THE HISTORY OF PNEUMOCONIOSIS

A BRIEF REVIEW*

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The history of mining goes far back into antiquity. In prehistoric times men mined for salt, flint and ochre. Neolithic man seemed to have discovered that he could work freshly-mined flint, before it lost its water, much more easily than flint found on the surface, and perhaps that is why flint mines were found where flints are also found near or on the surface. E. L. Collis has suggested that the neolithic miner may have suffered from silicosis. The fact is that in at least two prehistoric bodies signs of pneumoconiosis were found and that signs of the disease were found in a number of Egyptian mummies. Collis' suggestion, in his 1915 Milroy lectures, that silicosis is the most ancient industrial disease, therefore rests on strong grounds.

In the days of Roman and Greek greatness metalliferous mining was conducted on a large scale, and the conditions were extremely hazardous and onerous. It appears that usually only the lowest type of slaves were employed. Justinian remarks that condemnation to mining is almost as severe as the death penalty, thus '*proxima morti poena metalli coercitio*'. There are many references in Roman and Greek writings to the arduous conditions and dangers of mining, particularly of silver and gold.

The earliest reference to protection against inhalation of dust is in Pliny's *Natural History*. He records that some miners used bladder skins to cover their mouths. Julius Pollux (124-192 A.D.) confirms this, and also refers to the use of bags for the same purpose (Legge, *Industrial Medicine*, 1936).

Agricola and Paracelsus

The dark age descended upon Europe, and it is only during the 16th century that we again find records of miners' diseases. Agricola and Paracelsus are our informants. Paracelsus, whose real name was Theophrastus Bombastus von Hohenheim, published his *Von der Bergsucht und anderen Bergkrankheiten* in 1534, and Agricola his *De re metallica* in 1556. Agricola, whose real name was Georg

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Bauer, was a physician, not an engineer, although his monumental work covers every phase of mining. At the age of 32, and for his time a highly educated man, he was appointed city physician at Joachimstal, on the Bohemian side of the Erzgebirge, situated in the middle of a flourishing silver-mining area. Agricola made a remarkably thorough study of every aspect of the mining in this area, and at the same time read widely on the subject in the Greek and Latin classics. In the preface to his book he remarks: 'I have omitted all those things which I have not myself seen, or have not read, or heard from persons upon whom I can rely.' We may accept his descriptions, and particularly those of diseases, as being entirely trustworthy.

It is interesting to note that in those mines, in Agricola's time, the working hours were 7 hours a day on 5 days a week. There were generally 3 7-hour shifts in the 24 hours, the remaining 3 hours being used in entering and leaving the workings. The night shift, which ran from 8 p.m. to 3 a.m., was only permitted by the authorities when there was pressing necessity. But Agricola also records that, while in some mines the miners are not allowed to work two successive shifts, it is allowed in other mines '. . . because he (the miner) cannot subsist on the pay of one shift as provisions grow dearer.' So the problem of 'cost structure' seems to have existed even 400 years ago!

It is Agricola's 6th book of *De re metallica* that is of special interest for our present purpose. In this he describes the diseases and accidents he observed among the miners. Especially interesting for us is his description of pulmonary diseases. He speaks of a disease of the lungs which produced 'suppuration' of the lung tissues, associated with emaciation. He recognized the role of dust in producing this disease, which seemed to have been very common and to have a high mortality. He, for instance, records that there were women who had married seven husbands 'all of whom this terrible consumption has carried off to a premature death'. He advised the use of respirators and efficient ventilation. Thus: 'On the other hand some mines are so dry that they are entirely devoid of water, and this dryness causes the workmen even greater harm, for the dust, which is stirred and beaten up by digging, penetrates into the windpipe and lungs and produces difficulty in breathing and the disease the Greeks named "Asthma". If the dust has corrosive qualities, it eats away the lungs . . .'

