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MODERN VIEWS ON SILICOSIS¹

By W. E. COOKE, M.D., F.R.C.P., D.P.H.

From the Pathological Dept. Wigan Infirmary

(With Plates I-IV)

INTRODUCTION

SOME months ago Prof. M. J. Stewart (1933) gave an address on silicosis in which he covered the whole of the pathology of the various types of the disease. It may seem strange, therefore, that the same subject should be chosen for discussion so shortly afterwards. My apologia is that silicosis presents many-sided problems and that since Prof. Stewart's paper appeared the claim has been ventured that the cause of silicosis has been demonstrated. Discussions have been taking place during the past twelve months at the Institution of Mining and Metallurgy—discussions stimulating in themselves and showing the necessity of further research along old and new avenues.

Therefore it may be useful to go over a few of the salient features common to all the group of industrial pneumoconioses. In doing so, the obvious may sometimes appear to be stressed, but elementary principles are apt to be forgotten or neglected in discussions on etiology.

Under the general designation "Silicosis" are included the pneumoconioses of gold and other metalliferous miners, stone-masons, file-grinders, potters, etc., and the fibroses of coal-miners, haematite miners and asbestos workers. Whether the term is adequately or even approximately descriptive is a matter outside this discussion.

"Silicosis" was defined by the International Congress on Silicosis in 1930 (1930) as a pathological condition of the lungs due to the inhalation of silicon dioxide (SiO_2), and to produce the disease, silica must reach the lungs in a chemically uncombined state.

The definition was unequivocal and was acceptable to the two schools, one of which believed that chemical action was the more important and the other that the hardness, sharpness and insolubility of quartz particles caused the lung damage by mechanical action.

In 1933 W. R. Jones (1933) exploded a mine beneath both schools. He stated that free silica (SiO_2) played a very small part, if any at all, in the production of silicosis. The villain of the piece, he claimed, was sericite—a hydrated silicate of aluminium and potassium. He based his opinion on the results of examination of the minerals obtained from lungs of many types of workers by

¹ A paper read at the Liverpool Medical Institution on October 25, 1934.

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7, 1st ed. p. 59.

3rd ed. pp. 405-6.

6th ed. p. 798.

—Ed.)

"sliming" with strong nitric acid. He states: (1) the bulk of the mineral residue obtained from silicotic lungs consists of sericite, which mineral is present in abundance in all the rocks and materials which give rise to dust in the working processes; (2) the number of quartz particles is very small compared with the countless fibres of sericite; and (3) rocks which contain a relatively small percentage of quartz, but which contain fibrous silicates such as sericite and sillimanite, give off dust which has caused a large number of silicosis cases.

He hastens to deny that minute particles of quartz could not, under any circumstances whatever, enter the lungs in sufficient numbers and cause silicosis, but insists that the fibrous silicates, sericite, sillimanite, and tremolite are of far greater importance than quartz, and, as regards free silica rocks, the cryptocrystalline forms, such as chert and flint, are more dangerous than the crystalline quartz.

That sums up the various views on the subject to-day. The chemical theory has been mentioned, and while the solubilities of silica or the silicates in plasma have not yet been ascertained, there are certain known facts concerning silica that appear to have a bearing on the discussion.

SOLUBILITY OF SiO_2

Silicon is, next to oxygen, the most abundant element in nature, and although it does not occur free, its compounds, silica and silicates, make up 60 per cent. of the lithosphere.

Silica is present in most river, well and spring waters, in some cases, as in the volcanic springs of Iceland, to the extent of 0.52 parts per 1000. Many petrifying springs owe their properties to solutioned silicic acid, and, of course, the silica of diatom valves and sponge spicules must be extracted from their environment.

Mellor (1925), quoting S. Calderon, states the solubility of silica in distilled water to be 0.01 part per 100, increased in the presence of oxygen and CO_2 , nitric and sulphuric acids. The size of the grain has a remarkable effect on the solubility.

Mellor (1913) gives the following interesting results. He took powdered rock crystal (quartz) and flint with a 15 per cent. solution of KOH and found:

Average diameter of grain	...	...	...	165 μ	32 μ
Rock crystal dissolved %	...	...	...	0.96	6.40
Flint dissolved %	...	...	...	2.52	12.10

And Lunge and Schoror-Tscherny (1894) found with a sample of powdered quartz the amount dissolved after two hours' action was:

	KOH solution %		NaOH solution %	
	5.0	10.0	5.0	10.0
Quartz dissolved %	16.84	21.36	16.20	19.80

In thirty-two hours all was dissolved by a 15.0 per cent. solution of KOH, NaOH taking 2 hours longer.

