40	94.92
45-54	93.42	85.61	99.20	90.60
55-64	89.92	81.37	83.90	83.52
65-74	93.95	73.39	79.00	78.33
75+	93.38	64.78	77.27	75.27
All	93.73	81.65	83.03	84.12

Table 5.33 Mean percent predicted FVC by age and smoking group

Age (yrs)	Smoking Group			All
	non	current	ex	
<35	103.43	105.02	98.93	104.04
35-44	107.66	101.92	105.36	104.08
45-54	103.44	99.66	107.21	101.99
55-64	101.94	98.29	97.92	98.62
65-74	100.43	94.17	95.20	95.32
75+	103.64	90.35	94.55	94.34
All	103.45	97.79	97.57	98.62

Table 5.34 Mean percent predicted $FEV_1/FVC\%$ by age and smoking group

Age (yrs)	Smoking Group			All
	non	current	ex	
<35	91.60	95.32	93.76	93.73
35-44	94.22	93.61	93.83	93.81
45-54	93.11	89.61	95.72	91.59
55-64	90.36	84.71	88.35	86.96
65-74	96.45	79.49	84.45	83.71
75+	92.48	70.21	81.53	79.26
All	93.09	85.12	86.79	87.05

Table 6.1. Results of logistic regression. Positive response is median profusion of small opacities 1/0+. Models show relationship with ISP quartz exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	1+/F/01	1+/F/02	1+/F/03	1+/F/04	1+/F/05	1+/F/06	1+/F/07
constant	-3.500	-3.445	-3.610	-4.524	-5.588	-4.025	-4.932
	(-6.44)	(-5.48)	(-5.89)	(-6.95)	(-7.68)	(-6.83)	(-5.84)
age	0.04250	0.0413	0.02966	0.04723	0.0657	0.04746	0.0446
	(4.97)	(3.72)	(3.04)	(4.79)	(6.15)	(5.26)	(3.17)
quartz ISP 0+1+2		0.0139					0.0944
		(0.17)					(1.06)
quartz ISP 3			0.5677				0.271
			(6.97)				(2.61)
quartz ISP 4				0.6644			0.305
				(7.47)			(2.58)
quartz ISP 5					0.816		0.555
					(7.19)		(3.91)
quartz ISP 6+7						1.645	-0.506
						(3.76)	(-0.96)
resid. deviance	630.1	630.1	576.7	564.6	570.1	615.5	539.7
resid. df	545	544	544	544	544	544	540

Table 6.2. Results of logistic regression. Positive response is median profusion of small opacities 2/1+. Models show relationship with ISP quartz exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	2+/F/01	2+/F/02	2+/F/03	2+/F/04	2+/F/05	2+/F/06	2+/F/07
constant	-4.015	-4.584	-4.12	-5.80	-7.55	-4.627	-7.54
	(-4.85)	(-4.78)	(-3.99)	(-4.99)	(-5.98)	(-4.92)	(-4.63)
age	0.0269	0.0396	0.0076	0.0350	0.0663	0.0325	0.0514
	(2.07)	(2.36)	(0.46)	(2.00)	(3.65)	(2.26)	(1.96)
quartz ISP 0+1+2		-0.150					0.034
		(-1.17)					(0.23)
quartz ISP 3			0.680				0.228
			(5.91)				(1.43)
quartz ISP 4				0.852			0.536
				(7.23)			(3.61)
quartz ISP 5					1.005		0.721
					(7.07)		(4.01)
quartz ISP 6+7						1.686	-0.778
						(3.15)	(-1.07)
resid. deviance	316.1	314.8	279.6	255.1	264.4	307.4	236.6
resid. df	545	544	544	544	544	544	540

Table 6.3. Results of logistic regression. Positive response is median profusion of small opacities 1/0+. Models show relationship with ISP dust (excluding quartz) exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	1+/F/01	1+/F/08	1+/F/09	1+/F/10	1+/F/11	1+/F/12	1+/F/13
constant	-3.500	-3.622	-3.727	-4.917	-5.456	-4.154	-5.086
	(-6.44)	(-5.69)	(-5.97)	(-7.11)	(-7.56)	(-6.92)	(-6.00)
age	0.04250	0.0452	0.02613	0.0481	0.0608	0.04834	0.0451
	(4.97)	(4.01)	(2.63)	(4.73)	(5.83)	(5.29)	(3.14)
dust ISP 0+1+2		-0.00158					0.0011
		(-0.37)					(0.23)
dust ISP 3			0.0819				0.0341
			(6.49)				(1.99)
dust ISP 4				0.1325			0.0636
				(7.38)			(2.16)
dust ISP 5					0.1418		0.0721
					(6.77)		(2.25)
dust ISP 6+7						0.2377	-0.0441
						(4.17)	(-0.61)
resid. deviance	630.1	630.0	584.5	570.0	579.1	611.9	560.6
resid. df	545	544	544	544	544	544	540

Table 6.4. Results of logistic regression. Positive response is median profusion of small opacities 2/1+. Models show relationship with ISP dust (excluding quartz) exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	2+/F/01	2+/F/08	2+/F/09	2+/F/10	2+/F/11	2+/F/12	2+/F/13
constant	-4.015	-4.539	-4.42	-6.59	-6.95	-4.842	-7.36
	(-4.85)	(-4.71)	(-4.17)	(-4.97)	(-5.69)	(-4.97)	(-4.70)
age	0.0269	0.0386	0.0037	0.0353	0.0537	0.0340	0.0448
	(2.07)	(2.28)	(0.22)	(1.83)	(3.06)	(2.30)	(1.76)
dust ISP 0+1+2		-0.00705					-0.0032
		(-1.06)					(-0.42)
dust ISP 3			0.1085				0.0205
			(5.41)				(0.71)
dust ISP 4				0.2024			0.1533
				(6.76)			(3.56)
dust ISP 5					0.1807		0.0695
					(6.17)		(1.59)
dust ISP 6+7						0.2640	-0.0500
						(3.74)	(-0.54)
resid. deviance	316.1	315.0	284.0	258.3	276.4	303.4	254.8
resid. df	545	544	544	544	544	544	540

Table 6.5. Results of logistic regression. Positive response is median profusion of small opacities 1/0+. Models show relationship with combinations of ISP quartz dust exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	1+/F/14	1+/F/15	1+/F/16	1+/F/17	1+/F/18	1+/F/19
constant	-4.298	-5.591	-5.586	-5.346	-4.958	-5.315
	(-6.45)	(-7.39)	(-7.68)	(-6.94)	(-5.88)	(-6.89)
age	0.0394	0.0614	0.0657	0.0537	0.0450	0.0532
	(3.78)	(5.52)	(6.15)	(4.61)	(3.19)	(4.57)
quartz ISP 0+1+2					0.0955	
					(1.07)	
quartz ISP 3	0.292			0.269	0.258	0.281
	(2.86)			(2.63)	(2.51)	(2.73)
quartz ISP 4	0.474	0.450		0.286	0.299	0.292
	(4.36)	(4.44)		(2.45)	(2.55)	(2.49)
quartz ISP 5		0.515	0.820	0.498	0.506	0.548
		(3.95)	(6.34)	(3.79)	(3.86)	(3.86)
quartz ISP 6+7			-0.039			-0.512
			(-0.08)			(-0.97)
resid. deviance	556.5	548.7	570.1	541.8	540.7	540.9
resid. df	543	543	543	542	541	541

Table 6.6. Results of logistic regression. Positive response is median profusion of small opacities 2/1+. Models show relationship with combinations of ISP quartz dust exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	2+/F/14	2+/F/15	2+/F/16	2+/F/17	2+/F/18	2+/F/19
constant	-5.57	-7.96	-7.55	-7.699	-7.53	-7.67
	(-4.67)	(-5.33)	(-5.98)	(-5.05)	(-4.63)	(-5.04)
age	0.0269	0.0626	0.06654	0.0547	0.0510	0.0545
	(1.44)	(2.93)	(3.66)	(2.43)	(1.94)	(2.43)
quartz ISP 0+1+2					0.040	
					(0.27)	
quartz ISP 3	0.249			0.207	0.206	0.229
	(1.65)			(1.32)	(1.31)	(1.44)
quartz ISP 4	0.712	0.623		0.525	0.529	0.533
	(4.97)	(4.83)		(3.57)	(3.59)	(3.60)
quartz ISP 5		0.677	1.029	0.652	0.658	0.716
		(4.00)	(6.56)	(3.87)	(3.87)	(4.02)
quartz ISP 6+7			-0.235			-0.784
			(-0.36)			(-1.07)
resid. deviance	252.5	239.6	264.2	237.9	237.8	236.7
resid. df	543	543	543	542	541	541

Table 6.7. Results of logistic regression. Positive response is median profusion of small opacities 1/0+. Models show relationship with combinations of ISP non-quartz dust exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	1+/F/20	1+/F/21	1+/F/22	1+/F/23	1+/F/24	1+/F/25
constant	-4.688	-5.413	-5.458	-5.172	-5.085	-5.174
	(-6.63)	(-7.25)	(-7.56)	(-6.81)	(-6.00)	(-6.80)
age	0.0402	0.0551	0.0608	0.0472	0.0452	0.0470
	(3.66)	(5.07)	(5.84)	(4.05)	(3.15)	(4.03)
dust ISP 0+1+2					0.00106	
					(0.23)	
dust ISP 3	0.0345			0.0338	0.0336	0.0342
	(2.03)			(1.98)	(1.97)	(2.01)
dust ISP 4	0.100	0.0929		0.0618	0.0623	0.0630
	(4.22)	(3.73)		(2.11)	(2.12)	(2.14)
dust ISP 5		0.0651	0.1435	0.0640	0.0640	0.0721
		(2.24)	(5.57)	(2.19)	(2.20)	(2.25)
dust ISP 6+7			-0.0078			-0.0441
			(0.11)			(-0.61)
resid. deviance	565.9	565.0	579.1	561.1	561.0	560.7
resid. d.f.	543	543	543	542	541	541

Table 6.8. Results of logistic regression. Positive response is median profusion of small opacities 2/1+. Models show relationship with combinations of ISP non-quartz dust exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	2+/F/20	2+/F/21	2+/F/22	2+/F/23	2+/F/24	2+/F/25
constant	-6.49	-7.19	-6.95	-7.07	-7.33	-7.10
	(-4.81)	(-5.10)	(-5.68)	(-4.93)	(-4.68)	(-4.94)
age	0.0302	0.0432	0.0538	0.0389	0.0446	0.0390
	(1.47)	(2.12)	(3.06)	(1.80)	(1.75)	(1.81)
dust ISP 0+1+2					-0.00316	
					(-0.42)	
dust ISP 3	0.0252			0.0188	0.0193	0.0199
	(0.89)			(0.65)	(0.68)	(0.69)
dust ISP 4	0.1828	0.1685		0.1545	0.1532	0.1546
	(4.77)	(4.49)		(3.58)	(3.55)	(3.60)
dust ISP 5		0.0641	0.1814	0.0600	0.0595	0.0699
		(1.62)	(5.27)	(1.50)	(1.49)	(1.60)
dust ISP 6+7			-0.0035			-0.0498
			(-0.04)			(0.54)
resid. deviance	257.5	255.7	276.4	255.2	255.1	254.9
resid. df	543	543	544	542	541	541

Table 6.9. Results of logistic regression. Positive response is median profusion of small opacities 1/0+ and 2/1+. Models show relationships with combinations of quartz and non-quartz dust exposures for ISPs 3, 4 and 5. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	1+/F/26	1+/F/27	1+/F/28	1+/F/29	2+/F/26	2+/F/27	2+/F/28	2+/F/29
constant	-3.635	-4.767	-5.672	-5.307	-4.23	-6.43	-7.56	-7.61
	(-5.87)	(-6.93)	(-7.65)	(-6.84)	(-4.00)	(-4.83)	(-5.95)	(-5.49)
age	0.02855	0.0481	0.0659	0.0549	0.0045	0.0371	0.0663	0.0549
	(2.86)	(4.76)	(6.13)	(4.56)	(0.26)	(1.93)	(3.65)	(2.41)
quartz ISP 3	0.480			0.347	0.497			0.311
	(2.79)			(1.75)	(2.33)			(1.09)
dust ISP 3	0.0153			-0.0120	0.0381			-0.0215
	(0.57)			(-0.37)	(1.03)			(-0.42)
quartz ISP 4		0.444		0.331		0.514		0.399
		(2.69)		(1.71)		(2.48)		(1.66)
dust ISP 4		0.053		-0.0150		0.0998		0.0483
		(1.55)		(-0.30)		(1.92)		(0.67)
quartz ISP 5			0.670	0.588			0.985	0.843
			(3.05)	(2.36)			(3.42)	(2.71)
dust ISP 5			0.0318	-0.0054			0.0048	-0.0586
			(0.77)	(-0.11)			(0.08)	(-0.82)
resid. deviance	576.4	562.3	569.5	541.3	278.6	251.6	264.3	237.0
resid. df	543	543	543	539	543	543	543	539

Table 6.10. Results of logistic regression. Positive responses are median profusion of small opacities 1/0+ and 2/1+. Models show relationship with combinations of ISP quartz dust exposure variables and time variables for two particular OGSNs (F514 & F553). Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	1+/F/30	1+/F/31	1+/F/32	1+/F/33	2+/F/30	2+/F/31	2+/F/32	2+/F/33
constant	-5.346	-5.415	-5.307	-5.379	-7.69	-7.91	-7.78	-8.02
	(-6.94)	(-7.02)	(-6.88)	(-6.96)	(-5.05)	(-5.13)	(-5.00)	(-5.06)
age	0.0537	0.0554	0.0534	0.0552	0.0547	0.0604	0.0562	0.0624
	(4.61)	(4.75)	(4.59)	(4.73)	(2.43)	(2.65)	(2.45)	(2.67)
quartz ISP3	0.269	0.279	0.266	0.277	0.207	0.205	0.199	0.195
	(2.63)	(2.69)	(2.60)	(2.66)	(1.32)	(1.29)	(1.24)	(1.20)
quartz ISP4	0.286	0.122	0.273	0.098	0.525	0.225	0.533	0.212
	(2.45)	(0.88)	(2.33)	(0.69)	(3.57)	(1.15)	(3.57)	(1.07)
quartz ISP5	0.498	0.575	0.429	0.508	0.652	0.811	0.539	0.704
	(3.79)	(4.19)	(3.09)	(3.53)	(3.87)	(4.47)	(3.00)	(3.67)
time in F514		0.001681		0.01791		0.01692		0.01816
		(2.11)		(2.21)		(2.42)		(2.56)
time in F553			0.00807	0.00847			0.00852	0.00932
			(1.87)	(2.00)			(2.52)	(2.73)
resid. deviance	541.8	536.3	537.2	531.1	237.9	231.2	231.4	223.8
resid. df	542	541	541	540	542	541	541	540

Table 6.11 Results of logistic regression for two subpopulations; **1. men who spent time in OGSNs F514 or F553 (n=118), 2. men who did not spend time in OGSNs F514 or F553 (n=429)** (whole population in italics for comparison). The response is median profusion of small opacities 1/0+. Models show relationship with ISP quartz exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

	Group 1				Group 2				
variables	1+/F/34	1+/F/35	1+/F/36	1+/F/37	1+/F/38	1+/F/39	1+/F/40	1+/F/41	
constant	-1.95	-1.59	-3.67	-5.47	-4.263	-4.295	-4.417	-5.312	*-5.346*
	(-1.53)	(-1.17)	(-2.26)	(-2.95)	(-6.30)	(-5.95)	(-5.97)	(-6.20)	*(-6.94)*
age	0.0333	0.0037	0.0261	0.0475	0.0491	0.0410	0.0425	0.0549	*0.0537*
	(1.60)	(0.16)	(0.98)	(1.64)	(4.71)	(3.64)	(3.71)	(4.26)	*(4.61)*
quartz ISP3		0.586	0.234	0.230		0.420	0.357	0.341	*0.269*
		(3.28)	(1.15)	(1.10)		(4.04)	(2.86)	(2.74)	*(2.63)*
quartz ISP4			0.747	0.605			0.149	-0.077	*0.286*
			(3.71)	(2.94)			(0.93)	(-0.43)	*(2.45)*
quartz ISP5				0.575				0.521	*0.498*
				(2.60)				(2.91)	*(3.79)*
resid. deviance	160.8	148.7	131.7	124.3	432.7	416.3	415.4	407.3	*541.8*
resid. df	116	115	114	113	427	426	425	424	*542*

Table 6.12. Results of logistic regression for two subpopulations; **1. men who spent time in OGSNs F514 or F553 (n=118), 2. men who did not spend time in OGSNs F514 or F553 (n=429)** (whole population in italics for comparison). The response is median profusion of small opacities 2/1+. Models show relationship with ISP quartz exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

	Group 1				Group 2				
variables	2+/F/34	2+/F/35	2+/F/36	2+/F/37	2+/F/38	2+/F/39	2+/F/40	2+/F/41	
constant	-1.50	-0.79	-3.02	-4.51	-6.28	-6.52	-6.927	-10.50	*-7.699*
	(-1.03)	(-0.45)	(-1.42)	(-1.91)	(-4.53)	(-4.07)	(-4.10)	(-4.55)	*(-5.05)*
age	0.0055	-0.0354	-0.0136	-0.0001	0.0509	0.0455	0.0504	0.0992	*0.0547*
	(0.23)	(-1.12)	(-0.38)	(0.00)	(2.44)	(1.90)	(2.02)	(3.04)	*(2.43)*
quartz ISP3		0.657	0.304	0.311		0.404	0.265	0.211	*0.207*
		(3.24)	(1.30)	(1.28)		(2.20)	(1.18)	(0.93)	*(1.32)*
quartz ISP4			0.732	0.646			0.337	-0.075	*0.525*
			(3.49)	(3.12)			(1.22)	(-0.24)	*(3.57)*
quartz ISP5				0.510				1.081	*0.652*
				(2.29)				(3.68)	*(3.87)*
resid. deviance	129.3	117.4	101.9	96.5	149.2	144.7	143.3	131.0	*237.9*
resid. df	116	115	114	113	427	426	425	424	*542*

Table 6.13. Results of logistic regression. Models show relationship between symptoms of chronic bronchitis and ISP dust exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	CB/F/01	CB/F/02	CB/F/03	CB/F/04	CB/F/05	CB/F/06	CB/F/07
constant	-3.969	-4.112	-3.984	-4.213	-4.370	-4.172	-4.263
	(-6.44)	(-5.87)	(-6.28)	(-6.56)	(-6.61)	(-6.58)	(-6.59)
age	0.0320	0.0353	0.0229	0.0313	0.0348	0.0330	0.0289
	(3.70)	(3.06)	(2.42)	(3.51)	(3.87)	(3.78)	(3.19)
smoker	1.494	1.493	1.589	1.511	1.506	1.501	1.548
	(3.95)	(3.94)	(4.15)	(3.98)	(3.97)	(3.96)	(4.06)
ex-smoker	0.911	0.902	0.974	0.913	0.909	0.925	0.940
	(2.32)	(2.30)	(2.47)	(2.32)	(2.31)	(2.35)	(2.39)
dust ISP 0+1+2		-0.0019					
		(0.43)					
dust ISP 3			0.0350				
			(2.88)				
dust ISP 4				0.0374			
				(2.24)			
dust ISP 5					0.0414		
					(2.14)		
dust ISP 6+7						0.0990	
						(1.76)	
dust Total							0.0160
							(2.84)
resid. deviance	614.9	614.8	606.6	609.9	610.4	611.9	606.9
resid. df	544	543	543	543	543	543	543