Paracelsus was a contemporary of Agricola. The son of a Swiss physician of a noble family, he was a great traveller and a man of independent ideas—a reformer by nature. He early revolted against the orthodox tenets accepted in medicine, basing his teaching not on the dicta of the ancients but on his own experience. As is usual, his heterodoxy gave rise to opposition from his conservative-minded colleagues, and later to frank persecution. He was forced out of Germany and wandered as far as Scandinavia. But his very misfortunes gave him opportunities for wide study and experience. Among these was the study of miners' diseases in Sweden, Denmark, Hungary and other parts. He appears not to have had any previous knowledge of miners' diseases, and therefore records only personal observations. These are not of any importance as regards silicosis, although very interesting to the student of the evolution of medical thought. The sole reason for mentioning Paracelsus is that he was seemingly the first European physician to recognize that the ailments of miners were occupational, for he states '. . . we must also have gold and silver, also other metals, iron, tin, copper, lead and mercury. If we wish to have these, we must risk both life and body . . .' That was an important step forward.

Seventeenth Century

In the 17th century several monographs appeared on miners' diseases, and among these a popular book for the guidance of miners by Martin Pansa, in which he speaks of mineral particles being deposited 'on the walls of the lungs'. There was also one by Stockhausen in which he defines 'Bergsucht' as a disease in which there is '. . . difficult breathing and short-windedness, together with a severe hard cough and marked hoarseness. Such affections commonly degenerate into a consumption and kill the individual'. (Legge, *op. cit.*). This is a recognizable description of pneumoconiosis. He also records that very large quantities of dust were created in calcining rock to enable easier breaking, and also in powder blasting. It was in this century that the Father of Industrial Hygiene, Bernardino Ramazzini, was born and made his great contribution to this subject. He recognized the existence of a miners' lung disease and advised respirators and ventilation.

Nineteenth Century

Throughout the 18th and 19th centuries the various diseases to which miners were especially prone were studied and written about. Thus Thomas Beddoes, in an essay published in 1799, remarks that inhalation of dust may lead to pulmonary consumption.

An important publication in 1832 was *The Effects of Arts, Trades and Professional and Civic States and Habits of Living on Health and Longevity* by Dr. Charles Turner Thackrah of Leeds. It was the first book in English, by an Englishman, on industrial medicine. To us it is of interest because Thackrah's book gives the first definite information on the mortality and morbidity of British miners. In it is the first mention of what was later recognized as miners' nystagmus. He pointed out that work is dangerous in sandstone, but not in limestone. The following is a significant passage in explanation of this difference in hazard: '. . . that the latter (limestone) is full of vertical and other fissures, which allow the superincumbent beds of water to percolate through the roof of the mine; whilst the sandstone strata, which are impervious to water, preserve the mine quite dry; consequently the minute particles of rock formed by blasting or the pickaxe are kept in a dry state within the sandstone mine, forming as it were an atmosphere of dust which the miner is constantly inhaling. In the limestone mine the particles, on the contrary, are laid as they are formed by the constant oozing, dropping and splashing of the insinuating water.' He states that the conditions were so bad that even though miners worked only a 6-hour day few survived beyond the age of 40, the deaths being chiefly due to affections of the lungs and bowels. So far as I can ascertain, Thackrah was the first te mention the special danger of sandstone.

For South African miners particular interest attaches to Farr's analysis of the mortality of Cornish metal miners (W. Farr, *Mortality of Miners*, 1843-53 and 1860-62: *Vital statistics*, 1885). In brief, Farr showed that until the age of 35 there was a marked progressive increase of the death rate among the miners, rising from about a 50% excess in the age-group 35-45, to over double in the age-group 45-55.

over treble in the group 55-65, and over double in the group 65-75. He also showed that deaths from pulmonary diseases, whilst nearly the same for miners and non-miners in Cornwall in the age-groups 15-25 and 25-35, rapidly rise to nearly double in the 35-45 group, to nearly 5 times in the 45-55 group, to over 8 times in the 55-65 group, and to about 5 times in the 65-75 group. From these data Farr justifiably concluded that pulmonary diseases resulting from the conditions incident to mining are the chief causes of the high mortality.

The importance of these findings to South Africa lies in that many of the earlier miners in the South African gold mines came from Cornwall, after having worked for varying periods in the mines there. Many of these succumbed to silicosis with and without tuberculosis after relatively short periods of work in South Africa. Farr's statistical analysis is paralleled by other statistics published up to the end of the 19th century, and his main contention is, of course, now placed beyond doubt; that is to say, that there is a high mortality associated with mining in hard rock.