As mentioned above, but Tideswell (1934) records from 3.0 to 6.0 per cent. silica.

LAR

We are dealing now particles obtained by try. The numerous papers is the minuteness of the silica particles of a diameter between 1 and 8.5 μ . Only exceeding 8.5 μ , and the repeated, and it must be in lungs are of the order in diameter.

When mineral residue numerable particles are light. There must be, therefore, of silica in silicotic lungs.

It has become usual to to 5 μ in diameter and respirable. This is very n

The minerals mentioned acids and are silica and contain, in addition, they present a far different picture.

The average diameter 250 μ (Miller, 1893) and 3 therefore, any anatomical They can and in fact do are a marked feature in the asbestos workers, and are normal adult lungs.

The Lancashire coal ste. clarain, durain and fusain. red amber in colour and each other when occurring. opaque and angular, is eas

In digests of coal-min of coal are present in large of the spicules varies from

The spicules are sometimes in the figures, which I believe

) the bulk of the mineral sericite, which mineral is which give rise to dust in particles is very small compared with rocks which contain a relatively small amount of fibrous silicates such as asbestos. This has caused a large number of

quartz could not, under any circumstances, cause the formation of, sillimanite, and tremolite. In regards free silica rocks, the more dangerous than the

to-day. The chemical theory of silica or the silicates in the light of known facts concerning them.

element in nature, and silica and silicates, make up

waters, in some cases, as in 1-52 parts per 1000. Many of the silicic acid, and, of course, the silicates must be extracted from

solubility of silica in distilled water in the presence of oxygen and CO₂, has a remarkable effect on the

results. He took powdered silica and a solution of KOH and found:

65μ	32μ
96	6.40
52	12.10

with a sample of powdered silica and a solution of KOH, the results were as follows:

NaOH solution %	
5.0	10.0
16.20	19.80

per cent. solution of KOH,

As mentioned above, the solubilities in plasma have not been worked out, but Tideswell (1934) records the extremely important observation that he found from 3.0 to 6.0 per cent. of the total silica in six silicotic lungs to be colloidal silica.

LARGE MINERAL PARTICLES IN LUNGS

We are dealing now with the microscopical characters of the mineral particles obtained by tryptic digestion.

The numerous papers on the mineral content of lungs stress one feature. It is the minuteness of the fragments. McCrae (1913) found 70 per cent. of the silica particles of a diameter less than 1μ, and the remaining 30 per cent. varied between 1 and 8.5μ. Only a negligibly small number of particles had diameters exceeding 8.5μ, and the longest was 10.5μ. His observations have been repeated, and it must be accepted that the particles of silica and silicates found in lungs are of the order of 0.1-5μ, with occasional larger fragments 10-20μ in diameter.

When mineral residues are examined by dark ground illumination innumerable particles are seen which are invisible by transmitted or polarised light. There must be, therefore, enormous numbers of ultra-microscopic particles of silica in silicotic lungs.

It has become usual to speak of "respirable" dust to indicate particles up to 5μ in diameter and to discard particles over 10μ or even 5μ as non-respirable. This is very misleading.

The minerals mentioned above are obtained by digestion of lungs with strong acids and are silica and silicates. The deposits by tryptic digestion (1932) contain, in addition, those minerals which are soluble in strong acids, and present a far different picture.

The average diameter of lung alveoli is given by different observers as 250μ (Miller, 1893) and 300-500μ (McDowell, 1933). There does not appear, therefore, any anatomical reason why larger particles should not enter them. They can and in fact do so. Large fragments 20-100 or more micra in length are a marked feature in the trypsinised deposits of the lungs of coal-miners and asbestos workers, and are constantly present in fewer numbers, of course, in normal adult lungs.

The Lancashire coal seams are composed of varying proportions of vitrain, clarain, durain and fusain. Of these, vitrain, clarain and durain are yellow to red amber in colour and doubly refractile, but cannot be differentiated from each other when occurring in small fragments in lung dust. Fusain, black, opaque and angular, is easily recognised.