Table 6.14. Results of logistic regression. Models show relationship between symptoms of chronic bronchitis and ISP dust exposure variables. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	CB/F/01	CB/F/08	CB/F/09	CB/F/10	CB/F/11	CB/F/12	CB/F/13	CB/F/14
constant	-3.969	-4.027	-4.325	-4.366	-4.071	-4.142	-4.149	-4.145
	(-6.44)	(-6.18)	(-6.51)	(-6.61)	(-6.29)	(-6.15)	(-6.17)	(-6.16)
age	0.0320	0.0237	0.0329	0.0347	0.0240	0.0254	0.0256	0.0254
	(3.70)	(2.40)	(3.56)	(3.86)	(2.51)	(2.50)	(2.53)	(2.51)
smoker	1.494	1.581	1.511	1.506	1.582	1.584	1.578	1.584
	(3.95)	(4.13)	(3.98)	(3.97)	(4.13)	(4.13)	(4.12)	(4.13)
ex-smoker	0.911	0.967	0.911	0.915	0.974	0.968	0.967	0.972
	(2.32)	(2.45)	(2.32)	(2.33)	(2.47)	(2.45)	(2.45)	(2.46)
dust ISP 3		0.0315			0.0315	0.0318	0.0290	0.0315
		(1.86)			(2.40)	(1.88)	(2.05)	(1.86)
dust ISP 4		0.0069	0.0243			-0.0071		-0.0079
		(0.30)	(0.98)			(-0.23)		(-0.26)
dust ISP 5			0.0205	0.0330		0.0214	0.0120	0.0165
			(0.71)	(1.34)		(0.74)	(0.45)	(0.52)
dust ISP 6+7				0.3680	0.0430		0.0260	0.0271
				(1.75)	(0.71)		(0.36)	(0.37)
resid. deviance	614.9	606.5	609.4	607.3	606.1	606.4	605.9	605.8
resid. df	544	542	542	542	542	541	541	540

Table 6.15. Results of logistic regression. Models show relationship between breathlessness and ISP dust exposure variables, and wheezing (in older men only) and ISP dust exposure. Table contains regression coefficients, with ratio of coefficient to standard error in parenthesis.

variables	BR/F/01	BR/F/02	WH/F/01	WH/F/02
constant	-4.969	-5.082	-1.787	-3.100
	(-7.86)	(-7.76)	(-2.40)	(-3.07)
age	0.0619	0.0567	0.0088	0.0110
	(6.56)	(5.72)	(0.79)	(0.98)
smoker	0.533	0.590	1.123	1.162
	(1.91)	(1.85)	(3.37)	(3.47)
ex-smoker	0.248	0.284	0.641	0.661
	(0.76)	(0.87)	(1.88)	(1.93)
dust ISP 0+1+2				
dust ISP 3		0.0263		
		(2.21)		
dust ISP 4				
dust ISP 5				
dust ISP 6+7				
dust Total				0.149
				(1.96)
resid. deviance	619.7	614.8	607.6	603.7
resid. df	545	544	461	460

Table 6.16. Results of fitting different regression models to lung function. Variable analysed is forced expiratory volume (FEV1, in litres). Tabulated values are estimated regression coefficients; ratio of estimate to standard error is in parenthesis.

variables	FEV/F/01	FEV/F/02	FEV/F/03	FEV/F/04	FEV/F/05	FEV/F/06
constant	-0.689	-0.701	-0.664	-0.682	-0.608	-0.522
	(-0.82)	(-0.83)	(-0.79)	(-0.81)	(-0.72)	(-0.62)
age	-0.03283	-0.03228	-0.03137	-0.03246	-0.03291	-0.03318
	(-6.55)	(-6.07)	(-6.09)	(-6.45)	(-6.59)	(-6.64)
height	0.03258	0.03252	0.03227	0.03258	0.03244	0.03196
	(7.48)	(7.45)	(7.40)	(7.48)	(7.46)	(7.34)
smoking current	0.413	0.409	0.409	0.410	0.399	0.376
	(1.26)	(1.24)	(1.24)	(.25)	(1.22)	(1.15)
smoking ex	0.409	0.404	0.444	0.41	0.474	0.449
	(1.08)	(1.06)	(1.17)	(1.13)	(1.25)	(1.19)
age.smoking current	-0.01307	-0.01301	-0.01315	-0.01306	-0.01288	-0.01250
	(-2.25)	(-2.23)	(-2.26)	(-2.24)	(-2.22)	(-2.15)
age smoking ex	-0.01058	-0.01052	-0.01125	-0.01096	-0.01165	-0.01130
	(-1.66)	(-1.65)	(-1.76)	(-1.71)	(-1.82)	(-1.77)
dust ISP 0+1+2		-0.00038				
		(-0.31)				
dust ISP 3			-0.00403			
			(-1.21)			
dust ISP 4				-0.00396		
				(-0.86)		
dust ISP 5					-0.00979	
					(-1.85)	
dust ISP 6+7						-0.0434
						(2.03)
residual s.s	203.2	203.1	202.6	202.9	201.9	201.6
df	534	533	533	533	533	533
residual m.s.	0.3805	0.3811	0.3801	0.3806	0.3787	0.3782

Table 6.17. Results of fitting different regression models to lung function. Variable analysed is forced expiratory volume (FVC, in litres). Tabulated values are estimated regression coefficients; absolute value of ratio of estimate to standard error is in parenthesis.

variable	FVC/F/01	FVC/F/02	FVC/F/03	FVC/F/04	FVC/F/05	FVC/F/06
constant	-3.105	-3.101	-3.087	-3.103	-3.042	-2.991
	(-3.60)	(-3.59)	(-3.57)	(-3.60)	(-3.52)	(-3.46)
age	-0.03828	-0.03839	-0.03790	-0.03826	-0.03843	-0.03846
	(-15.63)	(-12.06)	(-14.18)	(-15.47)	(-15.65)	(-15.68)
height	0.05918	0.05918	0.05902	0.05918	0.05897	0.05873
	(11.63)	(11.62)	(11.54)	(11.62)	(11.58)	(11.52)
smoking current	-0.2334	-0.2333	-0.2355	-0.2335	-0.2338	-0.2357
	(-2.83)	(-2.83)	(-2.85)	(-2.83)	(-2.84)	(-2.86)
smoking ex	-0.1331	-0.1328	-0.1348	-0.1332	-0.1337	-0.1372
	(-1.55)	(-1.54)	(-1.56)	(-1.55)	(-1.55)	(-1.59)
weight	-0.00819	-0.00818	-0.00812	-0.00818	-0.00807	-0.00818
	(-3.23)	(-3.22)	(-3.20)	(-3.23)	(-3.18)	(-3.23)
dust previous		0.00008				
		(0.06)				
dust ISP3			-0.00122			
			(-0.35)			
dust ISP4				-0.00028		
				(-0.06)		
dust ISP5					-0.00503	
					(-0.91)	
dust ISP6+7						-0.0277
						(-1.24)
residual s.s.	223.3	223.3	223.3	223.3	223.0	222.7
df	535	534	534	534	534	534
residual m.s.	0.4174	0.4182	0.4181	0.4182	0.4175	0.4170

Table 6.18. Results of fitting different regression models to lung function of ex-employees. Variable analysed is the percentage ratio of FEV_1 to FVC. Tabulated values are estimated regression coefficients; the ratio of estimate to standard error is in parenthesis.

variables	Ratio/F/01	Ratio/F/02	Ratio/F/03	Ratio/F/04	Variables	Ratio/F/05	Ratio/F/06
constant	111.5	110.4	111.8	111.8	constant	112.4	113.5
	(7.11)	(7.03)	(7.12)	(7.12)		(7.16)	(7.22)
age	-0.1822	-0.1491	-0.1680	-0.1791	age	-0.1827	-0.1866
	(-2.19)	(-1.69)	(-1.96)	(-2.14)		(-2.19)	(-2.24)
height	-0.1660	-0.1660	-0.1705	-0.1665	height	-0.1690	-0.1728
	(-2.11)	(-2.11)	(-2.16)	(-2.11)		(-2.14)	(-2.19)
smoking current	-5.7	-5.6	-5.6	-5.9	smoking current	-5.8	-6.2
	(-0.56)	(-0.56)	(-0.55)	(-0.58)		(-0.57)	(-0.61)
smoking ex	-4.4	-4.9	-4.0	-4.3	smoking ex	-3.7	-4.1
	(-0.39)	(-0.43)	(-0.35)	(-0.38)		(-0.32)	(-0.36)
age.smoking current	-0.3497	-0.3461	-0.3511	-0.3491	age.smoking current	-0.3481	-0.3428
	(-3.61)	(-3.57)	(-3.62)	(-3.60)		(-3.60)	(-3.54)
age.smoking ex	-0.238	-0.234	-0.245	-0.242	age.smoking ex	-0.249	-0.246
	(-2.24)	(-2.20)	(-2.29)	(-2.26)		(-2.33)	(-2.31)
weight.smoking non	-0.0089	-0.0117	-0.0060	-0.0094	weight.smoking non	-0.0068	-0.0099
	(-0.12)	(-0.16)	(-0.08)	(-0.13)		(-0.09)	(-0.14)
weight.smoking cur	0.2500	0.2468	0.2486	0.2516	weight.smoking current	0.2501	0.2508
	(2.81)	(2.77)	(2.79)	(2.82)		(2.81)	(2.82)
weight.smoking ex	0.1773	0.1792	0.1763	0.1781	weight.smoking ex	0.1762	0.1786
	(1.86)	(1.88)	(1.84)	(1.86)		(1.84)	(1.87)
dust ISP 0+1+2		-0.0234			dust ISP5	-0.0929	
		(-1.16)				(-1.09)	
dust ISP 3			-0.0376		dust ISP6+7		-0.495
			(-0.70)				(-1.43)
dust ISP 4				-0.0364			
				(-0.49)			
residual s.s.	52289	52158	52241	52266		52173	52087
df	531	530	530	530		530	530
residual m.s.	98.47	98.41	98.57	98.61		98.44	98.28

Table 6.19. Results of linear regression analyses of lung function, including an indicator for the profusion rate as explanatory variable. Variable analysed is FEV1, in litres. Tabulated values are estimated regression coefficients; the ratio of estimate to standard error is in parenthesis.

variable	FEV/F/07	FEV/F/08	FEV/F/09	FEV/F/10
constant	-0.639	-0.675	-0.558	-0.677
	(-0.76)	(-0.80)	(-0.66)	(-0.81)
age	-0.03288	-0.03196	-0.03228	-0.03104
	(-6.57)	(-6.44)	(-6.50)	(-5.86)
height	0.03231	0.03250	0.03206	0.03234
	(7.42)	(7.52)	(7.40)	(7.46)
smoking current	0.395	0.329	0.309	0.323
	(1.19)	(1.01)	(0.95)	(0.99)
smoking ex	0.407	0.411	0.438	0.416
	(1.07)	(1.10)	(1.17)	(1.11)
age.smoking current	-0.01280	-0.01144	-0.01115	-0.01138
	(-2.19)	(-1.98)	(-1.93)	(-1.97)
age.smoking ex	-0.01056	-0.01068	-0.01114	-0.01079
	(-1.66)	(-1.70)	(-1.77)	(-1.71)
opacities 1		-0.1190	-0.1071	-0.1133
		(-1.73)	(-1.55)	(-1.62)
opacities 2		-0.248	-0.227	-0.239
		(-2.20)	(-1.99)	(-2.08)
opacities 3		-0.303	-0.273	-0.289
		(-0.99)	(-0.89)	(-0.94)
opacities L		-0.642	-0.623	-0.636
		(-3.73)	(-3.61)	(-3.68)
dust ISP 6+7			-0.0286	
			(-1.33)	
dust Total				-0.00052
				(-0.50)
residual s.s.	202.1	194.8	194.2	194.7
df	532	528	527	527
residual m.s.	0.3799	0.3689	0.3684	0.3687

Table 6.20. Results of linear regression analyses of lung function, including an indicator for the profusion rate as explanatory variable. Variable analysed is FVC. Tabulated values are estimated regression coefficients; the ratio of estimate to standard error is in parenthesis.

Variables	FVC/F/07	FVC/F/08	FVC/F/09	FVC/F/10
constant	-3.042	-3.102	-3.018	-3.102
	(-3.54)	(-3.60)	(-3.47)	(-3.59)
age	-0.03820	-0.03752	-0.03772	-0.03779
	(-15.51)	(-14.92)	(-14.92)	(-11.90)
height	0.05873	0.05962	0.05925	0.05976
	(11.54)	(11.69)	(11.56)	(11.66)
smoking current	-0.2354	-0.2399	-0.2415	-0.2393
	(-2.86)	(-2.90)	(-2.92)	(-2.89)
smoking ex	-0.1349	-0.1432	-0.1454	-0.1424
	(-1.57)	(-1.67)	(-1.70)	(-1.66)
weight	-0.00806	-0.00925	-0.00917	-0.00925
	(-3.18)	(-3.62)	(-3.59)	(-3.62)
profusion 1		-0.0374	-0.0297	-0.0391
		(-0.52)	(-0.40)	(-0.53)
profusion 2		-0.143	-0.129	-0.146
		(-1.20)	(-1.06)	(-1.20)
profusion 3		-0.226	-0.206	-0.230
		(-0.69)	(-0.63)	(-0.70)
profusion L		-0.560	-0.546	-0.562
		(-3.07)	(-2.98)	(-3.07)
dust ISP6+7			-0.0180	
			(-0.79)	
dust Total				-0.00015
				(0.14)
residual s.s.	221.7	217.3	217.1	217.3
df	533	529	528	528
residual m.s.	0.4160	0.4108	0.4111	0.4113

Table 6.21. Results of linear regression analyses of lung function, including an indicator for the profusion rate as explanatory variable. Variable analysed is percentage ratio of FEV1 to FVC. Tabulated values are estimated regression coefficients; the ratio of estimate to standard error is in parenthesis.

Variables	Ratio/F/07	Ratio/F/08	Ratio/F/09
constant	111.5	106.6	106.6
	(7.09)	(6.86)	(6.86)
age	-0.1822	-0.1609	-0.1435
	(-2.18)	(-1.95)	(-1.64)
height	-0.1656	-0.1290	-0.1230
	(-2.10)	(-1.65)	(-1.68)
smoking current	-5.5	-4.6	-4.7
	(-0.54)	(-0.46)	(-0.47)
smoking ex	-4.4	-3.7	-3.7
	(-0.39)	(-0.33)	(-0.33)
age.smoking current	-0.3523	-0.3292	-0.3281
	(-3.61)	(-3.44)	(-3.42)
age.smoking ex	-0.238	-0.243	-0.245
	(-2.24)	(-2.33)	(-2.34)
weight.smoking non	-0.0089	-0.0285	-0.0284
	(-0.12)	(-0.39)	(-0.39)
weight.smoking current	0.2499	0.2239	0.2232
	(2.80)	(2.55)	(2.54)
weight.smoking ex	0.1773	0.1722	0.1731
	(1.85)	(1.83)	(1.84)
profusion 1		-2.64	-2.54
		(-2.38)	(-2.26)
profusion 2		-5.62	-5.44
		(-3.08)	(-2.94)
profusion 3		-5.29	-5.03
		(-1.06)	(-1.01)
profusion L		-10.45	-10.33
		(-3.75)	(-3.70)
dust Total			-0.0098
			(-0.59)
residual s.s.	52282	49887	49854
df	529	525	524
residual m.s.	98.83	95.02	95.14

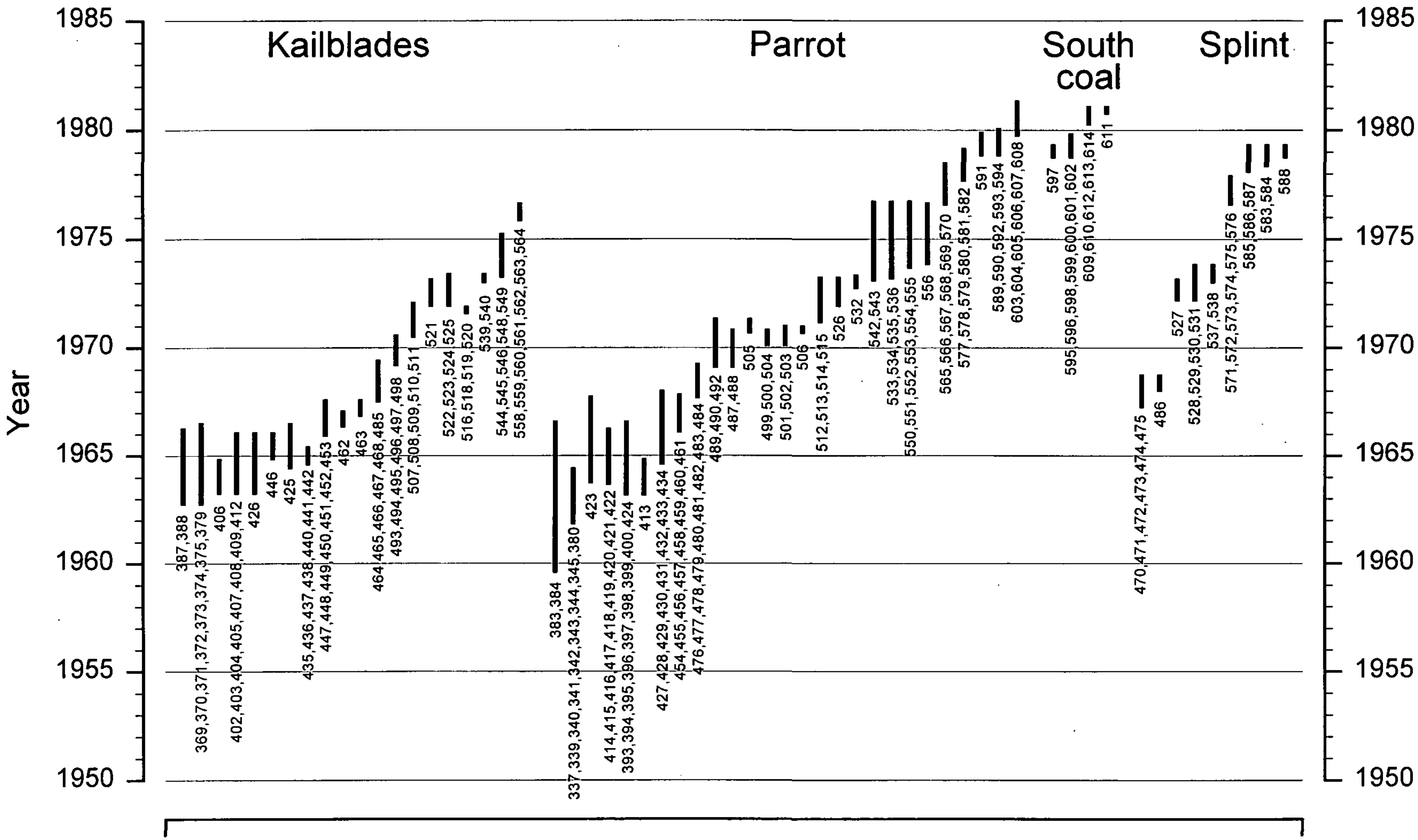

Figure 4.1. Lifespans of occupational groups within coal seams at Colliery P over PFR phase II.