Greenhow

The demonstration that silica is the most important harmful dust originated with Dr. E. H. Greenhow, the first medical inspector of factories in England, who in 1864 identified particles of silica in the lungs of grinders by the use of polarized light. He was probably the first to use polarized light for this purpose.

In concluding this section, it may be of interest to say that the introduction of the term 'silicosis' is ascribed to an Italian named Visconti by another Italian, Rovida, who in 1871 published a paper on a case of silicosis. The term 'pneumonokoniosis' was introduced by Zenker. It is now generally abbreviated to 'pneumoconiosis'.

SILICOSIS IN SOUTH AFRICA

In their paper presented before the International Conference on Silicosis, held in Johannesburg in August 1930, Drs. L. G. Irvine, A. Mavrogordato and Hans Pirow divided the history of silicosis on the Witwatersrand mines into 4 periods:

1. The initial period of gold mining on the Rand, from 1886 to 1899, i.e. from the date of the first discovery of the reef until the outbreak of the South African War. One may fairly call this period, so far as local conditions are concerned, a period of ignorance of the dangers of silicosis.

2. The period of first realization of the menace of silicosis and of tentative preventive measures, from 1901 to 1910.

3. The period of the introduction of a legal system of compensation for the disease, and of the trial of more systematic preventive measures, from 1911 to 1916.

4. Finally, what one may call the 'present-day' system of fully systematized measures of prevention, detection and compensation, from 1916 to the present time.

The last period can be taken as still continuing.

In the late 1880s, after the discovery of gold on the Witwatersrand, there was scepticism about the future; the lay-out of the mines was rather primitive and proved a handicap for the deep-level workings which had to be undertaken in the late '90s, when the true value of the deeper deposits was more fully appreciated. Until then a number of workings were open-cast, and the underground mines, such as they were, were in oxidized and comparatively soft and friable ground. Most drilling was done by hand; the dust was consequently of large size and probably of low silica ratio, and the miners were thus exposed to relatively low hazard from dust. Most miners were immigrants from Europe with previous mining experience, and a large proportion were Cornishmen. In about the middle '90s the oxidized zone was passed. The dry drilling, which now was done by machine as well as by hand, and the blasting, created a great deal of dangerous dust. The 'cut' and 'round' were blasted separately during the shift, at all hours, and men returned to face into clouds of dust and fumes. The danger was not fully realized. It was only after the South African War, in 1901, that the menace was pointed out in the Transvaal Government Mining Engineer's report for the 6 months ending December 1901. He recorded that, of 1,377 machine men employed before the war, 255 were known to have died between October 1899 and January 1902.

In December 1902 Lord Milner appointed a '*Miners' Phthisis Commission*', which issued a report in 1903. They could only examine 1,201 miners, for many refused to be examined; of this number 15·4% were found to be suffering from miners' phthisis, and another 7·3% were considered suspect. The rate was probably higher, for it is reasonable to assume that among those who refused examination there was a larger ratio of miners' phthisis cases. On the one hand, many of the sufferers had probably started their disease in Cornwall. On the other hand, Haldane, Martin and Thomas, in their 1904 report on Cornish miners, state that many of the deaths of Cornish miners were among men who had worked on the Witwatersrand. The Transvaal Commission found that among those rock-drill miners who worked only in the Transvaal the average working period before becoming affected by phthisis was under 6 years. The Haldane report states that Cornish miners who worked only in the Transvaal contracted the disease in an average of 4·7 years.

In 1905 regulations were issued aimed at the suppression of dust. The slogan of the time was: 'Dry mining must, as far as possible, become wet mining.' The regulations provided that sprays or water jets were to be used with machine drills: that broken ground was to be damped down and that men should not be allowed in workings until the air was cleared after blasting. There were also regulations designed to provide more efficient ventilation. Unfortunately these regulations were not carried out with the necessary thoroughness, largely because of the conservatism of the miners, although considerable improvement was effected. The danger of blasting dust was not appreciated, and nothing much was done to control it.