In digests of coal-miners' lungs particles of fusain and other constituents of coal are present in large numbers. Pl. I, figs. 1-14 are examples. The length of the spicules varies from 22.5 to 85.0μ.

The spicules are sometimes covered with a golden yellow deposit as those in the figures, which I believe to be a colloidal combination of tissue proteins

and silica adsorbed on to the insoluble mineral. These bodies are found in alveoli and in fibrosed and necrotic areas. Pl. II, figs. 1 and 2, illustrate them in fibrosed areas, and also illustrate that the golden yellow material occurs in clumps without any apparent nucleus.

The dust in chrysotile asbestos works—before the days of exhaust ventilation—consisted of asbestos fibres together with multitudes of black iron-containing fragments which appear as part of the fibre itself (Pl. II, fig. 3). These particles were present in the lungs of the workers in the dusty processes of manufacture. They are illustrated in Pl. II, figs. 4 and 5. Fig. 4 shows the large black fragments in a fibrotic area and Fig. 5 a large particle 360μ in length in a necrotic area of lung.

In tryptic digests of asbestos workers' lungs there are, in addition to asbestos fibres and these black particles, myriads of "bodies" which are composed of a central core of asbestos fibre covered with the same, or similar, golden yellow material as are the fusain spicules in coal-dampers. Their shapes and sizes are legion and are now familiar to everyone. The two illustrated in Pl. I, figs. 16 and 17, are examples of the longer forms. The upper one is 13μ in length and the lower 12μ . The colloidal coating of this has been fractured and shows the fine central asbestos fibre base. This coating is soluble in strong acids and alkalis. Pl. I, fig. 18, shows a fibre under polarised light after the body had been treated with strong nitric acid.

We know little about the golden yellow material. It withstands prolonged trypsinisation and a considerable degree of heat and gives the Prussian blue reaction for iron. It is not birefringent nor does the X-ray diagram give a clue to its composition.

It is possible by repeated trypsinisation and washings to obtain the bodies from asbestos lungs in a pure state. The bodies so obtained were analysed by T. H. Byrom, F.I.C., with the following result:

Organic matter	%
Inorganic matter	67.80
	32.20

The composition of the dust was

Free silica	5.45
Combined silica	21.10
Total silica	26.55
Ferrous oxide	79.55
Magnesium oxide	2.55
Calcium oxide	Nil
Alkali	0.80

The chrysotile in which woman worked contained 40 per cent. of combined silica, 41 per cent. of magnesium oxide and 2.8 per cent. of ferrous oxide.

No free silica is present in chrysotile nor in the mother rock associated with it. But Ross (1921) states that chrysotile asbestos is attacked by very weak acids with the exception of the bases—chiefly magnesium and calcium—and have

almost pure silica. It is probable that some chemical account for the free silica.

The large percentage of iron salt in chrysotile is not solutioned. But the iron also gives an intense haemoglobin.

Two conditions—presence of silica and presence of protein—being section and a fibre.

The bodies are present in apparent clumps in the lung digest. The bodies are scattered in the lung digest. The bodies are polarised light. The bodies are encountered as well and 11).

An interesting present in asbestos lungs of the lungs and traces of silica. The reason of this cases.

Large mineral present in mechanical damage. Minerals may be found in the lungs. (Cambridge University Press, 1921).

Minerals

As mentioned above, the bodies are birefringent, but the ashing to which the quartz, sericite, or feldspar. As the bodies are a world of

Birefringence

These bodies are found in
Pl. I and 2, illustrate them
yellow material occurs

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21.10
26.55
70.55
2.55
Nil
0.80

ed 40 per cent. of com-
2.8 per cent. of ferrous

ther rock associated with
, attacked by very weak
and calcium—and leave

almost pure silica without destroying the appearance of the fibre. It is possible that some chemical action has taken place within the lungs which would account for the free silica in the analysis.

The large percentage of iron in the ash is also remarkable. Possibly the iron salt in chrysotile is insoluble and remains after the Mg has been solutioned. But the golden yellow material of the bodies found in coal-miners also gives an intense Prussian blue reaction. The iron may be derived from haemoglobin.