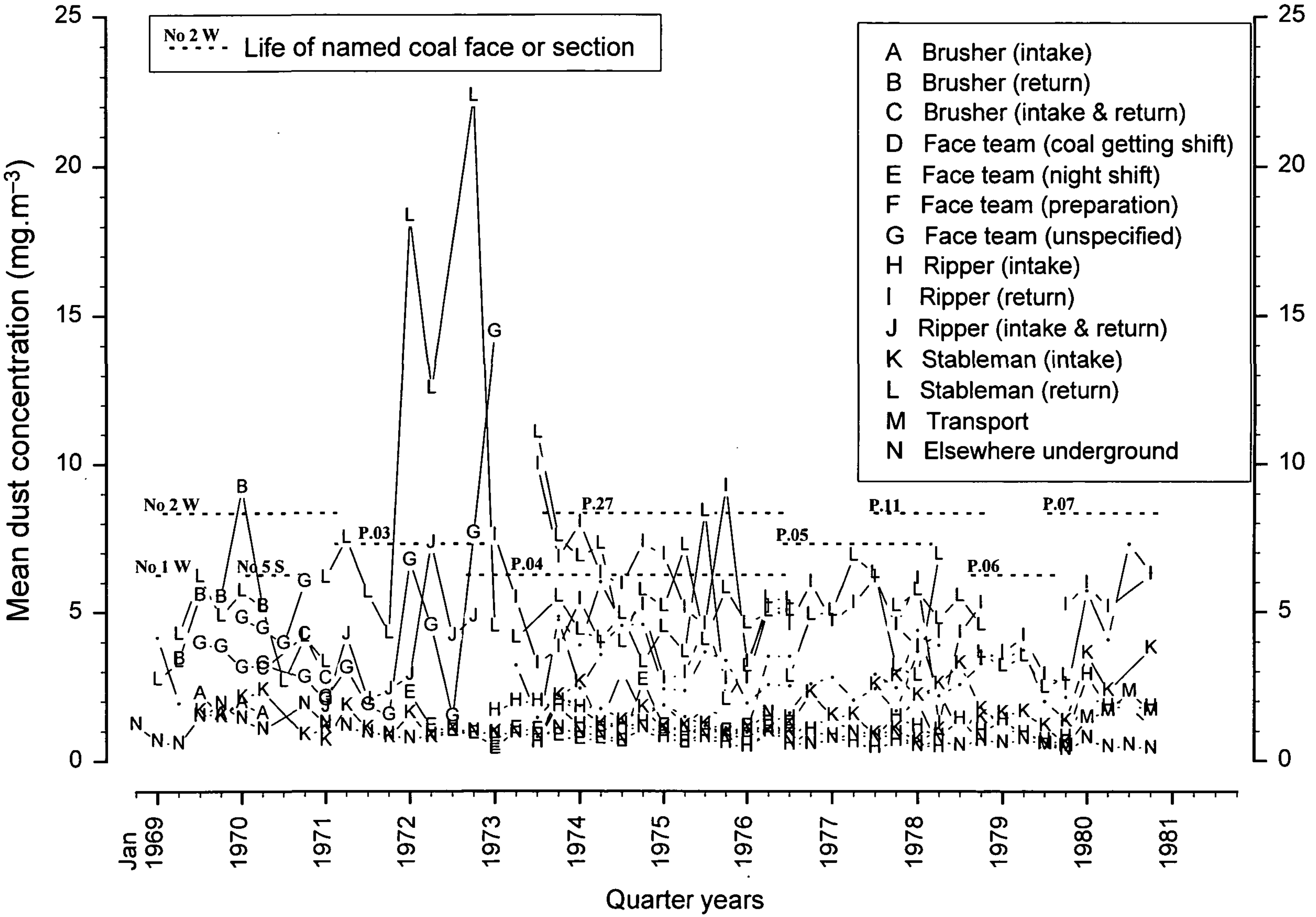

Figure 4.2. Quarterly mean respirable dust concentrations by occupation: Parrot seam.

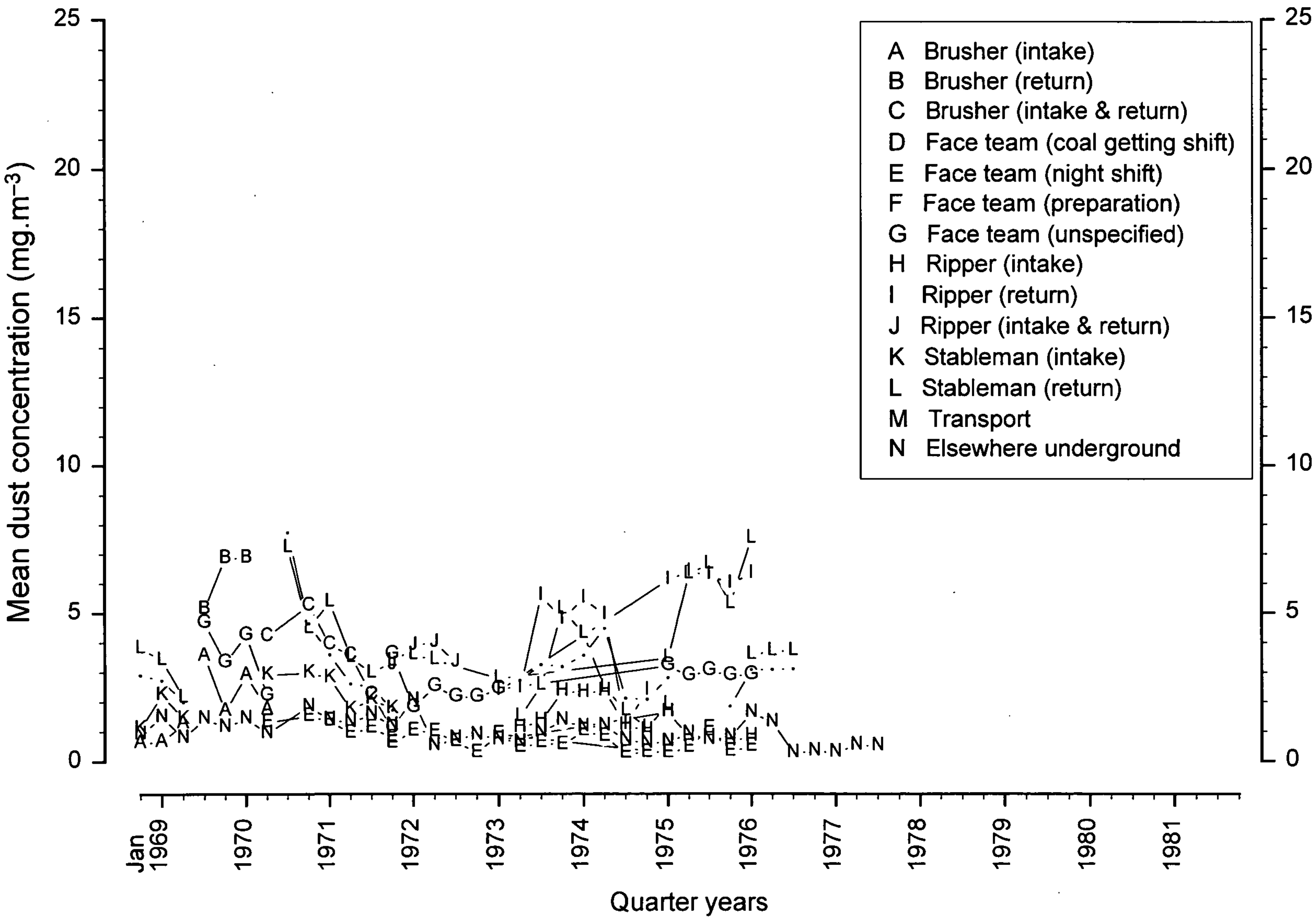

Figure 4.3. Quarterly mean respirable dust concentrations by occupation: Kailblades seam.

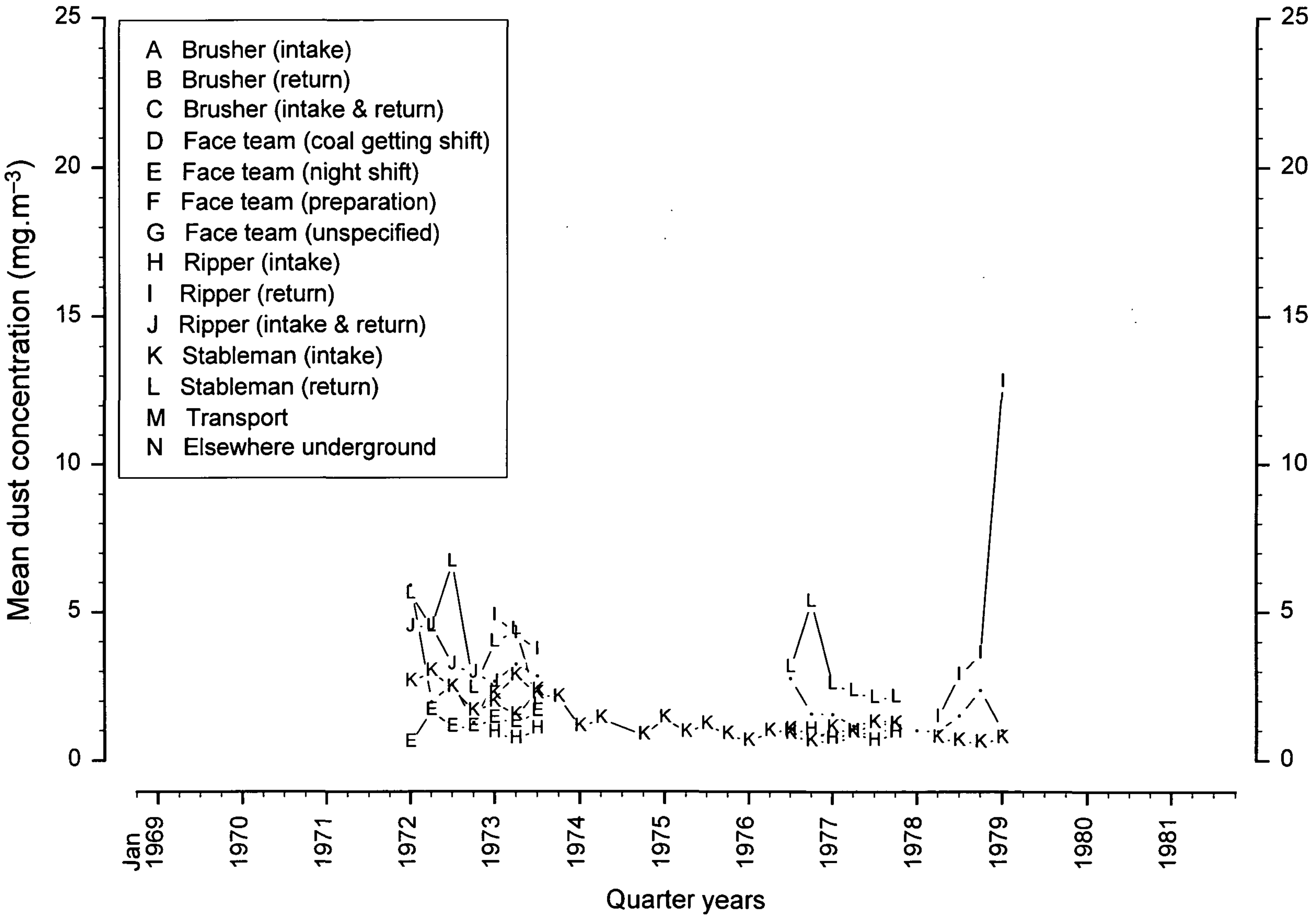

Figure 4.4. Quarterly mean respirable dust concentrations by occupation: Splint seam.

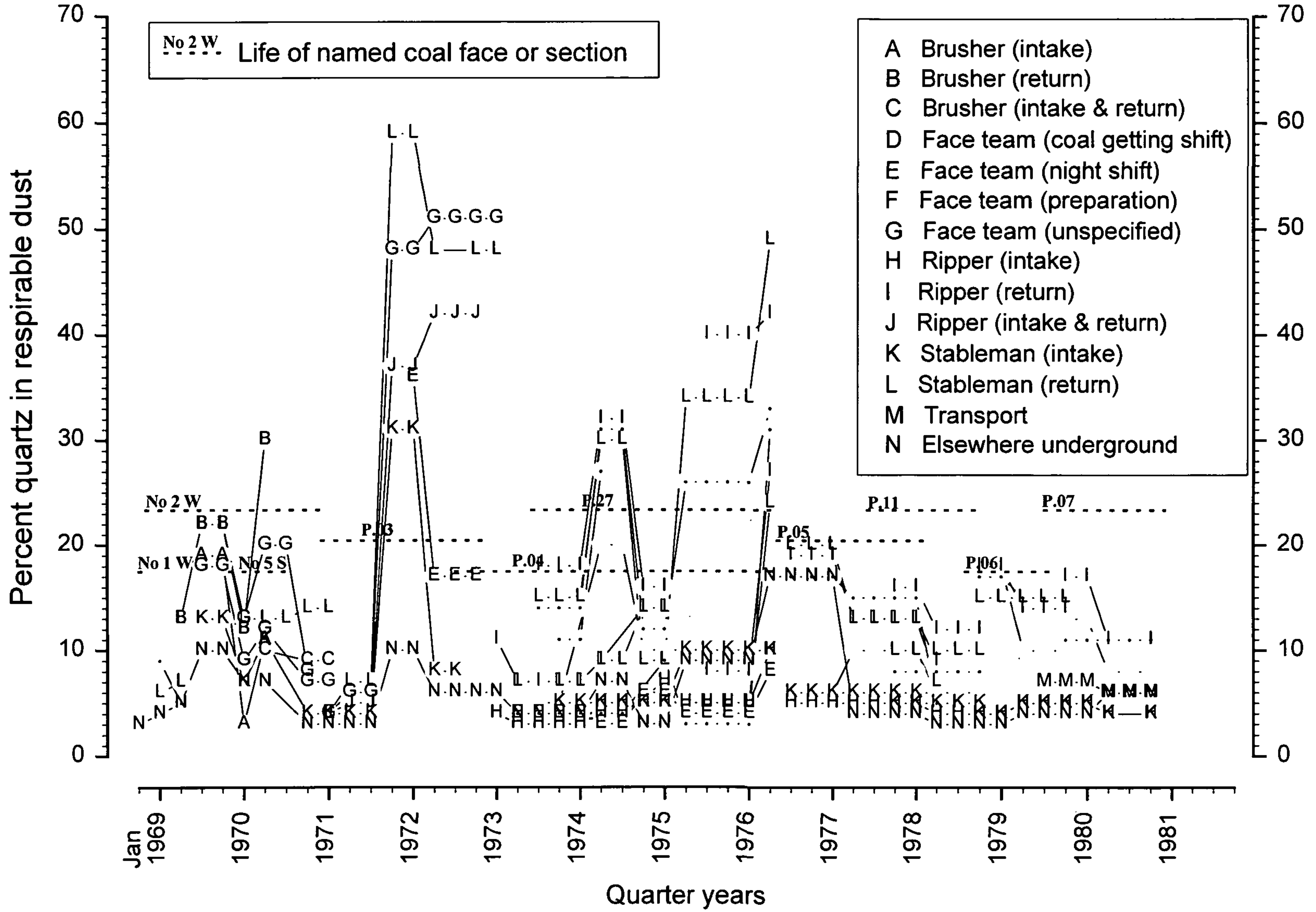

Figure 4.5. Quarterly percent quartz in respirable dust by occupation: Parrot seam.

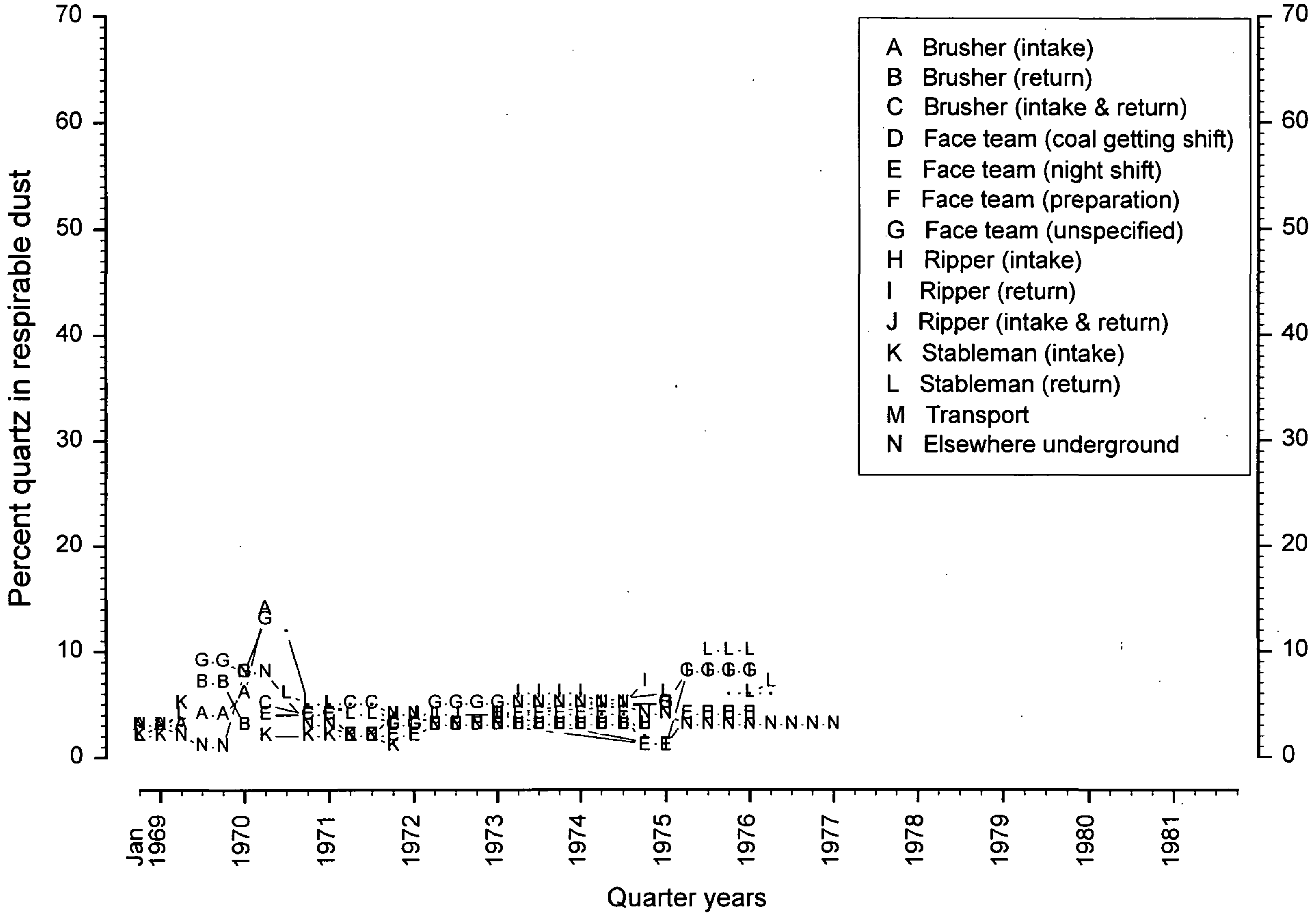

Figure 4.6. Quarterly percent quartz in respirable dust by occupation: Kailblades seam.