A *second Commission* was appointed in 1907. Its report was issued in 1910. Evidence given by Drs. Macaulay and Irvine before this Commission shows that in the period 1905-07 the mortality rate among miners was sixfold that of other adult males on the Witwatersrand.

As a result of the Commission's recommendations, *new regulations* were issued. Among the important new provisions were: That a water-blast was to be used to control dust from blasting: improved ventilation standards: and the placing of the responsibility on underground officials for the carrying out of preventive measures. The effect of these measures, backed probably by more general appreciation of their importance and of the real menace of silicosis, is reflected in the dust content of the air of a typical mine sampled at the bottom of an upcast shaft. In September 1911 it varied during the period from 9 a.m. to 5.15 p.m. between 80 mg. and 280 mg. per cubic metre; in April 1912 it was between 14 and 39, and in September 1912 between 0·2 and 17·1. Sprays were used in the last two periods and not in the first.

At the close of 1910, 84 mines on the Witwatersrand employed over 10,000 Europeans and 120,000 Natives; they worked 5,500 'dry' rock-drills at a maximum depth of 4,500 feet and an average stoping depth of 1,100 feet, and hoisted 27,000,000 tons of rock in the year.

In 1911 *a Commission* was appointed, consisting entirely of medical men, to enquire into the prevalence of miners' phthisis and tuberculosis on the mines, and to advise from the medical point of view on compensation. The Commission medically examined 3,163 miners; 326 were radiologically examined by the late Dr. A. H. Watt. This was the first time that radiological examination was used on such a scale for the diagnosis of silicosis. They found definite disease in about 26% and doubtful disease in an additional 5·5%. The average duration of work of those affected was 8·2 years. For men on rock drills it was only 6·1 years.

Miners' Phthisis Act

On the basis of this Commission's report, the 1912 Miners' Phthisis Act was passed. This, the first Act providing compensation for miners' phthisis, was followed by a long series of amending and consolidating legislation, culminating in the 1956 Act.

The 1912 Act provided for the contribution by miners of 2½% of their wages to the compensation fund for silicosis. The compensation was limited to a maximum total in each of the two stages of miners' phthisis defined in the Act. All these provisions were profoundly modified by subsequent legislation, which progressively prescribed higher rates of compensation, widened the scope of entitlement to it, and abolished contributions by the miners.

The medical examination before employment, and for benefits, was carried out by a panel of medical practitioners in the case of Europeans and the Mines' Medical Inspector in the case of Natives. The panel system not only resulted in great lack of uniformity in the standards of certification for fitness to work underground and entitlement to compensation, but also in a substantial number of fraudulent claims, mostly by substitution.

During the period 1912-16, 6,472 European miners were awarded compensation, and of these 3,235 were certified as being in the 'second stage', which was defined as 'a miner who has contracted silicosis in a marked degree, and whose physical capacity for underground work is thereby seriously and permanently impaired'. It was the opinion at the time that the 'production rate' was about 900 cases a year among the approximately 10,000 miners—compared with the present 'production rate' of about 80 per 10,000. (Note: 'Production rate' means the ratio of cases of silicosis certified during the year to the average number of men at work.)

Pneumoconiosis Bureau

In 1916 the medical examination of miners was placed in the hands of the Miners' Phthisis Medical Bureau (now called the Pneumoconiosis Bureau), staffed by full-time medical officers. Periodical examinations were instituted including radiological examinations at each visit. Measures were introduced to prevent fraudulent practice such as substitution.

A most important regulation was introduced in 1917. This prohibited blasting the 'cut' and 'round' separately during one shift, and provided that blasting shall take place only once in 24 hours, at the end of the day shift, and that no person shall enter the mine until after a period subsequent to blasting which is fixed by the Inspector of Mines. Other provisions, important from the preventive angle, were the regulations concerning adequate ventilation, the appointment of a dust and ventilation officer on each mine, and the permitting of machine drilling only with axially water-fed drills. These regulations were amplified and amended from time to time in the light of further knowledge and experience.

Methods of dust determination were improved, the chief change being from the gravimetric to the particle-counting methods.