Two conditions seem necessary for the formation of the bodies, viz. the presence of silica or soluble silicates and spicules of insoluble mineral, and the presence of protein. But masses of the golden yellow material are present in lung section and digests without any discernible nucleus, as pointed out above.

The bodies are not confined to asbestosis and silico-anthraxis, but are present in apparently normal lungs. Not very rarely both types are found in one lung digest. I have found them in general labourers, gas-workers, mill-hands, seamen, house-wives, dock labourers, haematite workers and fitters. The digests of these lungs all showed more silica particles than normal by polarised light. In addition, diatoms and fragments of Foraminifera may be encountered as well as unclassifiable particles (Pl. IV, figs. 4, 5, 6, 7, 8, 9, 10, and 11).

An interesting fact may be recorded here. These bodies are consistently present in asbestosis, usually present in fewer or greater numbers in miners' lungs of the Lancashire coalfields and less frequent or absent in the silico-anthraxis of South Wales. In the silicosis of stone-masons, file-grinders, haematite-miners and Cornish tin-miners they are extremely rare, or absent. The reason, I think, is that long spicules of mineral are rarely present in these cases.

Large mineral particles do then reach the alveoli. Whether they cause much mechanical damage when they are present in the numbers found in coal-miners may be debatable. The retention of coal dust in quantities sufficient to cause anthracosis seems to occur only in the presence of excessive amounts of silica (Cummins and Sladden, 1930; Cooke, 1932, 1932a). It is important to bear this in mind, because it has been suggested that sericite acts mechanically.

MINERALS OBTAINED BY NITRIC ACID DIGESTION

As mentioned above the vitrain, clarain and durain constituents of coal are birefringent, but these are destroyed by the action of strong nitric acid and the ashing to which the lung residues are subjected. The remaining minerals are quartz, sericite, rutile, zircon, etc., but we are concerned only with quartz and sericite. As the birefringence of minerals is of great importance in the study of silicosis a word on the subject is necessary.

Birefringence. If the visibility of a transparent particle is increased when

the light has passed through crossed nicol prisms, the particle has two indices of refraction and possesses the property of birefringence. The greater the difference between the two indices (ω ordinary index, ϵ extraordinary index) the more is the visibility of the particle increased by polarised light. For example, the ω index of quartz is 1.544 and the ϵ index 1.553, the difference being 0.009, which is the measure of its birefringence.

	Refractive index	Birefringence
Quartz	1.543	0.009
Sericite	1.59-1.65	0.042-0.06
Canada balsam in xylene	1.524	
Canada balsam dried hard	1.54	
Gilson's euparal	1.483	

A good example of birefringence is seen in Pl. III, figs. 1 and 2, illustrating one of the unclassifiable bodies found in lungs. It is 240μ long and embedded in a mass of fibrous tissue in a coal-miner's lung. Fig. 1 was taken by transmitted light, and Fig. 2 between crossed nicols. The substance in the body is much more brilliant in Fig. 2, showing that it is doubly refractile.

The above table shows that the birefringence of sericite is $4\frac{1}{2}$ to nearly 7 times that of quartz. To give maximum white polarisation a piece of quartz must be $4\frac{1}{2}$ to 7 times the thickness of sericite of minimum size to give the same white polarisation.

As the refractive index of Canada balsam is very nearly that of quartz thin flakes of that mineral may not be visible at all when mounted in this medium. Gilson's euparal has a much lower refractive index and is, I think, the best mounting medium for permanent specimens of lung sections and digests. Quartz particles are certainly more easily seen.

Sericite. Secondary white mica or sericitic mica is hydrated silicate of aluminium and potassium ($K_2AlO_3 \cdot 6SiO_2 \cdot 2H_2O$) formed by the mineralogical transformation of potash felspar ($KAlSi_3O_8$). The name sericite is given when the white mica occurs in fine needles. Pl. III, fig. 3 (photo taken between crossed nicols), represents a felspar crystal in granite undergoing transformation into sericite. The average diameter of these fibres is 20.8μ . When rock containing these fine needles is drilled they are given off in clouds, and being extremely small and light remain in the atmosphere long after the heavier particles of the dust have settled. The section is of the granite near the lode in a tin mine in which silicosis is said to be fairly common.