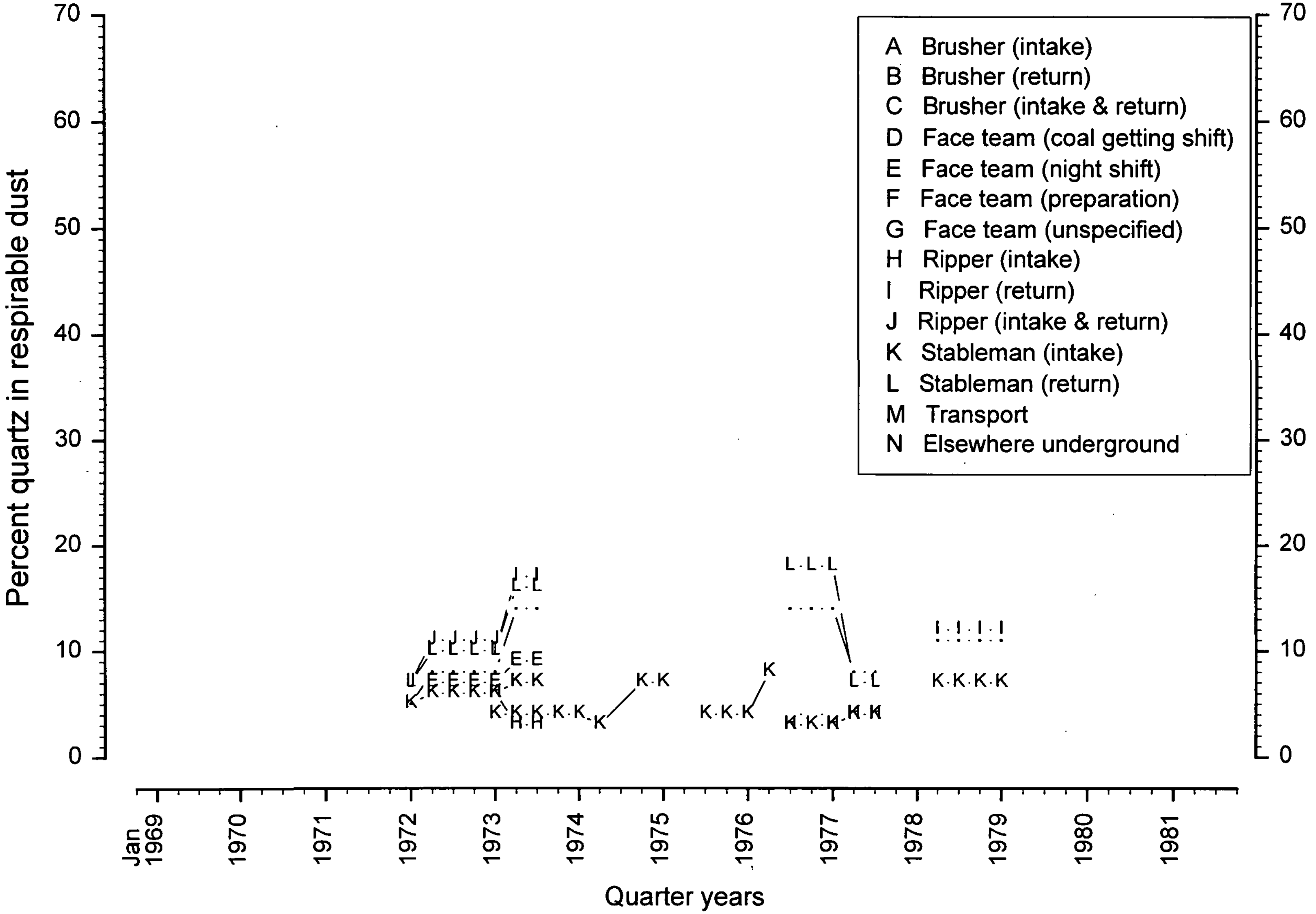

Figure 4.7. Quarterly percent quartz in respirable dust by occupation: Splint seam.

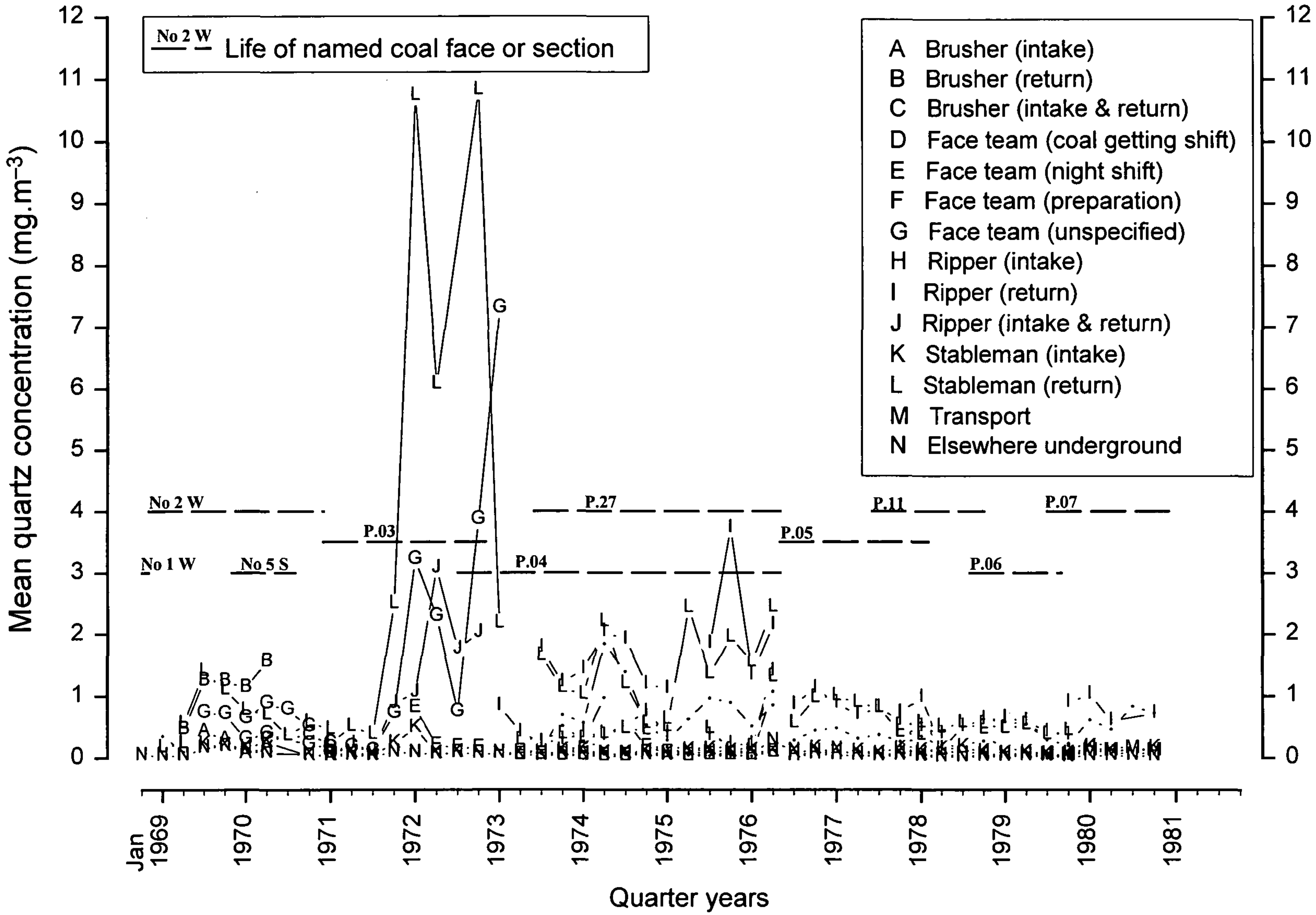

Figure 4.8. Quarterly mean respirable quartz concentrations by occupation: Parrot seam.

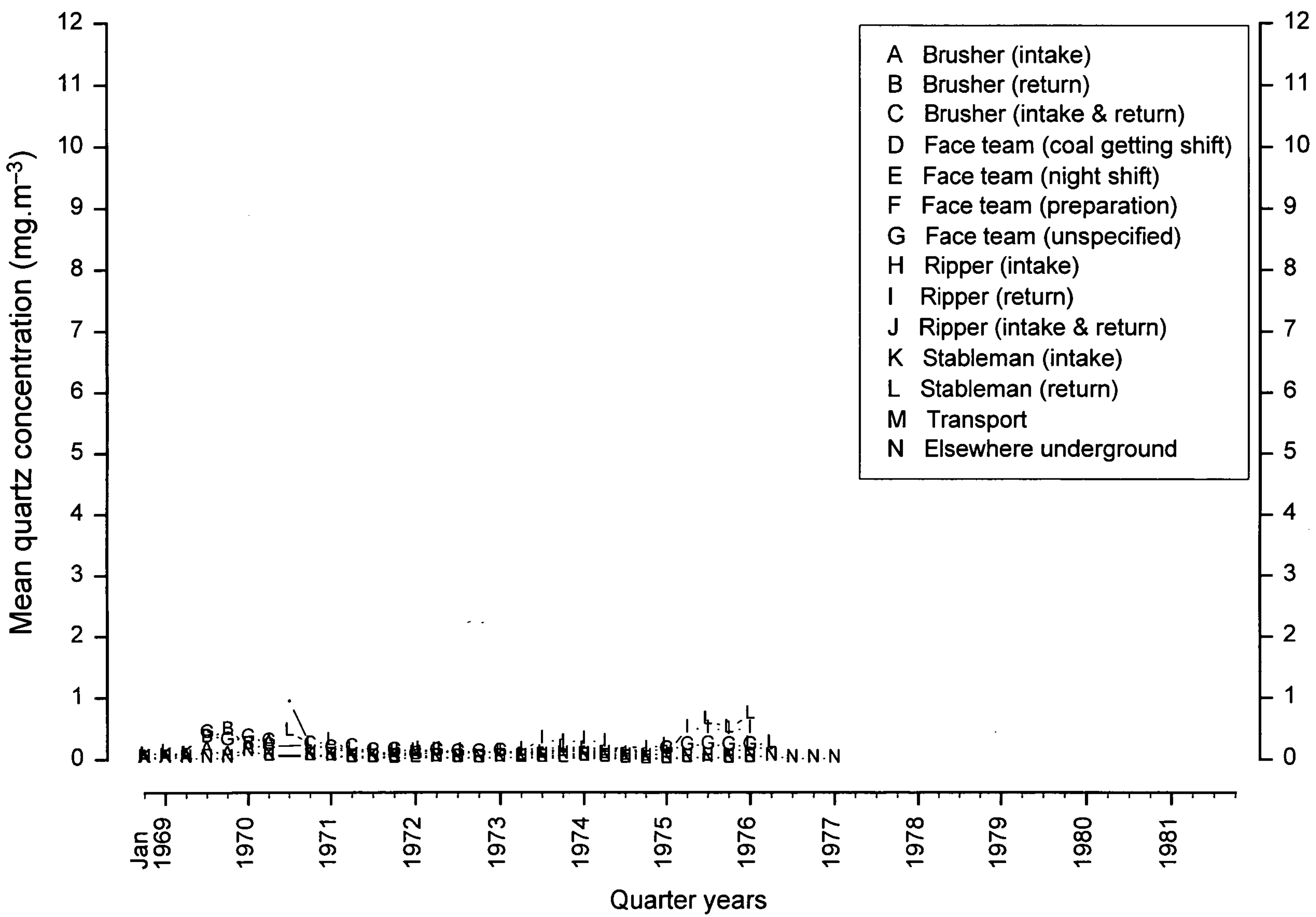

Figure 4.9. Quarterly mean respirable quartz concentrations by occupation: Kailblades seam.

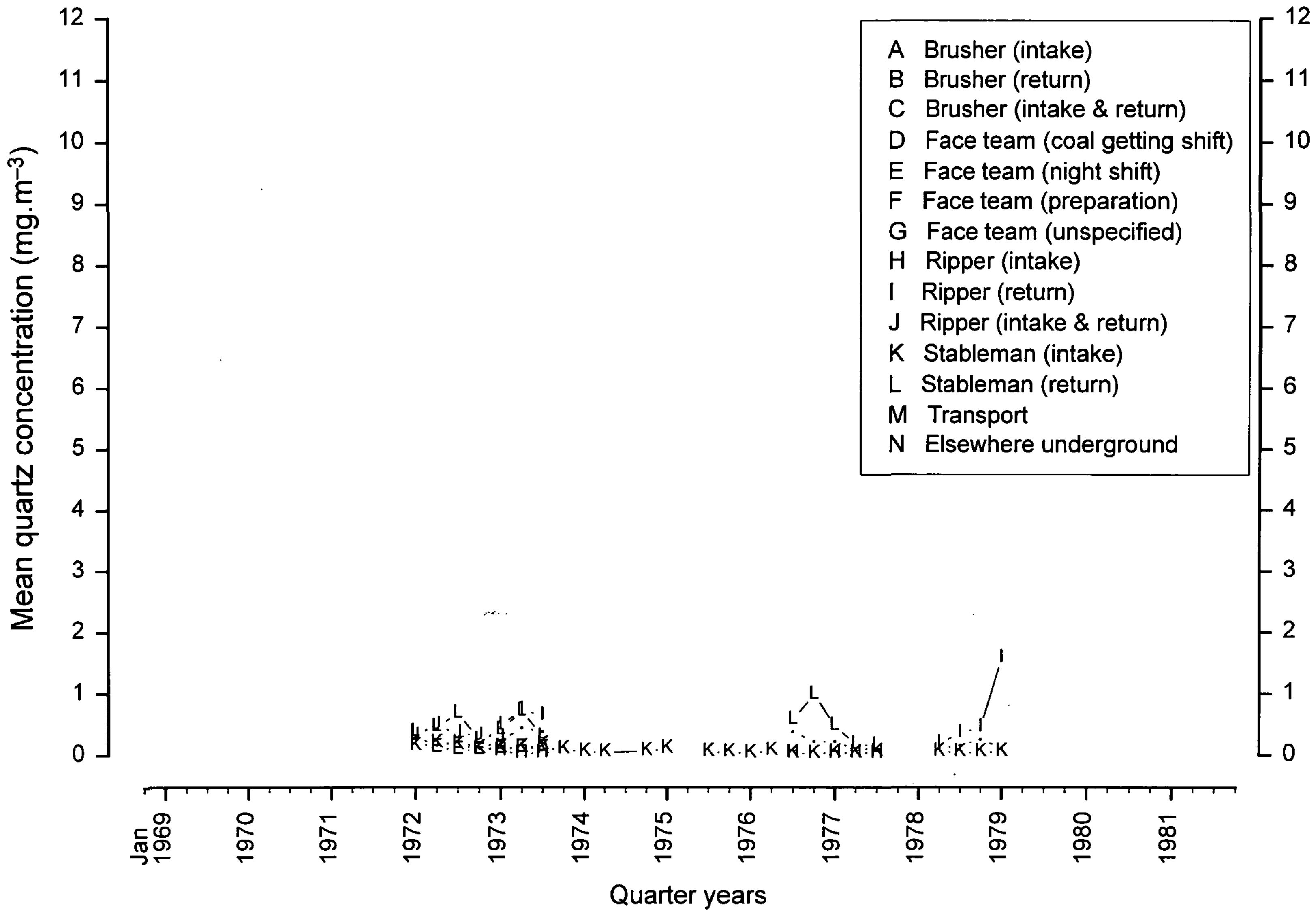

Figure 4.10. Quarterly mean respirable quartz concentrations by occupation: Splint seam.

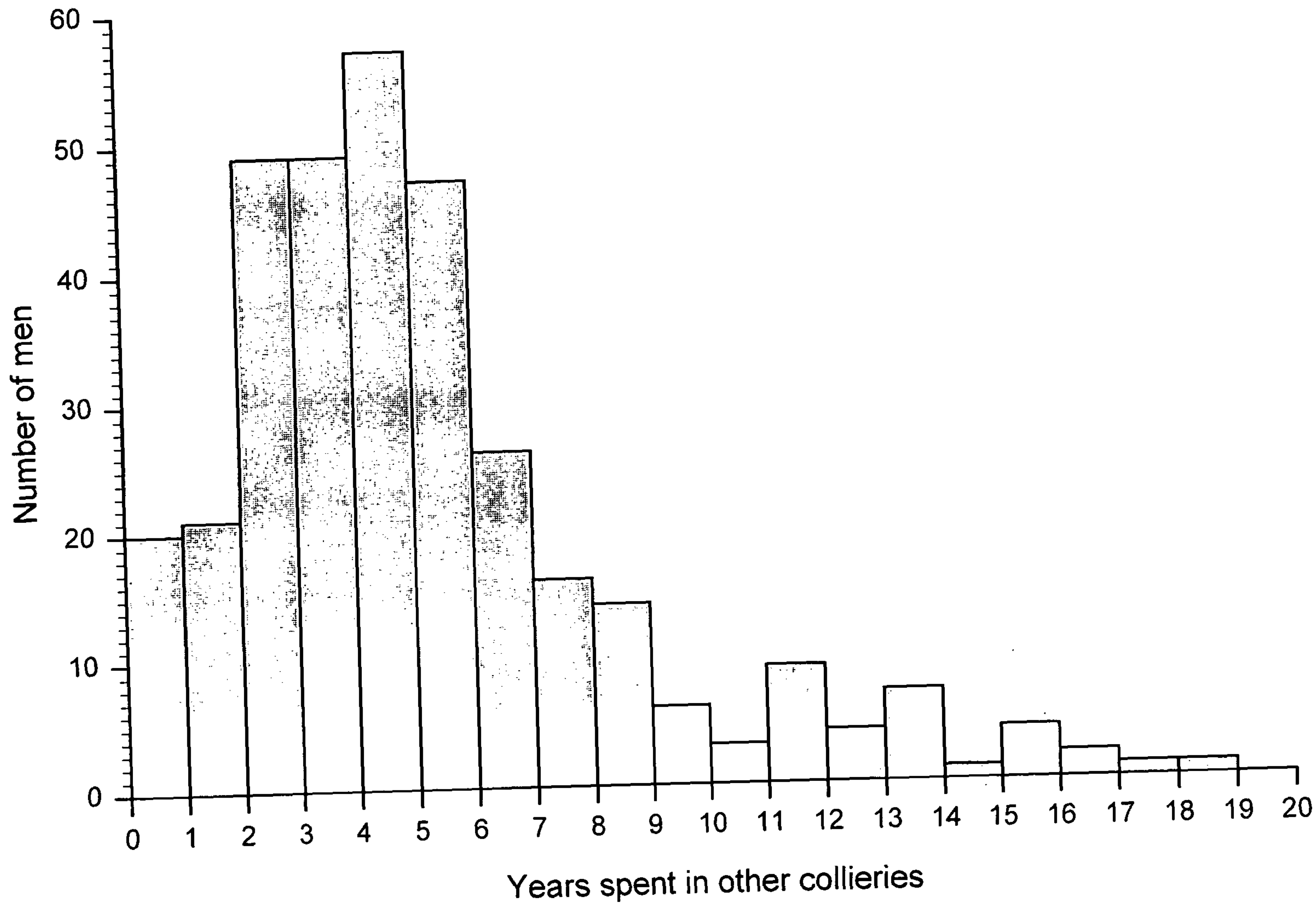

Figure 4.11. Distribution of time spent at other collieries after leaving Colliery P.