Lest the preceding brief review give the impression that preventive measures were forced by Government on more or less reluctant managements, it must be here recorded that the managements, both as regards the directorates and technical staffs, at least in the 42 years during which I have been associated with the Witwatersrand mining industry, have whole-heartedly and eagerly cooperated in the study and practical application of dust-control measures, and in this the Chemical, Metallurgical and Mining Society of South Africa has played a very worthy part.

Review of Results

At this point it might be as well to review the results of 40 years intensive endeavour in the campaign against silicosis in South Africa. Long statistical tables are a vexation to such a meeting as this. I shall therefore present this phase of my submission by means of 3 fairly simple graphs.

The first graph (Fig. 1) presents the mean ages of European miners who worked in the period 1918 to 1953. It can be seen that there is an upward trend.

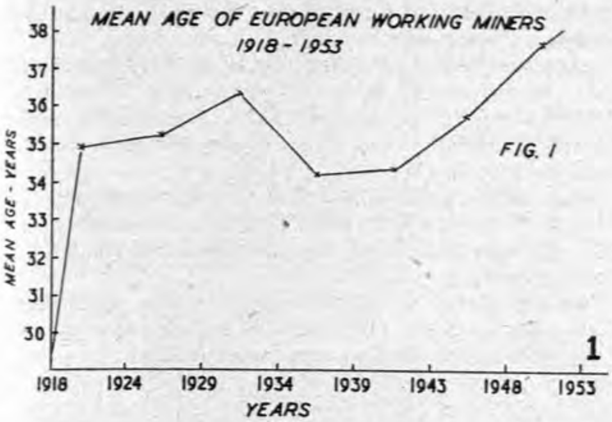
The second (Fig. 2) presents the mean ages of European miners at the time of their certification as having silicosis. Here too there is a marked upward trend, from 39·09 years to 53·12 years. The standard deviation is about 8·5 years.

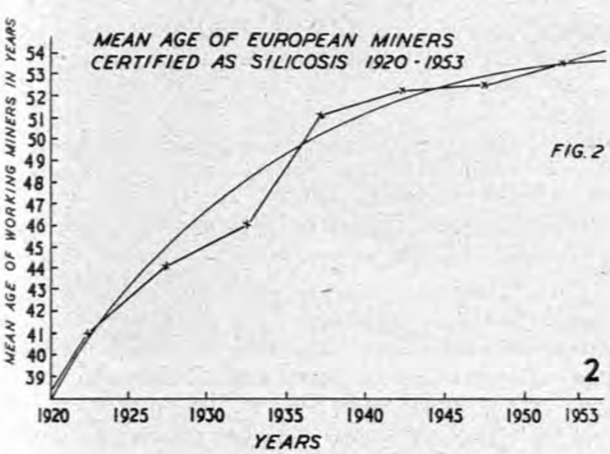
The third (Fig. 3) presents the 'production rate' of silicosis. There is a definite downward trend, except for the large peak due to the introduction of the ante-primary stage and another smaller peak which coincides with the introduction of 'pulmonary disability'.

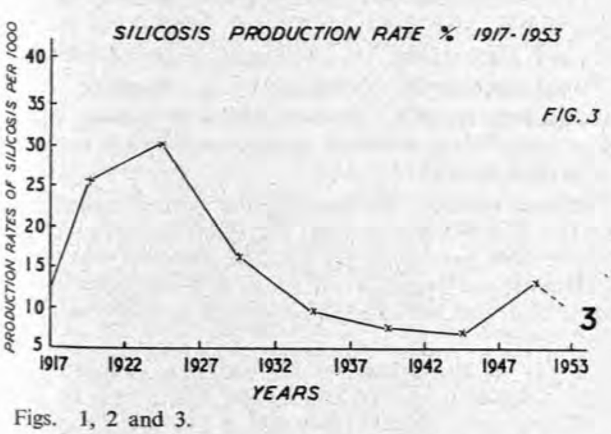
These graphs taken together can, I think, safely be stated as demonstrating that the prophylactic measures adopted—not the least among them the pre-employment examination of prospective workers—have very considerably reduced the hazard of silicosis.