Pl. III, fig. 4, represents a potash felspar crystal in which the secondary mica appears as flakes (average diameter 105μ). The specimen is from granite near the lode in another tin mine a few miles away from the first. Silicosis is said to be rare in the workers in this mine. (The manager of the first mine told me he could tell the men who would get silicosis when they started work. They are of Spanish descent with bad tuberculous family histories.) These granites contain a large percentage of quartz.

In Lancashire the mudstones and shales of the mines contain sericite in abundance. Pl. III, fig. 5, shows a section of a Lancashire shale (photo taken

between crossed nicols) of sericite. Pl. III, fig. 6 (return airway of a Lancashire drilling in shale was taken) a fragment of quartz. The light needles and flakes

It is the custom in Lancashire mudstone.

Sericite and quartz. The sericite fibre is very small in depth— 0.5 cubic μ . The thickness of Pl. IV, fig. 1, is 0.5 and would contribute to the fibres would be very small in grain of quartz. Jones silica than sericite but the fibres of sericite in the action of sericite fibres quartz, is out of all proportion remembered, too, that the acid) from every siliceous stone-masons, potters, &c.

Our results are quoted in (1916) in 1916 were very refractile particles seen at first surprising, but in lung residues and in repeated their work in fig. 2, shows a section of point out in their section micrographs. The first was the first to publish (light.) The second, the third that in the advance the newly establishing

On examination by the particles are quartz dark marked, the coverslip in alcohol and dried; the rest of the tissue. The drops of strong nitric acid repeated for three days be seen that there are appeared in the section.

quartz. Watkins-Pitchford's and Mair's conclusions were that the mineral contents of Rand silicotic lungs were identical, physically, chemically, and in the numerical ratios of the particles of quartz to that of particles of accessory polarising mineral, with the finer portions of Rand mine dust. Quartz particles were, of course, by far the most numerous. They add that there was no indication of physiological selection of particles except in regard to size. It would have been strange if there had been, and we have seen that even size does not very much matter—within wide limits.

Our observations on the residues of lungs of several stone-masons, a file-grinder, a Cornish miner and a sand-blaster, lead to the conclusion that they are composed almost entirely of quartz, sericite fibres being comparatively rare. In these residues, mounted in euparal, innumerable minute thin scales of quartz are seen far outnumbering all the other birefringent minerals.

In Lancashire miners' silicosis is a very rare disease. It is axiomatic that workers in difficultly soluble dust must have traces of their occupation implanted in their lungs. Every underground worker has a larger proportion of silica in his lungs than the normal 3.5 per cent. of lung ash. In this case the predominant silica compound is sericite, because it is present in the dust of the shales and mudstones of our coal measures and in the stone dust used in many mines to check explosions. The other components of mine dust—fusain, vitrain, clarain and durain, microspores, and unclassifiable bodies and a few quartz grains—are also present, and as an index of silica action, the golden yellow material of the curious bodies. In the residues obtained by nitric acid sericite is naturally predominant. On examination of the lungs of a pit pony that had been down the mine for seventeen years sections and nitric acid digests showed quantities of sericite fibres, but there were no silicotic nodules nor other evidence of silicosis. The alveolar septa, in parts, showed a small amount of fibrosis, as did the peribronchial tissue, but the lungs were favourably comparable with the lungs of an ordinary town dweller. Tryptic digests showed the usual large numbers of coal particles with a few curious bodies. The findings in the miners' lungs are similar even when they have worked ten, twenty, thirty or fifty years underground, but there is no silicosis. The story is very different in the case of the drillers. In addition to shale and mudstone, these men drill through quartz-bearing rocks, such as sandstone, and silicosis is not infrequent amongst them. Their lungs show either gross anthracotic consolidation or the discrete nodular silicosis as it occurs in stone-masons and gold-miners. Sections under polarised light are seen to be full of sericite, but the nitric acid digests contain large quantities of minute flakes of quartz, far exceeding in numbers the needles of sericite. Quartz particles, except when very large, and quartz plates, unless they are seen edgewise, are quite invisible in sections.

These minute quartz plates $0.1-5\mu$ in diameter, are extremely thin—they are not equidimensional—and unless the digests are examined under perfect optical and microscopical conditions cannot be seen. The suggestion that the

secondary white material occurs in flakes and is at once by the examination never drilled in quartz whatever term be applied. If silicosis is not present enough, especially in the advanced, their chemical composition of mica plates does mine dust and in the

There are some production of silicosis length of time of dusty atmosphere, existing disease, is not yet told. To be fitting to mention a problem. Kettle disease causes an abscess which by amorphous and develop. By nitric digests of silicosis appeared entirely soluble that it was in direction of actual and Cummings with silica which, less than the end fibrosis.