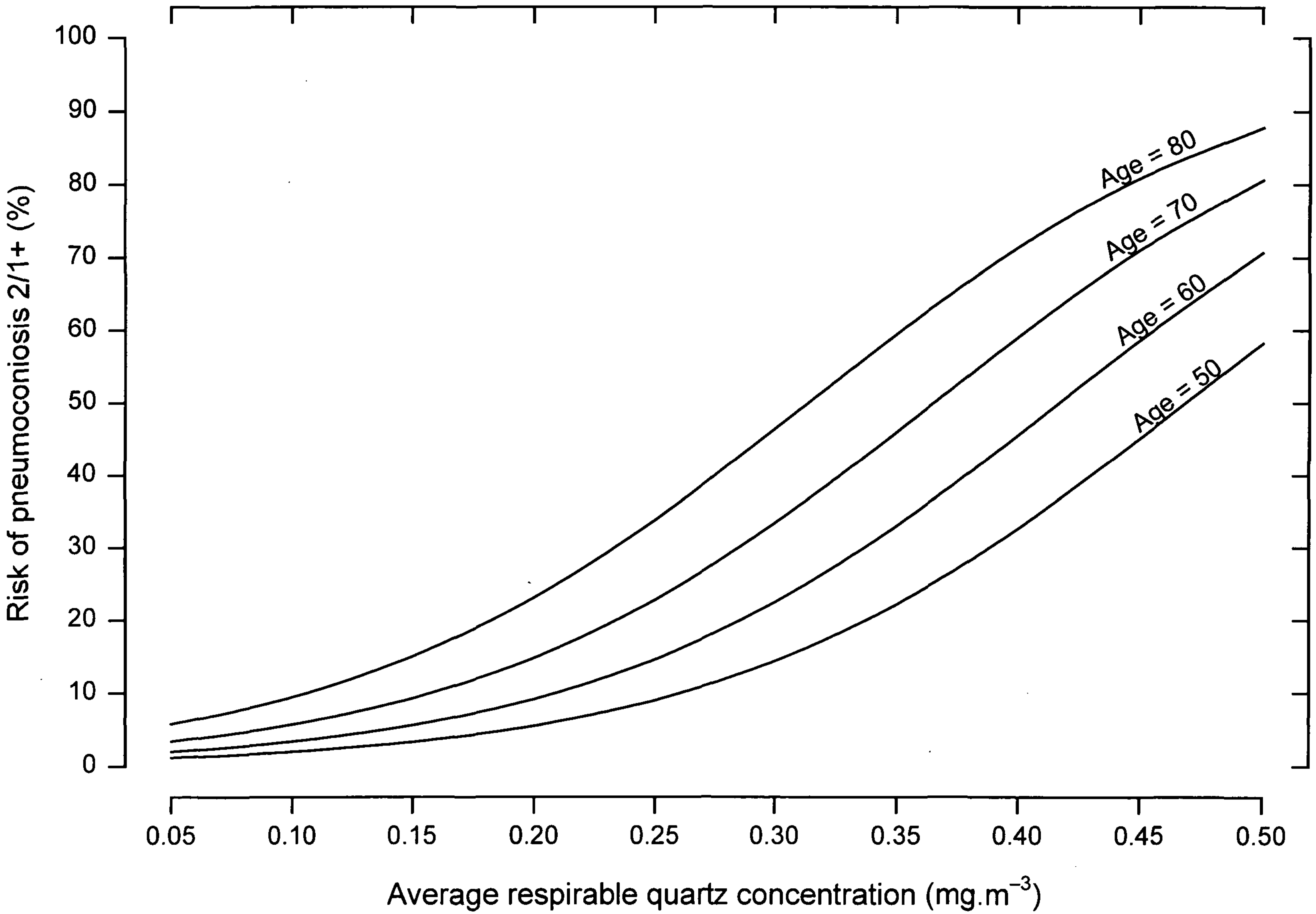

Figure 7.1. Predicted risks of small opacities category 2/1+ at follow up, as a function of age and average respirable quartz concentration experienced 1964 - 1978.

APPENDIX A1: Documents used in tracing and during surveys

Exhibit A1.1	Contact letter forwarded by Department of Social Security
Exhibit A1.2	Contact letter forwarded by British Coal Pensions and Insurance
Exhibit A1.3	Survey questionnaire and data recording forms
Exhibit A1.4	List of occupations used in coding occupational history data

Exhibit A1.1 Contact letter used by Department of Social Security

Dear Mr

You may remember attending our medical surveys in the 1970s at Colliery P. We are inviting everyone who took part in those surveys to help with some new research into pneumoconiosis, and we would be grateful if you would agree to take part again. Because our record of your address has not been updated since we last saw you, we do not know if it is still correct. The Department of Social Security has therefore agreed to forward this letter to you. We would be grateful if, when replying, you could give us your present address.

You would be asked to have a chest X-ray and simple breathing tests, and answer some questions on chest symptoms etc. This examination would take place in a mobile unit sited locally. The research has the support of British Coal and of the mining unions nationally.

The results of the examination will of course be treated confidentially, and will not be released to anyone without your permission. I will send a brief report to you and, if necessary, and if you give your permission, to your family doctor.

Please complete and return the tear-off slip in the reply-paid envelope (you do not need a stamp). We will then contact you to arrange an appointment at a time convenient to you, in a few months' time. If required, we will provide assistance with transport. If you would prefer not to take part, please complete and return the slip anyway, since this will ensure that you are not bothered again.

I very much hope you will agree to help this work. Please feel free to write to me at the above address if you have any questions.

Yours sincerely

Dr CA Soutar

I *agree/do not agree to take part in the survey of ex-Colliery P miners.

(* Please delete as applicable.)

Name: Date of birth:

Address:

Tel No: Pxxxx

Exhibit A1.2 Contact letter used by British Coal Pensions and Insurance

30th July, 1990

Mr.

Dear Mr.

You may remember attending our medical surveys in the 1970's, at Colliery P. We are inviting everyone who took part in those surveys to help with some new research into pneumoconiosis, and we would be grateful if you would agree to take part again.

Because our record of your address has not been updated since we last saw you, we do not know if it is still correct. British Coal has therefore agreed to forward this letter to you. You may already have received an earlier letter forwarded by D.S.S. but unless we receive a reply, we cannot know whether our letters have reached you. We would be grateful if, when replying, you could give us your present address.

You would be asked to have a chest x-ray and simple breathing tests, and answer some questions on chest symptoms etc. This examination would take place in a mobile unit sited locally. The research has the support of British Coal and of the mining unions nationally.

The results of the examination will of course be treated confidentially, and will not be released to anyone without your permission. I will send a brief report to you and, if necessary, and if you give your permission, to your family doctor.

Please complete and return the tear-off slip in the reply-paid envelope (you do not need a stamp). We will then contact you to arrange an appointment at a time convenient to you, in a few months' time. If required, we will provide assistance with transport. If you would prefer not to take part, please complete and return the slip anyway, since this will ensure that you are not bothered again.

I very much hope you will agree to help this work. Please feel free to write to me at the above address if you have any questions.

Yours sincerely,

Dr CA Soutar

- -

I *agree/do not agree to take part in the survey of ex-Colliery P miners.

(* Please delete as applicable).

Name :- Date of birth :-

Address :- Telephone no :-

Exhibit A1.3 Survey questionnaire and data recording forms

¦CP1¦ I.D.No. ¦P____¦ Page 1

INSTITUTE OF OCCUPATIONAL MEDICINE Ltd.

Health Survey of Colliery P ex-workers

IDENTIFICATION

Surname Forename

¦________________________¦ ¦____________________¦

Date of birth / / Date of attendance

¦ . / . / . ¦ ¦ . / . / . ¦
d d m m y y d d m m y y

Address

¦__________________________________¦
¦__________________________________¦
¦__________________________________¦
¦__________________________________¦

===

TICK for :	X-ray Taken	Questionnaires Completed	Lung-Function Measured
	¦__¦	¦__¦	¦__¦

===

Exhibit A1.3 *continued*

¦CP2¦ I.D.No. ¦P ¦ Page 2

OCCUPATIONAL HISTORY since leaving Colliery P

Preamble : I would like to ask you about jobs you have held since you left Colliery P; I would also like to know about any periods when you were not working. When did you finish at Colliery P?

Seq No.	START DATE ¦m m y y¦	END DATE ¦m m y y¦	OCCUPATION	CODE
0.1	●●●●●●●	. . . .	(Date of Leaving Colliery P)	
0.2	. . . .	. . . .		. . .
0.3	. . . .	. . . .		. . .
0.4	. . . .	. . . .		. . .
0.5	. . . .	. . . .		. . .
0.6	. . . .	. . . .		. . .
0.7	. . . .	. . . .		. . .
0.8	. . . .	. . . .		. . .
0.9	. . . .	. . . .		. . .
1.0	. . . .	. . . .		. . .
1.1	. . . .	. . . .		. . .
1.2	. . . .	. . . .		. . .
1.3	. . . .	. . . .		. . .
1.4	. . . .	. . . .		. . .
1.5	. . . .	. . . .		. . .
1.6	. . . .	. . . .		. . .
	¦m m y y¦	¦m m y y¦		

Exhibit A1.3 *continued*

¦CP3¦ I.D.No. ¦P____¦ Page 3

RESPIRATORY SYMPTOMS/SMOKING.

PREAMBLE : I would like to ask you some questions, mainly about your chest. Your answers will be treated in the strictest confidence. I would like you to answer Yes or No whenever possible.

COUGH

1.Do you cough when you get up or first thing in the morning? ¦_¦

IF YES to Q1:
1a. Do you cough like this on most days for as much as three months in the year? ¦_¦

2. Do you cough during the rest of the day? ¦_¦

IF YES to Q2:
2a. Do you cough like this on most days for as much as three months in the year? ¦_¦

PHLEGM

3. Do you bring up phlegm when you get up or first thing in the morning? ¦_¦

IF YES to Q3:
3a. Do you bring up phlegm like this on most days for as much as three months in the year? ¦_¦

4. Do you bring up phlegm during the rest of the day? ¦_¦

IF YES to Q4:
4a. Do you bring up phlegm like this on most days for as much as three months in the year? ¦_¦

PERIODS OF COUGH AND PHLEGM

5. In the past three years have you had a period of increased cough and phlegm lasting for three weeks or more? ¦_¦

IF YES to Q5
5a. Have you had more than one such period? ¦_¦

BREATHLESSNESS

6. Do you have to walk slower than other people on level ground because of your chest? ¦_¦

Exhibit A1.3 *continued*

¦CP3¦ I.D.No. ¦P____¦ Page 4

WHEEZING

7. Do you ever have wheezing or whistling in your chest? - I don't mean only when you have a cold ¦_¦

CHEST ILLNESSES

8. In the last three years have you had a chest illness that has kept you from your usual activities for more than a week? ¦_¦

IF YES to Q8:
8a. What did your doctor say it was? ¦_¦

(Asthma; Bronch; Cold; D=Bronch&Asthma; Flu; Some other; Not chest)

PAST ILLNESSES

Have you ever had or been told that you have had:

9. An injury or operation affecting your chest ¦_¦
10. Heart trouble ¦_¦
11. Bronchitis ¦_¦
12. Pneumonia ¦_¦
13. Pleurisy ¦_¦
14. Pulmonary Tuberculosis ¦_¦
15. Bronchial asthma ¦_¦
16. Other chest trouble ¦_¦
17. Hay fever ¦_¦

Exhibit A1.3 *continued*

¦CP4¦ I.D.No. ¦P____¦ Page 5

SMOKING HISTORY

Preamble : I would like to ask you some questions about your smoking habits. Please try to answer Yes or No whenever possible.

18. Do you smoke? ¦_¦

IF NO to Q18:
18a. Have you ever smoked as much as one cigarette a day (or one cigar a week or one ounce of tobacco a month) for as long as a year? ¦_¦

** If subject answers NO to both questions 18 and 18a then
** OMIT the remaining questions on smoking.

19. How old were you when you first started smoking regularly? ¦_._¦

20. Do/did you smoke MANUFACTURED CIGARETTES? ¦_¦

IF YES to Q20:
20a. How many do/did you smoke per day on weekdays? ¦_._¦

20b. How many do/did you smoke per day at weekends? ¦_._¦

---

21. Do/did you smoke HAND-ROLLED CIGARETTES? ¦_¦

IF YES to Q21
21a. How much tobacco do/did you usually smoke per week in this way? ¦_._:_¦

---

22. Do/did you smoke A PIPE? ¦_¦

IF YES to Q22
22a. How much pipe tobacco do/did you usually smoke per week? ¦_._:_¦

---

23. Do/did you smoke SMALL CIGARS? ¦_¦

IF YES to Q23
23a. How many of these did you usually smoke per day? ¦_._¦

---

24. Do/did you smoke OTHER CIGARS? ¦_¦

IF YES to Q24
24a. How many of these did you usually smoke per week? ¦_._¦

For CURRENT SMOKERS

25. Have you been cutting down your smoking over the past year? ¦_¦

For EX-SMOKERS

26. When did you give up smoking altogether? ¦_._._._¦
m m y y

Exhibit A1.3 *continued*

¦CP5¦ I.D.No. ¦P____¦ Page 6

LUNG FUNCTION TESTS

Height (m) ¦_¦_._¦ Weight (kg) ¦_._._¦

Lung function results from Gaensler Spirometer

1. FEV1 (l) ¦_¦_._¦ FVC (l) ¦_¦_._¦

2. FEV1 (l) ¦_¦_._¦ FVC (l) ¦_¦_._¦

3. FEV1 (l) ¦_¦_._¦ FVC (l) ¦_¦_._¦

4. FEV1 (l) ¦_¦_._¦ FVC (l) ¦_¦_._¦

5. FEV1 (l) ¦_¦_._¦ FVC (l) ¦_¦_._¦

Comments ____

____

Operator ¦_¦

Exhibit A1.3 *continued*

¦CP6¦ I.D.No. ¦P____¦ Page 7

INSTITUTE OF OCCUPATIONAL MEDICINE Ltd.

Health Survey of Colliery P ex-workers

SUMMARY SHEET

Subjects name ______________________________

Identity number ¦P____¦ Age ¦_._¦

Lung function

FEV1	(l)	¦_¦_._¦	% predicted	¦_._._¦
FVC	(l)	¦_¦_._¦	% predicted	¦_._._¦
FEV1/FVC	(l)	¦_¦_._¦	± predicted	¦_¦_._¦

Past illnesses

Tick any relevant box.

An injury or operation affecting your chest	¦__¦
Heart trouble	¦__¦
Bronchitis	¦__¦
Pneumonia	¦__¦
Pleurisy	¦__¦
Pulmonary Tuberculosis	¦__¦
Bronchial asthma	¦__¦
Other chest trouble	¦__¦

Smoking status

Tick one box.

non-smoker ¦__¦ current smoker ¦__¦ ex-smoker ¦__¦

Exhibit A1.4 List of occupations used in coding occupational history data

001	ASSIST CHIEF ELECT. ENGINEER	E/WHERE U/G
002	ASSIST CHIEF MECHANICAL ENGINEER	E/WHERE U/G
003	BRICKLAYER	E/WHERE U/G
004	BACK RIPPER	E/WHERE U/G
005	BUNKER ATTENDANT	E/WHERE U/G
006	BELTMAN	E/WHERE U/G
007	BRICKLAYER	SURFACE(GENERAL)
008	BANKSMAN	SURFACE(DUSTY)
009	BATHS ATTENDANT	SURFACE(GENERAL)
010	BUNKER ATTENDANT	SURFACE(DUSTY)
011	BOILERHOUSE ATTENDANT	SURFACE(DUSTY)
012	CONVEYOR ATTENDANT	E/WHERE U/G
013	CONVEYOR MAINTENANCE	E/WHERE U/G
014	CONVEYOR MOVER/SHIFTER	FACE
015	COAL SAMPLER	SURFACE(DUSTY)
016	CLERICAL	W/SHOPS
017	DEPUTY	AREA NOT SPECIFIED
018	MINE DRIVER	DEVELOPMENT IN COAL
019	MINE DRIVER	DEVELOPMENT IN COAL AND STONE
020	DEPUTY	DEVELOPMENT IN COAL
021	DEPUTY	DEVELOPMENT IN STONE
022	DEPUTY	E/WHERE U/G
023	DUST SAMPLER	E/WHERE U/G
024	DEPUTY(P/L)	FACE
025	DEPUTY(HAND)	FACE
026	MINE DRIVER	DEVELOPMENT IN STONE
027	DEVELOPMENT	SALVAGE
028	ELECTRICIAN	E/WHERE U/G
029	ELECTRICIAN	FACE
030	ELECTRICIAN	SURFACE(GENERAL)
031	FITTER	E/WHERE U/G
032	FITTER	FACE
033	FILLER(HAND)	FACE
034	FITTER	SURFACE(GENERAL)
035	FITTER	W/SHOPS
036	GREASER	SURFACE(GENERAL)
037	GREASER	E/WHERE U/G
038	GENERAL LABOURER	E/WHERE U/G
039	GENERAL LABOURER	SURFACE(DUSTY)
040	GENERAL LABOURER	W/SHOPS
041	HAULAGE	E/WHERE U/G
042	LOCO DRIVER	E/WHERE U/G
043	LAMP ROOM ATTENDANT	SURFACE(GENERAL)
044	ONCOST	E/WHERE U/G
045	OVERMAN	AREA NOT SPECIFIED
046	OVERMAN	DEVELOPMENT IN COAL
047	OVERMAN	DEVELOPMENT IN STONE
048	OVERMAN	E/WHERE U/G
049	OVERMAN(P/L)	FACE
050	OVERMAN(HAND)	FACE