RECENT RESEARCH

I shall close with a very brief review of a few points which may be of interest to you. The present knowledge of the aetiology and pathology of pneumoconiosis have been admirably presented to us by Drs. Walters, Webster and







Figs. 1, 2 and 3.

other speakers. I shall therefore confine myself to a few subjects not touched upon by them.

Size of Silica Particles

Animal experiments seem to show that the smaller particles are the most dangerous in the production of silicosis. This may be partly due to their more rapid solubility, and it is what we should of course expect if we accept that fibrosis is produced by the solution of silica particles lodged in the lung.

Another reason, however, for the greater danger associated with the smaller particles is that the time they remain suspended in the air is in inverse proportion to their size. H. S. Patterson (*Dust*, issued by the Transvaal Chamber of Mines, 1936) gives the free falling times for particles as follows:

Size in microns	*Time (in minutes) to fall 1 foot*
0·25	590
0·5	187
1	54
2	14·4
5	2·5

Assuming, therefore, a given number of silica particles in the inhalable air, the size frequency distribution becomes a matter of great importance in the pathogenicity of that dust.

It is also well to bear in mind that the greater the energy applied in fracturing a hard rock, the smaller will be the particle produced.

In a paper contributed to the Institution of Mining and Metallurgy on 15 June, 1939, H. S. Patterson discusses the size-distribution of particles produced in several kinds of rock by various processes of drilling. For the present purpose it is only necessary to summarize his findings thus:

1. The harder the rock the greater the number of small particles (less than 1 micron, 90%) with the same method of wet drilling.

2. Hard rocks produce more dust than soft rocks with the same method of wet drilling.

3. Dry drilling with a machine drill produces similar size frequency distribution in both soft and hard rocks, but the coarser particles predominate and coagulation of particles occurs.

4. In hand, hammer and jumper drilling the number of particles is small, the particles are larger, and they tend to coagulate.

5. When rock containing both hard and soft constituents is drilled, larger particles will tend to be produced from the softer constituent and smaller particles from the harder constituent.

Preventive Measures

From what was said, it follows that at present we must direct our attention to minimising dust, especially fine dust, in the air respired by the worker, and that we should be justified in regarding with some scepticism the ability of water to remove from the air the dangerous very fine particles.

Dust removal by means of suction applied at the drilling orifice does not seem at present to offer a satisfactory solution in practice, at least not in the conditions prevalent on the Witwatersrand gold mines.

At ore bins, filtration can be, and is, applied very effectively by various filters and also by electrical precipitation.

Blasting dust can be partly dealt with by sprays, but its danger must be neutralized further by ventilation and non-return of miners until the air is freed from dust as well as toxic fumes, as is laid down in Mining Regulation 158.

The work of Kettle, King and others has shown that in the test tube the solution of silica can be inhibited by several substances and that, of these *aluminium* is very effective.

The Canadian workers, Denny, Robson and Irwin announced that silicosis can be prevented by the inhalation of powdered metallic aluminium. For some years experiments were being conducted by Gardner and his associates at Saranac with hydroxides of aluminium. They also found that colloidal hydrate of aluminium could protect animals against fibrosis caused by quartz. The excessive use of this substance, however, caused 'progressive infection with attenuated tubercle bacilli'. (Gardner—Donald E. Cumings Memorial Lecture, 11 May, 1944.)

Using metallic powdered aluminium, Gardner and his co-workers failed to confirm fully the results obtained by the Canadians. This may have been due to some fault in technique. They failed to obtain effective prophylaxis against quartz, although there was a delay in the production of lung fibrosis.

Experimental work on the effect of aluminium on the production of silicosis in animals has since been continued at Saranac with equivocal results. Experimental work of a similar nature has just been concluded at the South African Institute for Medical Research, and the results are now being studied; a report may be expected in due course.

Masks are now commercially available which filter out fine dust without unduly hampering respiration. These masks have, however, a very limited field of usefulness in mining, because industrial workers are unlikely to wear them effectively throughout a working shift.

Recently the use of fine *aerosols* has been proposed. This is used to some extent in the Congo copper mines. As is the case with aluminium, the data available are far from being convincing.

We are therefore left with the one sure prophylactic: Keep fine dust down to a minimum, and keep that minimum away from the respiration zone of the worker.