1. Large particles do not appear to cause
2. The consensus silica plays the major role of quartz is important
3. The solubility have not been established. It has been established. Within the districts where
4. Asbestos, as minerals. It may be by the tissue fluid true cause of the fib

were that the mineral ally, chemically, and in of particles of accessory e dust. Quartz particles add that there was no ot in regard to size. It ave seen that even size

ral stone-masons, a file- he conclusion that they es being comparatively rable minute thin scales ingent minerals.

se. It is axiomatic that of their occupation im- is a larger proportion of ng ash. In this case the resent in the dust of the stone dust used in many

of mine dust—fusain, ifiable bodies and a few silica action, the golden s obtained by nitric acid the lungs of a pit pony sections and nitric acid were no silicotic nodules n parts, showed a small t the lungs were favour- dweller. Tryptic digests th a few curious bodies.

n they have worked ten, s no silicosis. The story is to shale and mudstone, s sandstone, and silicosis either gross anthracotic curs in stone-masons and to be full of sericite, but nute flakes of quartz, far z particles, except when eways, are quite invisible

are extremely thin—they examined under perfect . The suggestion that the

secondary white mica in the shales and mudstones of the Lancashire coalfields occurs in flakes and not in needles, and is therefore not dangerous, is answered at once by the examination of the lungs and lung digests of miners who have never drilled in quartz rock. They contain numerous fibres of sericite, or whatever term be applied to the secondary white mica of the shales, but silicosis is not present. Even if the mica is said to be in flakes, these are small enough, especially after drilling, to enter the alveoli, and if a chemical theory be advanced, their action should be the same as the needles because the chemical composition of both is the same. Whether they are called sericite fibres or mica plates does not affect the issue. The same mineral is found both in the mine dust and in the miners' lungs.

There are so many, hitherto unexplained, contributory factors in the production of silicosis—the concentration of silica and the size of the particle, length of time of exposure, the associated dusts, the energy expended in the dusty atmosphere, the presence of harmful gases, nasal obstruction and pre-existing disease, and individual idiosyncrasy—that it is obvious the full story is not yet told. To Prof. E. H. Kettle we owe a very great debt, and it would be fitting to mention a piece of work which throws considerable light upon the problem. Kettle (1934) has shown that colloidal silica injected subcutaneously causes an abscess with characteristic structure similar to the abscesses caused by amorphous and crystalline silica, although the latter take a little longer to develop. By intravascular injection of amorphous silica he produced the beginnings of silicotic nodules in the liver, but these lesions retrogressed and disappeared entirely. The conclusion was that the amorphous silica was so soluble that it was removed before it had time to influence the tissues in the direction of actual fibrosis. In contrast to this he quotes the work of Gardner and Cummings who produced actual nodules by the injection of crystalline silica which, less readily soluble, can act persistently and long enough to cause the end fibrosis.

CONCLUSIONS

1. Large particles enter the lung alveoli, and although sharp and angular do not appear to cause respiratory disability.
2. The consensus of opinion to-day is that the chemical action of free silica plays the major part in the production of silicosis. The size of the particles of quartz is important, probably on account of the effect of size on solubility.
3. The solubilities of the silicates, sericite and sillimanite, for example, have not been estimated, nor has their action in the production of silicosis been established. Wherever these silicates are found free silica is also present in the districts where silicosis occurs.
4. Asbestos, a silicate, causes pneumoconiosis, but is unique amongst minerals. It may act as a soluble silicate or, after the bases have been dissolved by the tissue fluids and eliminated, the resulting free silica fibre may be the true cause of the fibrosis.

5. One of the outstanding problems is to account for the reason why certain workers contract incapacitating silicosis, while some of their comrades doing the same work are not affected at all, and others, although affected to some extent, are not incapacitated.