Exhibit A1.4 *continued*

051 PLATER	E/WHERE U/G
052 PIT BOTTOM	E/WHERE U/G
053 PUMPSMAN	E/WHERE U/G
054 POWER LOADER(SHEARER)	FACE
055 POWER LOADER(CHOCKS)	FACE
056 PLATER/WELDER	SURFACE(GENERAL)
057 PREP PLANT	SURFACE(DUSTY)
058 ROPE SPLICER	E/WHERE U/G
059 RIPPER(HAND)	FACE
060 RIPPER(P/L)	FACE
061 SALVAGE	E/WHERE U/G
062 SUPPLIES	E/WHERE U/G
063 SHAFTSMAN	E/WHERE U/G
064 SWITCH ATTENDANT	E/WHERE U/G
065 STRATA CONTROL	E/WHERE U/G
066 SUPPLIES	FACE
067 SHOTFIRER(HAND)	FACE
068 SHOTFIRER(P/L)	FACE
069 SHAFTCAPPER	SURFACE(DUSTY)
070 TRANSPORT	E/WHERE U/G
071 TRAINING INSTRUCTOR	E/WHERE U/G
072 TRANSPORT	SURFACE(GENERAL)
073 TOOL ROOM ATTENDANT	W/SHOPS
074 WINDING ENGINEMAN	SURFACE(GENERAL)
075 WEIGHBRIDGE	SURFACE(DUSTY)
076 HAULAGE	AREA NOT SPECIFIED
077 BOILERMAKER	SURFACE(GENERAL)
078 ROAD REPAIRER	E/WHERE U/G
079 TRANSFER POINT	E/WHERE U/G
080 POWER LOADER(NOT SPECIFIED)	FACE
081 ELECTRICIAN	W/SHOPS
082 SAFETY DEPT	E/WHERE U/G
083 HAULAGE	SURFACE(GENERAL)
084 BUNKER ATTENDANT	AREA NOT SPECIFIED
085 DEVELOPMENT	AREA NOT SPECIFIED
086 TURNER	W/SHOPS
087 LOCO GREASER	AREA NOT SPECIFIED
088 PROJECTS ENGINEER	AREA NOT SPECIFIED
089 DAM BUILDER	E/WHERE U/G
090 BELT MAINTAINANCE	AREA NOT SPECIFIED
091 PACKER	FACE
092 ELECTRICIAN	AREA NOT SPECIFIED
093 BLACKSMITH/WELDER	SURFACE(GENERAL)
094 SUPPLIES	AREA NOT SPECIFIED
095 COMPRESSOR ATTENDANT	SURFACE(GENERAL)
096 TRANSPORT	AREA NOT SPECIFIED
201 OTHER MINING, SURFACE	NON COAL MINING
202 OTHER MINING, E/WHERE U/G	NON COAL MINING
203 OTHER MINING, FACE AND DEVELOPMENT	NON COAL MINING
204 BRICKWORKS (GENERAL)	NON COAL MINING
205 BRICKWORKS (DUSTY)	NON COAL MINING
206 BRICKWORKS (NOT DUSTY)	NON COAL MINING
207 CONSTRUCTION (STONEMASON etc)	NON COAL MINING
208 CONSTRUCTION (OTHER)	NON COAL MINING
209 CONSTRUCTION (UNKNOWN) NEC	NON COAL MINING
210 CIVIL ENGINEERING	NON COAL MINING

Exhibit A1.4 *continued*

211 DEMOLITION	NON COAL MINING
212 QUARRY (GENERAL/NON SPECIFIC)	NON COAL MINING
213 QUARRY WORK (DUSTY)	NON COAL MINING
214 QUARRY WORK (NOT DUSTY)	NON COAL MINING
215 ASBESTOS, LAGGING, STRIPPING ETC	NON COAL MINING
216 AGRICULTURE, FARMING, FORESTRY	NON COAL MINING
217 OTHER INDUSTRIAL(NOXIOUS OR DUSTY)	NON COAL MINING
218 OTHER INDUSTRIAL(NOT NOXIOUS) NEC	NON COAL MINING
219 OTHER NON INDUSTRIAL NEC	NON COAL MINING
220 ARMED SERVICES/ AT SEA	NON COAL MINING
231 ILL HEALTH	NON COAL MINING
232 REDUNDANT/UNEMPLOYED	NON COAL MINING
233 STRIKE	NON COAL MINING
234 RETIRED	NON COAL MINING
000 DATE OF LEAVING COLLIERY P	DATE OF LEAVING P
--- UNKNOWN	

APPENDIX A2: Documents used in epidemiological reading exercise

Exhibit A2.1	Protocol and instructions to readers
Exhibit A2.2	Standard IOM instructions for recording classifications
Exhibit A2.3	IOM standard form for recording radiological classifications

Exhibit A2.1 Reading protocol and instructions to readers

Colliery P Follow-up Study : Film Reading Exercise

Reading Protocol and Instructions to Readers

All readings will be made according to the ILO (1980) classification scheme (as implemented locally with minor variants), and recorded on IOM-designed forms. You are asked to re-familiarise yourself with the recording form and the attached instructions for its use.

This exercise includes about 1240 films from 486 men, all of whom were surveyed at Colliery P during the 1970s, and who have been recently resurveyed. The films are arranged in 13 batches, most of about 100 films from about 40 men. Batch 01 is smaller than the rest and will be used as a trial batch. Please do not proceed to batch 02 until the recording of data from 01 has been checked for consistent use of the instructions for recording classifications. If 01 turns up any problems, these can be reconciled before the remainder of the films are read. If necessary, 01 will be re-presented as the last batch for a fresh recording of classifications for that batch.

Each batch contains one temporary envelope per man. Each envelope contains the recently obtained film and one or two earlier films (although in a very few cases, the envelope contains only the recent film, the earlier film(s) having been mislaid). It is desired to obtain both

- independent randomised readings of the recent films; and

- readings side-by-side with earlier films, for progression.

The forms have been preprinted with the identities of the films in each envelope; there is room on a page for the results from two envelopes. The identities are of the form Pnnnn-yy, where nnnn is the man's PFR Xray number, and yy is the year in which the film was taken. Please note that all films from the recent surveys are dated 91 on the forms, even though many were obtained during December 1990; you are asked to consider these as dating from 1991. Before reading a batch, please ensure that the forms have the correct batch and reader codes preprinted.

You are asked to perform the reading as follows:

1. Take only the recent (91) film from the envelope, examine it alone, and record your classifications after comparison with the standard films.

2. Take the remaining films from the envelope, and view all the films as a series. Record your classifications of each of the pre-1990 films.

3. IF (and ONLY IF) sight of the earlier films causes you to revise your classification of the 91 film, record your revised classification on the line labelled Pnnnn-91+R. If you do not wish to revise the independent classification, leave this line blank.

Exhibit A2.1 *continued*

The contents of the envelopes should match the preprinted forms exactly; if you identify any mismatches, please inform myself or other IOM staff involved in the exercise, as soon as possible.

The ILO standard films will be available in the reading room, in the IOM-designed easy-access storage boxes. A copy of the ILO (1980) Guidelines booklet, along with other reading requisites, will be made available.

Thank you for your agreement to read these films, without which it would not be possible to complete this important project.

Brian G Miller
8 March 1991

Exhibit A2.2 Standard IOM instructions for recording classifications

Completion of forms for data from the Colliery P Follow-up Study film reading exercise

This note is intended to spell out the conventions to be used in the recording of data from this exercise. It is hoped that this will ensure that all readers record their results in the same, standard way which will help to avoid ambiguities.

By way of illustration, a copy of the form is attached with some examples which are intended to illustrate some combinations of codes which follow the ILO/IOM codes outlined below.

In what follows I will refer to the areas where recording takes place on the forms as fields; I have numbered them on the example form attached, for ease of reference here, and numbers in round brackets, e.g. (3) will refer to that numbering.

All references to Left and Right will be with reference to the subject of the film. With a P/A film, the subject's right side is on the reader's left, and the layout of the fields on the form reflects this.

Film Quality (1), (2)

Record the quality of the film as 1, 2, 3 or 4 at (1). This assessment should always be present unless the film is missing from the batch, in which case it (and every other field) should be left blank.

If the quality is scored as other than 1, i.e. less than perfect, the defects should be recorded at (2), using the IOM's standard in-house codes; a list of these codes is inside the ILO handbook. Up to three defects can be recorded in this way. If the quality is as bad as 4, i.e. unreadable, then fields (3) to (14) will be left blank, but a comment would still be permissible at (15) (see below).

CPA Off (3)

Sometimes a film has been taken in such a position that one or both of the costophrenic angles is below the bottom of the film and therefore not visible. This is really another aspect of the quality of the film. Such an occurrence is recorded at (3) using one of the symbols R, L, B for Right, Left or Both. If both angles are visible leave this field blank.

Film Normal (4)

By convention, if you observe no abnormalities at all on a film, we allow you to record this with an X in field (4). In this case fields (5) to (14) will be left blank, although a comment would still be permissible at (15) (see below). It is important to note that if any abnormality covered by the Classification is observed, then it is not appropriate to use this field.

Exhibit A2.2 *continued*

Small opacities (5), (6), (7)

This assessment is compulsory unless the film is unreadable. It may only be omitted where an X has been entered at field (4), which will be taken to imply a small opacities profusion score of 0/0.

Enter the profusion score assigned after comparison with the ILO standard films at field (5), using one of the 12 possible codes 0/-, 0/0, 0/1, 1/0, 1/1, 1/2, 2/1, 2/2, 2/3, 3/2, 3/3, 3/+. If the profusion is scored 0/- or 0/0 then fields (6) and (7) will be left blank, otherwise they must be completed.

When a score above 0/0 is assigned, mark the zones involved in diagrammatic form at (6), using x's. If all zones are involved a convenient short cut is to put a large X through the whole box at (6), but in other cases the zones must be marked individually. Enter the alphabetic codes for the predominant and secondary size and shape at (7). Since each can be one of the six letters P, Q, R, S, T, U, there are 36 possible 2-letter codes.

Large Opacities (8)

This assessment is also compulsory unless the film is unreadable. An X entered at (4) will be taken to imply a large opacities category of 0. Otherwise, enter the score for the category at (8) according to the definition in the Classification, using one of the codes 0, A, B, C.

Small and Large Opacities are the only compulsory assessments of abnormality; the remainder are all optional.

Pleural Thickening: Plaques (9)

Assess and record each lung separately. If there are no plaques in a lung then leave the field blank in the recording positions for that lung. If plaques are observed in a lung, their total extent must be recorded as 1, 2 or 3 as defined in the classification. The section marked FACE is used to indicate whether any of the plaques in that lung is seen wholly or partially face-on; if any are face-on, then a Y is entered. When all plaques are seen side-on, an N is entered. The maximum width is coded A, B or C as defined in the classification; it is noted there that if all of the plaques can be seen only face-on, it may not be possible to measure a width, and in this case the section marked WID may be left blank.

Pleural Thickening: Diffuse (10)

Diffuse pleural thickening is assessed for extent, whether or not face-on, and width in exactly the same way as for pleural plaques; the rules for recording are identical to those for (9).

Pleural Thickening: Diaphragm (11)

The occurrence of thickening of the diaphragm is scored and recorded R, L or B, according to whether it is observed on Right, Left or Both lungs.

Exhibit A2.2 *continued*

Costophrenic Angle Obliteration (12)

If obliteration of the costophrenic angle can be seen on Right, Left or Both lungs, record this observation by R, L or B; otherwise leave blank. It is possible that either or both angles may be off the film; that is recorded at (3), but obviously limits the site at which obliteration might be observed.

Pleural Calcification (13)

Pleural calcification is assessed independently for each lung. Record with an X the site(s) where it is observed (chest wall, diaphragm, other) and record the total extent over the whole lung as 1, 2 or 3 as defined in the Classification.

Other Abnormalities (14)

Record the presence of any other abnormalities observed using the 2-letter codes in the standard list. You may record up to 6 abnormalities in this way.

Comments (15)

A Comments book will be kept in the reading room for noting features not covered by the Classification. If you write a comment about a film, put an X in this field. It is always possible to comment, whatever other results have been recorded. (This is mainly used to record some clinically significant feature).

Brian G Miller
8 March 1991

INSTITUTE OF OCCUPATIONAL MEDICINE - I.O.M. - FILM READING PANEL PAGE: 1

READING ID: Coll_P BATCH ID: 01 READER ID: 999 [BATCH NUMBER:] DATE: / /

FILM ID	SEQ	SMALL OPS							PLEURAL THICKENING								PLEURAL CALC					
		QUAL	CPA OFF	N	PROF	ZONES	TYPE	LGE OPS	PLAQUES FACE	PLAQUES WID	PLAQUES EXT	DIFFUSE FACE	DIFFUSE WID	DIFFUSE EXT	DIA	CPA	CHEST WALL	DIA	OTHER	EXT	OTHER	C
		12 34	1- 9	X	012 3-+	X R L	P.Q.R S.T.U	0.A B.C	Y,N R L	ABC R L	123 R L	Y,N R L	ABC R L	123 R L	RLB	RLB	X R L	X R L	X R L	123 R L	ABN	X
P4297-91	001				/	:	/		.	.	.	.	.	.			.	.	.	.		
P4297-74	002				/	:	/		.	.	.	.	.	.			.	.	.	.		
P4297-78	003				/	:	/		.	.	.	.	.	.			.	.	.	.		
P4297-91+R	004				/	:	/		.	.	.	.	.	.			.	.	.	.		
					/	:	/		.	.	.	.	.	.			.	.	.	.		
P3422-91	005				/	:	/		.	.	.	.	.	.			.	.	.	.		
					/	:	/		.	.	.	.	.	.			.	.	.	.		
					/	:	/		.	.	.	.	.	.			.	.	.	.		
					/	:	/		.	.	.	.	.	.			.	.	.	.		
					/	:	/		.	.	.	.	.	.			.	.	.	.		

Exhibit A2.3 IOM standard form for recording radiological classifications

APPENDIX A3: Occupational concentration data

Exhibit A3.1 Tables of environmental data for Occupational Groups in Colliery P, from summary environmental report covering period 1964-74.

Exhibit A3.2 Tables of environmental data for Occupational Groups in Colliery P, from summary environmental report covering period 1975-81.

Exhibit A3.1 Tables of environmental data for Occupational Groups in Colliery P, from summary environmental report covering period 1964-74.

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F41	Face Repairers All Faces, All Seams	to 6/66	4	1.1 (1)	10.1 (E)	0.87	0.15
F42	Shotfirers All Districts, All Seams	to date	0, 1, 3, 5, 7, 9	3.5 (60)	18.3 (7)	1.18	0.21
F199	Face Supplies All Districts, All Seams	to 9/70	0, 4, 9	2.9 (19)	26.6 (E)	0.88	0.22
F264	Developers All Districts, All Seams	to date	0, 1, 2, 4, 9	1.7 (204)	17.3 (12)	0.72	0.09
F337	Brushers & (Intake & Return) No. 6 Section, Parrot Seam	to 4/64		0.9 (E)	6.7 (E)	0.41	0.07
F339	Intake Stablemen No. 6 Section, Parrot Seam	to 4/64		1.1 (E)	9.2 (E)	0.31	0.06
F340	Return Stablemen No. 6 Section, Parrot Seam	to 4/64	3, 4, 5	3.2 (6)	13.8 (E)	1.02	0.18
F341	Cable Attendants No. 6 Section, Parrot Seam	to 4/64	4	2.2 (1)	18.2 (E)	0.42	0.08
F342	P/L Operators No. 6 Section, Parrot Seam	to 4/64		2.2 (E)	18.2 (E)	0.62	0.11
F343	Snakers & Chockmen (c.g.s.) No. 6 Section, Parrot Seam	to 4/64	4, 7	2.2 (6)	18.2 (E)	0.81	0.15
F344	Chockmen (night shift) No. 6 Section, Parrot Seam	to 4/64	1	0.8 (1)	6.6 (E)	0.86	0.05
F345	Snakers & Chockmen (1st. prep.) No. 6 Section, Parrot Seam	to 4/64		2.0 (E)	16.5 (E)	0.56	0.10
F369	Intake Brushers No. 10 Sect., Kailblades Seam	to 5/66	4	2.2 (1)	28.2 (E)	1.01	0.11
F370	Return Brushers No. 10 Sect., Kailblades Seam	to 5/66	7	1.3 (1)	9.9 (E)	0.48	0.05
F371	Intake Stablemen No. 10 Sect., Kailblades Seam	to 5/66	1, 3	0.7 (3)	5.6 (E)	0.26	0.05
F372	Return Stablemen No. 10 Sect., Kailblades Seam	to 5/66	4, 5	4.4 (11)	23.6 (E)	1.80	0.20
F373	Cable Attendants No. 10 Sect., Kailblades Seam	to 5/66		3.6 (E)	37.2 (E)	1.66	0.18
F374	P/L Operators No. 10 Sect., Kailblades Seam	to 5/66	4	2.1 (5)	21.5 (E)	0.85	0.09

( ) No. of samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F375	Snakers & Chockmen (c.g.s.) No. 10 Sect., Kailblades Seam	to 5/66	4	3.0 (22)	31.0 (E)	1.23	0.14
F379	Chockmen (night shift) No. 10 Sect., Kailblades Seam	to 5/66	4	0.6 (1)	6.2 (E)	0.33	0.04
F380	Packers (night shift) No. 6 Section, Parrot Seam	to 4/64	4	1.0 (2)	8.3 (E)	0.32	0.06
F383	P/L Machinemen (c.g.s.) All Sections, Parrot Seam	to 6/66	3, 4, 5	3.7 (5)	30.9 (E)	1.38	0.25
F384	P/L Machinemen (prep.) All Sections, Parrot Seam	to 6/66	5	0.7 (1)	5.8 (E)	0.20	0.04
F387	P/L Machinemen (c.g.s.) All Sections, Kailblades Seam	to 2/66	3, 4, 5	1.6 (3)	16.9 (E)	0.44	0.05
F388	P/L Machinemen (prep.) All Sections, Kailblades Seam	to 2/66	3	0.8 (1)	8.3 (E)	0.22	0.02
F391	Face Belt Attendants (Int.) All Sections, All Seams	to 9/70	0, 1, 3	1.6 (19)	14.8 (E)	0.43	0.07
F392	Face Belt Attendants (Return) All Sections, All Seams	to 6/66	5, 7	5.6 (7)	31.8 (E)	2.01	0.34
F393	Intake Brushers No. 7 Section, Parrot Seam	to 6/66	0	1.0 (1)	12.6 (E)	0.19	0.03
F394	Return Brushers No. 7 Section, Parrot Seam	to 6/66	4, 7	1.1 (3)	5.5 (E)	0.39	0.07
F395	Intake Stablemen No. 7 Section, Parrot Seam	to 6/66	3, 4	0.6 (3)	4.7 (E)	0.16	0.03
F396	Return Stablemen No. 7 Section, Parrot Seam	to 6/66	5	4.6 (5)	20.1 (E)	1.48	0.27
F397	Cable Attendants No. 7 Section, Parrot Seam	to 6/66	4	1.6 (3)	13.5 (E)	0.46	0.08
F398	P/L Operators No. 7 Section, Parrot Seam	to 6/66	4	3.6 (5)	29.8 (E)	0.83	0.15
F399	Snakers & Chockmen (c.g.s.) No. 7 Section, Parrot Seam	to 6/66	4	3.0 (12)	25.0 (E)	0.85	0.15
F400	Chockmen (night shift) No. 7 Section, Parrot Seam	to 6/66	4	0.7 (1)	5.8 (E)	0.23	0.04
F402	Intake Brushers No. 1 Section, Kailblades Seam	to 12/65	1	1.2 (2)	15.4 (E)	0.32	0.04

( ) No. of samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F403	Return Brushers No. 1 Section, Kailblades Seam	to 12/65	7	1.0 (4)	7.3 (E)	0.30	0.03
F404	Intake Stablemen No. 1 Section, Kailblades Seam	to 12/65	3	1.0 (4)	8.0 (E)	0.37	0.04
F405	Return Stablemen No. 1 Section, Kailblades Seam	to 12/65	5	3.1 (3)	16.6 (E)	0.84	0.09
F406	Cable Attendants No. 1 Section, Kailblades Seam	to 9/64		1.9 (E)	19.6 (E)	0.61	0.07
F407	P/L Operators No. 1 Section, Kailblades Seam	to 12/65	4	4.1 (4)	42.1 (E)	1.51	0.17
F408	Snakers & Chockmen (c.g.s.) No. 1 Section, Kailblades Seam	to 12/65	4	2.8 (14)	28.6 (E)	0.88	0.10
F409	Chockers (night shift) No. 1 Section, Kailblades Seam	to 12/65	4	0.7 (1)	7.2 (E)	0.22	0.02
F412	Stablemen (spare) No. 1 Section, Kailblades Seam	to 12/65	3, 5	3.5 (7)	23.1 (E)	0.93	0.10
F413	Packers (night shift) No. 7 Section, Parrot Seam	to 9/64	4	0.6 (1)	5.0 (E)	0.17	0.03
F414	Intake Brushers No. 4 Section, Parrot Seam	to 2/66	0, 1	1.0 (5)	12.9 (E)	0.32	0.03
F415	Return Brushers No. 4 Section, Parrot Seam	to 2/66	7	3.8 (10)	19.8 (E)	0.85	0.12
F416	Intake Stablemen No. 4 Section, Parrot Seam	to 2/66	3	1.1 (5)	9.2 (E)	0.40	0.03
F417	Return Stablemen No. 4 Section, Parrot Seam	to 2/66	5	4.3 (20)	18.8 (E)	0.82	0.13
F418	Cable Attendants No. 4 Section, Parrot Seam	to 2/66	4	3.0 (5)	25.0 (E)	0.69	0.13
F419	P/L Operators No. 4 Section, Parrot Seam	to 2/66	4	5.5 (4)	45.5 (E)	1.54	0.38
F420	Snakers & Chockmen (c.g.s.) No. 4 Section, Parrot Seam	to 2/66	4	3.1 (23)	25.7 (E)	0.78	0.08
F421	Chockmen (night shift) No. 4 Section, Parrot Seam	to 2/66	4	0.8 (2)	6.2 (E)	0.34	0.06

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F422	Brushers (spare) No. 4 Section, Parrot Seam	to 2/66	7	5.4 (2)	39.8 (E)	1.23	0.22
F423	Trainers All Sections, Parrot Seam	to 8/67	3, 4, 5, 7	3.0 (8)	25.0 (E)	0.70	0.13
F424	Brushers (spare) No. 7 Section, Parrot Seam	to 6/66	7	1.5 (1)	11.1 (E)	0.28	0.05
F425	Stablemen (spare) No. 10 Sect., Kailblades Seam	6/64 - 5/66		3.5 (E)	23.4 (E)	1.40	0.15
F426	Brushers (spare) No. 1 Section, Kailblades Seam	to 12/65	7	1.6 (1)	12.2 (E)	0.59	0.07
F427	Intake Brushers No. 9 Section, Parrot Seam	8/64 - 11/67	1	0.8 (3)	10.5 (E)	0.47	0.08
F428	Return Brushers No. 9 Section, Parrot Seam	8/64 - 11/67	7	0.8 (4)	4.0 (E)	0.26	0.05
F429	Intake Stablemen No. 9 Section, Parrot Seam	8/64 - 11/67	3	1.0 (5)	8.5 (E)	0.34	0.06
F430	Return Stablemen No. 9 Section, Parrot Seam	8/64 - 11/67	5	5.9 (15)	22.1 (E)	1.98	0.49
F431	Cable Attendants No. 9 Section, Parrot Seam	8/64 - 11/67	4	2.7 (7)	14.3 (E)	1.00	0.29
F432	P/L Operators No. 9 Section, Parrot Seam	8/64 - 11/67	4	5.6 (10)	27.1 (E)	2.14	0.63
F433	Snakers & Chockmen (c.g.s.) No. 9 Section, Parrot Seam	8/64 - 11/67	1, 3, 4, 5, 7	2.8 (29)	20.8 (E)	1.02	0.28
F434	Chockmen (night shift) No. 9 Section, Parrot Seam	8/64 - 11/67	4	0.8 (4)	6.2 (E)	0.17	0.03
F435	Intake Brushers No. 11 Section, Kailblades Seam	8/64 - 4/65	1	0.5 (1)	6.4 (E)	0.25	0.03
F436	Return Brushers No. 11 Section, Kailblades Seam	8/64 - 4/65	7	4.8 (1)	36.7 (E)	2.45	0.27
F437	Intake Stablemen No. 11 Section, Kailblades Seam	8/64 - 4/65	3	1.0 (1)	8.0 (E)	0.32	0.04
F438	Return Stablemen No. 11 Section, Kailblades Seam	8/64 - 4/65	4, 5	4.8 (2)	25.7 (E)	2.45	0.27

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F440	P/L Operators No. 11 Section, Kailblades Seam	8/64 - 4/65	4	4.3 (1)	44.5 (E)	2.36	0.26
F441	Snakers & Chockmen (c.g.s.) No. 11 Section, Kailblades Seam	8/64 - 4/65	4	2.4 (3)	24.8 (E)	1.10	0.12
F442	Chockmen (night shift) No. 11 Section, Kailblades Seam	8/64 - 4/65	4	0.5 (1)	5.2 (E)	0.16	0.02
F443	Hole borers (coal) All Sections, All Seams	10/64 - 2/65	5	1.2 (1)	11.0 (E)	0.22	0.02
F444	Face Tradesmen (c.g.s.) All Sections, All Seams	9/64 - 2/73	0, 1, 3, 4, 9	1.7 (59)	5.9 (1)	0.64	0.14
F445	Face Tradesmen (prep.) All Sections, All Seams	9/64 - 2/73	0, 1, 4, 9	0.8 (16)	6.7 (E)	0.31	0.06
F446	Packers (night shift) No. 1 Section, Kailblades Seam	11/64 - 12/65	4	1.4 (1)	14.5 (E)	0.38	0.04
F447	Intake Brushers No. 2 Section, Kailblades Seam	12/65 - 6/67	1	1.8 (2)	22.4 (E)	0.40	0.04
F448	Return Brushers No. 2 Section, Kailblades Seam	12/65 - 6/67	7	3.1 (17)	24.0 (E)	1.16	0.20
F449	Intake Stablemen No. 2 Section, Kailblades Seam	12/65 - 6/67	3	1.6 (9)	12.8 (E)	0.53	0.07
F450	Return Stablemen No. 2 Section, Kailblades Seam	12/65 - 6/67	5	2.7 (11)	14.3 (E)	0.91	0.05
F451	P/L Operators No. 2 Section, Kailblades Seam	12/65 - 6/67	4	1.7 (3)	17.2 (E)	0.45	0.05
F452	Snakers & Chockmen (c.g.s.) No. 2 Section, Kailblades Seam	12/65 - 6/67	4	2.2 (20)	22.8 (E)	0.84	0.04
F453	Brushers (spare) No. 2 Section, Kailblades Seam	12/65 - 6/67	1, 7	2.2 (2)	17.2 (E)	0.52	0.06
F454	Intake Brushers No. 1 North, Parrot Seam	2/66 - 9/67	1	1.1 (3)	14.3 (E)	0.41	0.03
F455	Return Brushers No. 1 North, Parrot Seam	2/66 - 9/67	7, 9	4.4 (15)	22.8 (E)	1.33	0.17
F456	Intake Stablemen No. 1 North, Parrot Seam	2/66 - 9/67 -	3	0.9 (3)	7.8 (E)	0.21	0.04

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m³)			
				Resp. Dust	Total Dust	Ash	Quartz
F457	Return Stablemen No. 1 North, Parrot Seam	2/66 - 9/67	5	3.3 (7)	14.4 (E)	0.89	0.12
F458	Cable Attendants No. 1 North, Parrot Seam	2/66 - 9/67	4	1.3 (2)	10.8 (E)	0.30	0.05
F459	P/L Operators No. 1 North, Parrot Seam	2/66 - 9/67	4	2.3 (5)	19.2 (E)	0.65	0.12
F460	Snakers & Chockmen (c.g.s.) No. 1 North, Parrot Seam	2/66 - 9/67	4	2.6 (13)	21.7 (E)	0.79	0.10
F461	Chockmen (night shift) No. 1 North, Parrot Seam	2/66 - 9/67	4	1.1 (2)	9.1 (E)	0.31	0.06
F462	Cable Attendants No. 2 Section, Kailblades Seam	5/66 - 12/66		2.0 (E)	20.7 (E)	0.45	0.05
F463	Chockmen (night shift) No. 2 Section, Kailblades Seam	11/66 - 6/67	4	0.6 (2)	6.7 (E)	0.12	0.01
F464	Intake Brushers No. 3 Section, Kailblades Seam	7/67 - 4/69	0, 1, 7	1.2 (15)	15.2 (E)	0.27	0.04
F465	Intake Stablemen No. 3 Section, Kailblades Seam	7/67 - 4/69	3	1.6 (14)	12.8 (E)	0.38	0.05
F466	Return Stablemen No. 3 Section, Kailblades Seam	7/67 - 4/69	4, 5	2.8 (15)	14.2 (E)	0.75	0.08
F467	P/L Operators No. 3 Section, Kailblades Seam	7/67 - 4/69	4	3.7 (8)	37.5 (E)	1.00	0.14
F468	Snakers & Chockmen (c.g.s.) No. 3 Section, Kailblades Seam	7/67 - 4/69	4, 7	2.4 (21)	23.8 (E)	0.71	0.08
F470	Brushers (Intake & Return) No. 1 Section, Splint Seam	4/67 - 8/68	1, 7	1.6 (10)	6.9 (E)	0.69	0.11
F471	Intake Stablemen No. 1 Section, Splint Seam	4/67 - 8/68	3, 4	0.9 (8)	21.7 (E)	0.36	0.05
F472	Return Stablemen No. 1 Section, Splint Seam	4/67 - 8/68	5	2.7 (5)	17.8 (E)	0.96	0.12
F473	P/L Operators No. 1 Section, Splint Seam	4/67 - 8/68	4	1.3 (2)	11.6 (E)	0.44	0.06
F474	Snakers & Chockmen (c.g.s.) No. 1 Section, Splint Seam	4/67 - 8/68	1, 4	1.6 (12)	12.4 (E)	0.72	0.11

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m³)			
				Resp. Dust	Total Dust	Ash	Quartz
F475	Chockmen (night shift) No. 1 Section, Splint Seam	4/67 - 8/68	4	0.7 (2)	5.5 (E)	0.22	0.03
F476	Intake Brushers (c.g.s.) No. 1 West, Parrot Seam	9/67 - 2/69	1, 3	1.4 (6)	18.6 (E)	0.47	0.08
F477	Return Brushers (c.g.s.) No. 1 West, Parrot Seam	9/67 - 2/69	7	4.2 (6)	21.2 (E)	1.20	0.29
F478	Intake Stablemen No. 1 West, Parrot Seam	9/67 - 2/69	3	1.3 (9)	11.1 (E)	0.36	0.09
F479	Return Stablemen No. 1 West, Parrot Seam	9/67 - 2/69	3, 5, 7, 4	3.0 (14)	13.1 (E)	0.88	0.20
F480	P/L Operators No. 1 West, Parrot Seam	9/67 - 2/69	4	3.5 (8)	28.9 (E)	0.90	0.20
F481	Snakers & Chockmen (c.g.s.) No. 1 West, Parrot Seam	9/67 - 2/69	4	2.6 (22)	21.6 (E)	0.75	0.17
F482	Chockmen (night shift) No. 1 West, Parrot Seam	9/67 - 2/69	4	4.7 (2)	38.7 (E)	1.59	0.68
F483	Intake Brushers (night shift) No. 1 West, Parrot Seam	9/67 - 2/69	1, 7	1.4 (7)	17.8 (E)	0.53	0.16
F484	Return Brushers (night shift) No. 1 West, Parrot Seam	9/67 - 2/69	4, 7	3.1 (6)	16.0 (E)	0.81	0.17
F485	Return Brushers No. 3 Section, Kailblades Seam	7/67 - 4/69	1, 7	2.8 (6)	19.7 (E)	0.70	0.07
F486	Stablemen (spare) No. 1 Section, Splint Seam	1/68 - 8/68		2.2 (E)	29.2 (E)	0.81	0.07
F487	Intake Brushers No. 2 West, Parrot Seam	2/69 - 9/70	1, 7	2.0 (16)	15.1 (1)	0.73	0.24
F488	Return Brushers No. 2 West, Parrot Seam	2/69 - 9/70	5, 7	5.3 (27)	20.0 (3)	1.85	1.05
F489	Intake Stablemen No. 2 West, Parrot Seam	2/69 - 3/71	1, 3	1.6 (18)	14.0 (E)	0.50	0.15
F490	Return Stablemen No. 2 West, Parrot Seam	2/69 - 3/71	4, 5, 7	4.5 (36)	19.9 (4)	1.47	0.71
F492	Snakers & Chockmen No. 2 West, Parrot Seam	2/69 - 3/71	0, 1, 4, 5, 9	2.8 (113)	15.6 (3)	0.83	0.33

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m³)			
				Resp. Dust	Total Dust	Ash	Quartz
F493	Intake Brushers No. 4 Section, Kailblades Seam	3/69 - 6/70	1	2.8 (11)	34.8 (E)	0.70	0.20
F494	Return Brushers No. 4 Section, Kailblades Seam	3/69 - 6/70	7	5.6 (11)	25.3 (1)	1.71	0.31
F495	Intake Stablemen No. 4 Section, Kailblades Seam	3/69 - 6/70	3	3.1 (8)	24.6 (E)	0.93	0.25
F496	Return Stablemen No. 4 Section, Kailblades Seam	3/69 - 6/60	5	5.5 (7)	17.8 (1)	1.93	0.60
F497	P/L Operators No. 4 Section, Kailblades Seam	3/69 - 6/70	4	2.6 (4)	7.0 (1)	0.98	0.30
F498	Snakers & Chockmen No. 4 Section, Kailblades Seam	3/69 - 6/70	0, 4	4.0 (43)	24.7 (2)	1.46	0.39
F499	Intake Brushers No. 5 South, Parrot Seam	2/70 - 9/70	1	1.8 (1)	22.3 (E)	0.37	0.13
F500	Return Brushers No. 5 South, Parrot Seam	2/70 - 9/70	7	5.2 (3)	35.2 (2)	1.98	0.88
F501	Intake Stablemen No. 5 South, Parrot Seam	2/70 - 11/70	3	1.7 (4)	5.6 (1)	0.52	0.15
F502	Return Stablemen No. 5 South, Parrot Seam	2/70 - 11/70	5	3.4 (5)	25.6 (3)	1.16	0.30
F503	P/L Ops., Snakers & Chockmen No. 5 South, Parrot Seam	2/70 - 11/70	0, 4, 9	5.0 (14)	23.3 (6)	2.20	0.68
F504	Face Con. Attendants No. 5 South, Parrot Seam	2/70 - 9/70	9	4.7 (2)	20.0 (2)	2.00	0.50
F505	Brushers (Intake & Return) No. 2 West, Parrot Seam	9/70 - 3/71	1, 7	3.3 (50)	17.6 (3)	0.87	0.29
F506	Brushers (Intake & Return) No. 5 South, Parrot Seam	9/70 - 11/70	1, 7	2.0 (3)	25.3 (2)	0.58	0.08
F507	Brushers (Intake/Return, c.g.s.) No. 5 Section, Kailblades Seam	7/70 - 12/71	1, 7	3.8 (70)	29.4 (4)	1.25	0.17
F508	Intake Stablemen (c.g.s.) No. 5 Section, Kailblades Seam	7/70 - 12/71	3	2.4 (27)	18.8 (1)	0.67	0.05
F509	Return Stablemen (c.g.s.) No. 5 Section, Kailblades Seam	7/70 - 12/71	5	4.4 (22)	19.6 (3)	1.42	0.21

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F510	Power Loading Team (c.g.s.) No. 5 Section, Kailblades Seam	7/70 - 12/71	0, 1, 4, 7, 9	3.2 (104)	21.2 (7)	1.09	0.19
F511	P/L Team (night shift) No. 5 Section Kailblades Seam	7/70 - 12/71	0, 1, 4, 7	1.2 (61)	22.9 (1)	0.39	0.03
F512	Rippers (Intake & Return) P.03 Face, Parrot Seam	3/71 - 2/73	1, 3, 7	3.7 (169)	15.3 (17)	1.99	0.86
F513	Intake Stablemen P.03 Face, Parrot Seam	3/71 - 2/73	3	1.2 (67)	13.0 (1)	0.54	0.14
F514	Return Stablemen P.03 Face, Parrot Seam	3/71 - 2/78	5	9.6 (54)	25.7 (5)	5.74	2.84
F515	Power Loading Team P.03 Face, Parrot Seam	3/71 - 2/73	0, 1, 4, 5, 7, 9	3.2 (140)	16.6 (9)	1.98	0.95
F516	Rippers (Intake & Return) No. 12 Sect., Kailblades Seam	8/71 - 10/71		3.5 (E)	27.5 (E)	1.08	0.12
F518	Return Stablemen No. 12 Sect., Kailblades Seam	8/71 - 10/71		4.4 (E)	23.4 (E)	1.23	0.14
F519	Face Team (c.g.s.) No. 12 Sect., Kailblades Seam	8/71 - 10/71	4, 7	1.7 (4)	17.2 (E)	0.81	0.17
F520	Face Team (night shift) No. 12 Sect., Kailblades Seam	8/71 - 10/71	4, 5	1.2 (6)	14.6 (E)	0.46	0.07
F521	Rippers (Intake & Return) K.06 Face, Kailblades Seam	12/71 - 1/73	1, 7	3.8 (18)	28.0 (1)	1.20	0.14
F522	Intake Stablemen K.06 Face, Kailblades Seam	12/71 - 4/73		1.0 (E)	8.0 (E)	0.32	0.04
F523	Return Stablemen K.06 Face, Kailblades Seam	12/71 - 4/73	5	3.3 (12)	29.9 (3)	1.08	0.12
F524	P/L Team K.06 Face, Kailblades Seam	12/71 - 4/73	4, 9	2.3 (37)	20.5 (10)	0.81	0.10
F525	Face Team (night shift) K.06 Face, Kailblades Seam	12/71 - 4/73	0, 1, 3, 4, 7, 9	0.8 (33)	10.0 (3)	0.24	0.02
F526	Face Team (night shift) P.03 Face, Parrot Seam	12/71 - 2/73	1, 4, 5	1.1 (29)	14.0 (2)	0.59	0.24
F527	Rippers (Intake & Return) No. 2 Face, Splint Seam	3/72 - 1/73	1, 3, 7	3.6 (40)	31.4 (3)	1.78	0.35