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REFERENCES

- COOKE, W. E. (1932). *Brit. Med. J.* i, 656.
 — (1932a). "Silico-Anthracosis"—*Practitioner*, 129, 483.
 — (1933). Mineral Matter in Lungs, *Brit. Med. J.* ii, 492.
 CUMMINS, S. L. and SLADDEN, A. F. (1930). *J. Path. and Bact.* 33, 1123.
 JONES, W. R. (1933). *J. Hygiene*, 33, 307-29.
 KETTLE, E. H. (1934). The Action of Harmful Dusts—*Bull. Inst. Mining and Metall.* 137.
 LUNGE, G. and SCHORR-TSCHERNY, M. (1894). *Z. angew. Chem.* 7, 485.
 McCRAE, J. (1913). *Publications of the South African Institute of Medical Research*, 1, 122.
 McDOWELL, R. J. S. (1933). *Halliburton's Physiology*, London, 232.
 MELLOR, J. W. (1913). *Treatise on Quantitative Inorganic Analysis*, London, 664.
 — (1925). *Treatise on Inorganic and Theoretical Chemistry*, London, 277.
 MILLER, W. S. (1893). *J. of Morphol.* 8, 165.
 ROSS, J. G. (1931). *Chrysotile Asbestos in Canada*, Acland, Ottawa, 18.
 "Silicosis"—*Records of the International Conference at Johannesburg*, 1930, 86.
 STEWART, M. J. (1933). *Liverpool Med.-Chir. J.* 41, 142.
 TIDESWELL, V. F. (1934). *Refractories J.* 186.
 WATKINS-PITCHFORD, W. and MOIR, J. (1916). *Publ. S. African Inst. Med. Research*, 1913-21, and many other works.

EXPLANATION OF PLATES I-IV

All figures reproduced from photomicrographs.

The magnifications are given in diameters.

N.B. The black cardboards on which the original figures for Plates II-IV came to us were 23 cm. long and in the reproductions had to be reduced to a length of 20 cm. so as to fit our page. Consequently allowance must be made for a slight error in the magnifications given in the explanations to Plates II-IV. (Ed.)

PLATE I

Figs. 1-15. Bodies found in coal-miners' lungs. The measurements (in micra) of the spicules of fusain forming the core are: 1, 85.0; 2, 27.5; 3, 35.0; 4, 35.0; 5, 22.5; 6, 17.5 × 12.5; 7, 35.0; 8, 42.5; 9, 30.0; 10, 50.0; 11, the longest spicule in the group is 77.5; 12, 37.5; 13, 44.0; 14, 37.5; 15, a curious body from a case of asbestosis; a form unusual in asbestosis; length of core 40.0. × 400. (Reproduced by kind permission of the Editor of *The Practitioner*.)

Figs. 16, 17. Two asbestos bodies attain. The color of asbestos fibre bare. × 400.
 Fig. 18. The central asbestos body has been dissolved off the

Figs. 1 and 2. Illustrating golden yellow material with visible nucleus at A. × 400.
 Fig. 3. Chrysotile asbestos in carding rooms containing. × 400.
 Fig. 4. Shows these black fragments. × 400.
 Fig. 5. Large black fragments.

Fig. 1. Unclassifiable body. × 500.
 Fig. 2. The same body photomicrograph showing birefringence.
 Fig. 3. Photographed between crossed nicols showing optical transformation. Average diameter of the particles is 80.
 The slice was taken from a coal seam which frequently, suffer from silicosis, and is a bad tuberculous family.
 Fig. 4. Photographed between crossed nicols showing clear felspar in the ground glass. The particles mentioned above, with a diameter of 320 μ, max. × 80.
 Fig. 5. Photographed between crossed nicols. The shale contains needles of sericite. × 400.
 Fig. 6. Photographed between crossed nicols. The heavier particles of silicified coal floating in the atmosphere.

Fig. 1. (Diagram.) The core of the body. Around it the 2000 shagreened surface. The refractive index of the core is very prominent in section.
 Fig. 2. Photographed between crossed nicols. The drills and work in shale. The particles described in the text.
 Fig. 3. High-power view of the core. In addition to sericite.

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PLATE I (continued)

Figs. 16, 17. Two asbestos bodies. 16, 130 μ long; 17, 120 μ long. Illustrating the large size these bodies attain. The colloidal coating of the latter has been fractured leaving part of the fine asbestos fibre bare. $\times 400$.