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F528	Intake Stablemen No. 2 Face, Splint Seam	3/72 - 9/73	3	2.2 (31)	38.1 (3)	0.98	0.14
F529	Return Stablemen No. 2 Face, Splint Seam	3/72 - 9/73	5	4.2 (36)	29.5 (6)	2.20	0.47
F530	Face Team (c.g.s.) No. 2 Face, Splint Seam	3/72 - 9/73	0, 1, 4	2.4 (78)	16.2 (6)	1.24	0.22
F531	Face Team (night shift) No. 2 Face, Splint Seam	3/72 - 9/72	1, 3, 4, 5, 7	1.4 (46)	14.6 (5)	0.69	0.11
F532	Rippers (Intake & Return) P.04 Face, Parrot Seam	10/72 - 3/73		4.0 (E)	30.0 (E)	1.72	0.29
F533	Intake Stablemen P.04 Face, Parrot Seam	3/73 to date	3	1.9 (25)	20.3 (5)	0.74	0.09
F534	Return Stablemen P.04 Face, Parrot Seam	3/73 to date	5	4.6 (12)	22.0 (3)	1.72	0.39
F535	Face Team (c.g.s.) P.04 Face, Parrot Seam	3/73 to date	0, 1, 4	2.0 (20)	18.5 (4)	0.68	0.08
F536	Face Team (night shift) P.04 Face, Parrot Seam	3/73 to date	1, 3, 4, 5, 7	1.1 (34)	8.2 (5)	0.31	0.04
F537	Intake Rippers No. 2 Face, Splint Seam	1/73 - 9/73	1	0.8 (15)	9.8 (2)	0.30	0.03
F538	Return Rippers No. 2 Face, Splint Seam	1/73 - 9/73	7	4.4 (15)	18.0 (2)	2.32	0.65
F539	Intake Rippers K.06 Face, Kailblades Seam	1/73 - 4/73	1	0.7 (E)	8.7 (E)	0.22	0.03
F540	Return Rippers K.06 Face, Kailblades Seam	1/73 - 4/73	7	2.4 (2)	26.6 (1)	0.84	0.10
F541	Face Tradesmen All Shifts, All Seams	2/73 to date	0, 1, 4, 7, 9	3.6 (32)	19.7 (5)	1.63	0.56
F542	Intake Rippers P.04 Face, Parrot Seam	2/73 to date	1	1.6 (34)	15.1 (5)	0.53	0.06
F543	Return Rippers P.04 Face, Parrot Seam	2/73 to date	7	4.8 (19)	20.8 (4)	1.90	0.43
F544	Intake Rippers K.07 Face, Kailblades Seam	4/73 to date	1	1.9 (25)	19.4 (5)	0.74	0.06

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m³)			
				Resp. Dust	Total Dust	Ash	Quartz
F545	Return Rippers K.07 Face, Kailblades Seam	4/73 to date	7	3.7 (25)	26.2 (6)	1.58	0.22
F546	Intake Stablemen K.07 Face, Kailblades Seam	4/73 to date	3	2.7 (14)	39.4 (4)	0.98	0.09
F548	Face Team (c.g.s.) K.07 Face, Kailblades Seam	4/73 to date	0, 4	3.1 (45)	28.4 (6)	1.22	0.14
F549	Face Team (night shift) K.07 Face, Kailblades Seam	4/73 to date	1, 4, 7	0.6 (34)	7.6 (5)	0.20	0.02
F550	Intake Rippers P.27 Face, Parrot Seam	9/73 to date	1	1.4 (58)	11.6 (8)	0.49	0.05
F551	Return Rippers P.27 Face, Parrot Seam	9/73 to date	7	7.0 (31)	36.4 (7)	3.49	1.53
F552	Intake Stablemen P.27 Face, Parrot Seam	9/73 to date	3	1.9 (27)	13.6 (6)	0.72	0.09
F553	Return Stablemen P. 27 Face, Parrot Seam	9/73 to date	5	7.3 (31)	34.6 (7)	3.19	1.33
F554	Face Team (c.g.s.) P.27 Face, Parrot Seam	9/73 to date	0, 4, 9	4.7 (41)	17.0 (5)	2.32	0.87
F555	Face Team (prep., night shift) P.27 Face, Parrot Seam	9/73 to date	1, 3, 4, 5, 7	1.5 (20)	9.3 (3)	0.66	0.17
F556	Face Team (coaling, night shift) P.27 Face, Parrot Seam	11/73 to date	1, 3, 4, 5, 7	3.6 (26)	13.2 (2)	1.62	0.70

( ) No. of Samples, E = Estimated Values

Exhibit A3.1 *continued*

Mean Concentrations by Occupational Group (Non-faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
E21	Officials All Districts, All Seams	4/64 to date		2.2 (76)	11.0 (6)	0.95	0.14
E45	Mine Driving All Districts, All Seams	to 4/73		1.1 (E)	7.1 (E)	0.47	0.04
E61	E.U.S. Workers (exc. E21,E45) All Districts, All Seams	to 3/64		1.0 (E)	10.9 (E)	0.38	0.03
E62	E.U.G. Workers Parrot Seam	4/64 to date		1.0 (607)	11.0 (19)	0.36	0.04
E63	E.U.G. Workers Kailblades Seam	4/64 to date		1.1 (318)	12.3 (10)	0.38	0.04
E64	E.U.G. Workers General to pit	4/64 to date		0.4 (344)	9.2 (10)	0.13	0.01

( ) No. of Samples, E = Estimated Value

Mean Concentrations by Occupational Group (Surface Workers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
S.0.	Others Surface	to date		0.3 (237)	4.7 (5)	0.12	0.01
S.7	Tippler Attendants Surface	to 1/72		0.6 (46)	7.4 (3)	0.20	0.01

( ) No. of Samples, E = Estimated Value

Exhibit A3.2 Tables of environmental data for Occupational Groups in Colliery P, from summary environmental report covering period 1975-81.

Mean Concentration by Occupational Group (Faceworkers)

OGSH	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F 42	Shotfirers All Districts All Seams	to 3/81	1.3.5.7.9	3.0 (75)	15.3 (29)	1.43	0.40
F264	Developers All Districts All Seams	to 3/81	0.1.2.4.9	1.9 (116)	13.7 (25)	0.99	0.13
F522	Intake Stablemen K06 Face Kailblades Seam	1/75 to 2/76	No Intake Stable				
F523	Return Stablemen K06 Face Kailblades Seam	1/75 to 2/76	5	5.7 (20)	36.6 (9)	3.40	0.52
F524	Face Team (c.g.s) K06 Face Kailblades Seam	1/75 to 2/76	0.4.9	3.0 (33)	26.4 (9)	1.53	0.21
F525	Face Team (prep shift) K06 Face Kailblades Seam	2/75 to 2/76	1.4.7	0.4 (21)	11.8 (5)	0.16	0.02
F533	Intake Stablemen P04 Face Parrot Seam	to 8/76	3	1.0 (20)	14.9 (9)	0.36	0.09
F534	Return Stablemen P04 Face Parrot Seam	to 8/76	5	4.3 (12)	20.9 (7)	1.55	0.54
F535	Face Team (c.g.s) P04 Face Parrot Seam	to 8/76	0.1.4	1.6 (19)	14.7 (7)	0.64	0.26
F536	Face Team (night shift) P04 Face Parrot Seam	to 8/76	1.3.4.5.7	1.0 (39)	10.3 (6)	0.31	0.05
F539	Intake Rippers K06 Face Kailblades Seam	1/75 to 2/76	1	1.0 (16)	18.4 (7)	0.41	0.04
F540	Return Rippers K06 Face Kailblades Seam	1/75 to 2/76	7	6.2 (16)	32.7 (7)	3.06	0.45
F541	Face Tradesmen All Shifts All Seams	to 3/81	0.1.4.7.9.	3.5 (85)	12.4 (29)	1.76	0.59

Exhibit A3.2 *continued*

Mean Concentration by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F542	Intake Rippers P04 Face Parrot Seam	to 8/76	1	0.6 (5)	11.5 (2)	0.12	0.03
F543	Return Rippers P04 Face Parrot Seam	to 8/76	7	2.9 (9)	18.2 (5)	1.06	0.25
F550	Intake Rippers P27 Face Parrot Seam	to 8/76	1	1.1 (25)	10.5 (4)	0.36	0.09
F551	Return Rippers P27 Face Parrot Seam	to 8/76	7	5.4 (27)	21.5 (6)	3.00	1.66
F552	Intake Stablemen P27 Face Parrot Seam	to 8/76	3	1.0 (23)	14.3 (4)	0.37	0.10
F553	Return Stablemen P27 Face Parrot Seam	to 8/76	5	5.1 (33)	31.7 (8)	3.09	1.82
F554	Face Team (c.g.s.) P27 Face Parrot Seam	to 8/76	0.4.9	2.5 (45)	15.8 (5)	1.53	0.77
F555	Face Team (night shift prep) P27 Face Parrot Seam	to 8/76	1.3.4.5.7	3.1 (26)	9.0 (4)	1.58	0.75
F556	Face Team (night shift c.g.) P27 Face Parrot Seam		Coal-getting stopped N/S				
F557	Tradesmen All Seams Development Sections	6/75 to 3/81	0.1.3.4.5.7	1.6 (43)	10.7 (16)	0.67	0.11
F558	Intake Rippers K08 Face Kailblades Seam	11/75 to 7/76	1	0.9 (6)	13.0 (2)	0.38	0.06
F559	Return Rippers K08 Face Kailblades Seam	to 7/76	7	4.3 (6)	29.0 (2)	2.20	0.56

Exhibit A3.2 *continued*

Mean Concentration by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m³)			
				Resp. Dust	Total Dust	Ash	Quartz
F560	Intake Stablemen K08 Face Kailblades Seam	11/75 to 7/76	No Intake Stable				
F561	Return Stablemen K08 Face Kailblades Seam	11/75 to 7/76	5	3.6 (12)	23.0 (3)	1.68	0.24
F562	Face Team (c.g.s) K08 Face Kailblades Seam	11/75 to 7/76	0.4.9	3.0 (24)	18.2 (5)	1.43	0.18
F563	Face Team (prep shift) Kailblades Seam	11/75 to 7/76	1.4.7	2.1 (6)	18.0 (2)	0.99	0.06
F564	Advanced Heading Team. K08 Face Kailblades Seam	4/76 to 7/76	6	9.3 (5)	31.0 (1)	4.95	0.64
F565	Intake Rippers P05 Face Parrot Seam	8/76 to 5/78	1	0.7 (42)	7.6 (7)	0.33	0.08
F566	Return Rippers P05 Face Parrot Seam	8/76 to 5/78	7	4.9 (35)	21.2 (8)	2.07	0.78
F567	Intake Stablemen P05 Face Parrot Seam	8/76 to 5/78	3	1.4 (34)	22.4 (7)	0.65	0.08
F568	Return Stablemen P05 Face Parrot Seam	8/76 to 5/78	5	4.8 (33)	19.1 (7)	1.97	0.76
F569	Face Team (c.g.s) P05 Face Parrot Seam	8/76 to 5/78	0.4.9	2.5 (59)	16.7 (9)	1.16	0.39
F570	Face Team (prep) P05 Face Parrot Seam	8/76 to 5/78	1.4.7	1.2 (51)	12.6 (8)	0.51	0.10
F571	Intake Rippers Sp01 Face Splint Seam	8/76 to 10/77	1	0.9 (9)	7.8 (5)	3.02	0.58

Exhibit A3.2 *continued*

Mean Concentration by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F572	Return Rippers SpO1 Face Splint Seam	8/76 to 10/77	7	2.3 (6)	9.0 (3)	0.95	0.34
F573	Intake Stablemen SpO1 Face Splint Seam	8/76 to 10/77	3	1.0 (13)	11.0 (6)	0.37	0.04
F574	Return Stablemen SpO1 Face Splint Seam	8/76 to 10/77	5	3.1 (13)	12.7 (6)	1.43	0.51
F575	Face Team (c.g.s) SpO1 Face Splint Seam	8/76 to 10/77	0.4.9	1.5 (20)	17.0 (7)	0.76	0.18
F576	Face Team (prep shift) SpO1 Face Splint Seam	8/76 to 10/77	1.4.7	0.7 (8)	6.7 (3)	0.25	0.03
F577	Intake Rippers P11 Face Parrot Seam	9/77 to 1/79	1	0.9 (13)	9.8 (6)	0.32	0.05
F578	Return Ripper P11 Face Parrot Seam	9/77 to 1/79	7	4.8 (11)	20.3 (6)	2.08	0.64
F579	Intake Stablemen P11 Face Parrot Seam	9/77 to 1/79	3	2.4 (15)	45.8 (5)	0.84	0.12
F580	Return Stablemen P11 Face Parrot Seam	9/77 to 1/79	5	5.0 (19)	21.8 (9)	1.83	0.49
F581	Face Team (c.g.s) P11 Face Parrot Seam	9/77 to 1/79	0.4.9	2.8 (22)	23.5 (8)	1.31	0.24
F582	Face Team (prep shift) P11 Face Parrot Seam	9/77 to 1/79	1.4.7	1.7 (26)	19.4 (7)	0.69	0.11
F583	Intake Rippers SpO3 Face Splint Seam	5/78 to 3/79	No Intake Rippers				

Exhibit A3.2 *continued*

Mean Concentration by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F584	Return Rippers Sp03 Face Splint Seam	5/78 to 3/79	7	3.6 (14)	12.0 (4)	2.00	0.44
F585	Intake Stablemen Sp03 Face Splint Seam	2/78 to 3/79	3	0.6 (14)	7.0 (5)	0.34	0.04
F586	Face Team (c.g.s.) Sp03 Face Splint Seam	2/78 to 3/79	0.4.9	1.5 (21)	11.5 (4)	0.78	0.16
F587	Face Team (prep) Sp03 Face Splint Seam	2/78 to 3/79	1.4.7	0.5 (5)	8.7 (3)	0.29	0.04
F588	Return Stablemen Sp03 Face Splint Seam	10/78 to 3/79	5	5.4 (7)	22.0 (4)	3.33	0.72
F589	Intake Rippers P06 Face Parrot Seam	11/78 to 12/79	1	0.8 (12)	8.0 (5)	0.31	0.05
F590	Return Ripper P06 Face Parrot Seam	11/78 to 12/79	7	3.3 (17)	9.5 (6)	1.42	0.41
F591	Intake Stablemen P06 Face Parrot Seam	11/78 to 10/79	3	1.4 (12)	10.7 (6)	0.48	0.06
F592	Return Stablemen P06 Face Parrot Seam	11/78 to 12/79	5	3.1 (16)	11.2 (5)	1.41	0.34
F593	Face Team (c.g.s) P06 Face Parrot Seam	11/78 to 12/79	0.4.9	3.0 (13)	11.6 (5)	1.23	0.43
F594	Face Team (prep shift) P06 Face Parrot Seam	11/78 to 12/79	1.4.7	1.2 (18)	8.4 (8)	0.49	0.17
F595	Intake Ripper W01 Face South Coal	10/78 to 9/79	1	1.6 (9)	9.0 (5)	0.82	0.09

Exhibit A3.2 *continued*

Mean Concentration by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
F596	Return Ripper W01 Face South Coal	10/78 to 9/79	7	4.9 (3)	9.0 (1)	2.59	0.85
F597	Advanced Heading Team W01 Face South Coal	10/78 to 3/79	No Advanced Heading				
F598	Intake Stablemen W01 Face South Coal	10/78 to 9/79	3	2.2 (3)	30.0 (1)	1.13	0.11
F599	Return Stablemen W01 Face South Coal	10/78 to 9/79	5	8.9 (6)	27.5 (4)	7.25	3.00
F600	Face Team (c.g.s.) W01 Face South Coal	10/78 to 9/79	0.4.9	5.3 (3)	13.3 (3)	3.96	1.01
F601	Face Team (prep shift) W01 Face South Coal	10/78 to 9/79	4	1.7 (19)	10.0 (4)	0.90	0.18
F602	Return Rippers (prep shift) W01 Face South Coal	3/79 to 9/79	7	1.9 (6)	10.0 (2)	1.11	0.24
F603	Intake Ripper P07 Face Parrot Seam	10/79 to 3/81	1	1.7 (24)	10.5 (11)	0.66	0.07
F604	Return Ripper P07 Face Parrot Seam	10/79 to 3/81	7	5.6 (21)	13.9 (15)	2.64	0.72
605	Intake Stablemen P07 Face Parrot Seam	10/79 to 3/81	3	2.3 (20)	22.1 (7)	0.91	0.10
606	Return Stablemen P07 Face Parrot Seam	10/79 to 3/81	No Return Stable				

Exhibit A3.2 *continued*

Mean Concentration by Occupational Group (Faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3) Resp. Dust	Total Dust	Ash	Quartz
F607	Face Team (c.g.s.) P07 Face Parrot Seam	10/79 to 3/81	0.4.9	4.8 (25)	19.9 (14)	2.18	0.52
F608	Face Team (prep shift) P07 Face Parrot Seam	10/79 to 3/81	1.4.7	1.4 (23)	11.6 (11)	0.74	0.14
F609	Intake Ripper W03 Face South Coal	4/80 to 12/80	1	1.0 (4)	9.0 (3)	0.45	0.04
F610	Return Ripper W03 Face South Coal	4/80 to 12/80	7	4.4 (5)	12.4 (5)	2.71	0.83
F611	Intake Stablemen W03 Face South Coal	10/80 to 12/80	3	2.9 (1)	39.0 (1)	1.31	0.12
F612	Return Stablemen W03 Face South Coal	4/80 to 12/80	5	5.1 (2)	17.0 (2)	3.07	0.90
F613	Face Team (c.g.s.) W03 Face South Coal	4/80 to 12/80	0.4.9	2.2 (6)	13.5 (6)	1.33	0.24
F614	Face Team (prep shift) W03 Face South Coal	4/80 to 12/80	1.4.7	1.0 (4)	9.8 (4)	0.60	0.10

Exhibit A3.2 *continued*

Mean Concentration by Occupational Group (non-faceworkers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
E 21	Officials All Districts, All Seams	to 3/81		0·9 (73)	10.2 (27)	0.67	0.37
E 62	E.U.G. Workers Parrot Seam	to 3/81		0.7 (396)	8.0 (45)	0.28	0.06
E63	E.U.G. Workers Kailblades Seam	to 8/76		0.9 (77)	13.0 (9)	0.37	0.03
E64	E.U.G Workers General to Pit	to 3/81		0.2 (191)	3.7 (30)	0.05	0.01
E65	Transport Workers Parrot Sections	8/79 to 3/81		1·3 (35)	8.6 (20)	0.62	0.08
E66	Transport Workers South Coal Sections	8/79 to 12/80		2·1 (29)	11·6 (11)	1·25	0·28

Mean Concentration by Occupational Group (surface workers)

OGSN	Description	Period	Sampling Location Code	Mean Concentration (mg/m^3)			
				Resp. Dust	Total Dust	Ash	Quartz
S.O.	Others Surface	to 3/81		0.3 (256)	2.0 (43)	0.09	0.02

HEAD OFFICE:

Research Avenue North,
Riccarton,
Edinburgh, EH14 4AP,
United Kingdom
Telephone: +44 (0)870 850 5131
Facsimile: +44 (0)870 850 5132

Tapton Park Innovation Centre,
Brimington Road, Tapton,
Chesterfield, Derbyshire, S41 0TZ,
United Kingdom
Telephone: +44 (0)1246 557866
Facsimile: +44 (0)1246 551212

Research House Business Centre,
Fraser Road,
Perivale, Middlesex, UB6 7AQ,
United Kingdom
Telephone: +44 (0)208 537 3491/2
Facsimile: +44 (0)208 537 3493

Brookside Business Park,
Cold Meece,
Stone, Staffs, ST15 0RZ,
United Kingdom
Telephone: +44 (0)1785 764810
Facsimile: +44 (0)1785 764811

Email: iom@iom-world.org