Fig. 18. The central asbestos core of an asbestos body taken under polarised light. The covering has been dissolved off by strong nitric acid. The core is probably pure SiO_2 . $\times 400$.

PLATE II

Figs. 1 and 2. Illustrating particles of fusain in fibrosed areas of a coal-miner's lung, and the golden yellow material not only covering some of the spicules, but also lying free without any visible nucleus at A. $\times 500$.

Fig. 3. Chrysotile asbestos fibre showing black particles within fibre. $\times 150$. The dust in the carding rooms contained these black fragments in enormous numbers.

Fig. 4. Shows these black particles in a fibrosed area of an asbestos worker's lung. $\times 400$.

Fig. 5. Large black fragment of asbestos fibre in a necrotic area. The fragment is 360 μ long. $\times 150$.

PLATE III

Fig. 1. Unclassifiable body found in a coal-miner's lung, 240 μ long, taken by transmitted light. $\times 500$.

Fig. 2. The same body photographed between crossed nicols. $\times 500$. This is a good example of birefringence.

Fig. 3. Photographed between crossed nicols: an orthoclase felspar crystal undergoing mineralogical transformation into the acicular form of secondary white mica known as sericite. The average diameter of the fine needles in the figure is 20.8 μ . Maximum 23 μ , minimum 16 μ . $\times 80$.

The slice was taken from the granite near the lode in a Cornish tin mine where the workers, not infrequently, suffer from silicosis. The majority of silicosis cases occur in this mine in men with bad tuberculous family histories and of Spanish descent.

Fig. 4. Photographed between crossed nicols: a very coarse flakey white mica enclosed in orthoclase felspar in the granite near the lode of a Cornish tin mine a few miles away from the mine mentioned above, where silicosis is said to be very rare. The average diameter of the mica particles is 320 μ , maximum 510 μ , minimum 76 μ . No fine needles of sericite are present. $\times 80$.

Fig. 5. Photographed between crossed nicols: section of a shale above a coal seam in a Lancashire mine. The shale contains 20 per cent. of combined silica, the greater part of which is in fine needles of sericite. $\times 80$. Compare this with Fig. 3.

Fig. 6. Photographed between crossed nicols: dust collected in the return airway 100 yards from the coal face where drilling in shale and sandstone was taking place. The larger and heavier particles of dust have fallen, leaving the lighter particles of sericite and quartz floating in the atmosphere. $\times 80$.

PLATE IV

Fig. 1. (Diagram.) The centre block in the figure represents a quartz crystal of 10 cubic μ . Around it the 2000 short lines represent sericite fibres 2 μ in length and 5 μ in breadth. The refractive index of the brilliant little needles being so much greater than quartz makes them very prominent in sections and digests.

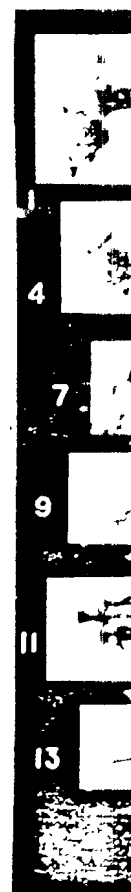
Fig. 2. Photographed between crossed nicols: a mine-driller's lung. Such men use compressed air drills and work in shale, mudstone and free silica containing rock. The prominent features are described in the text (p. 213). $\times 80$.

Fig. 3. High-power view of the more fibrosed part seen in Fig. 2. A few quartz particles are seen in addition to sericite fibres. $\times 500$.

PLATE IV (*continued*)

- Fig. 4. Curious body similar to an asbestosis body. From the lung of a dock labourer. $\times 500$.
Fig. 5. Diatom from lung digest of a case of silico-siderosis. $\times 500$.
Fig. 6. Curious body from lung digest of an able-seaman. $\times 500$.
Fig. 7. Curious body resembling those found in silico-anthracosis. From lung digest of a London housewife, aged 54 years. $\times 500$.
Fig. 8. Ditto in a London housewife aged 60 years. $\times 500$.
Fig. 9. Body similar to asbestosis bodies from lung digest of a dock labourer. $\times 500$.
Fig. 10. "Silico-anthracotic" body from a London housewife aged 64 years. $\times 500$.
Fig. 11. Diatoms from a cotton worker's lung digest. $\times 500$.

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of a dock labourer. $\times 500$.

from lung digest of a London

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