MODERN VIEWS ON SILICOSIS[1]

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(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 pneumonoconioses. 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 pneumonoconioses 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

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

"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, 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 1 μ, and the remaining 30 per cent. varied between 1 and 8·5 μ. Only a negligibly small number of particles had diameters exceeding 8·5 μ, and the longest was 10·5 μ. 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 0·1–5 μ, with occasional larger fragments 10–20 μ 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 5 μ in diameter and to discard particles over 10 μ or even 5 μ 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 250 μ (Miller, 1893) and 300–500 μ (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 85·0 μ.

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 curious 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-miners. 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 130μ in length and the lower 120μ. 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 ion. It is not birefringent nor does the X-radiogram 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	67·80
Inorganic matter	32·20

The composition of the ash was:

	%
Free silica	5·45
Combined silica	21·10
Total silica	26·55
Ferrous oxide	70·55
Magnesium oxide	2·55
Calcium oxide	Nil
Alkalis	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 (1931) states that chrysotile asbestos is attacked by very weak acids which dissolve the bases—chiefly magnesium 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-anthracosis, 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-anthracosis 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, 1932*a*). 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 4½ to nearly 7 times that of quartz. To give maximum white polarisation a piece of quartz must be 4½ 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 ($K_2 3AlO_3 6SiO_2 2H_2O$) 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 $20{\cdot}8\mu$. 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) revealing an enormous quantity of fine acicular fibres of sericite. Pl. III, fig. 6 (photo taken between crossed nicols), shows dust in the return airway of a Lancashire mine, a hundred yards from the coal face where drilling in shale was taking place. It is almost all sericite with here and there a fragment of quartz. The heavier dust particles have fallen leaving the fine light needles and flakes in the atmosphere.

It is the custom in many mines to dust the roads with crushed shale and mudstone.

Sericite and quartz in the lungs. Jones points out that the volume of a sericite fibre is very small—2μ in length by 0·5 in width and the same in depth—0·5 cubic μ. The grain of quartz $10 \times 10 \times 10\mu$, outlined in the centre of Pl. IV, fig. 1, is equal in volume to the 2000 sericite fibres around it, and would contribute more silica on analysis than 4000. The brilliant little fibres would be very much more striking by polarised light than the single grain of quartz. Jones argues from this that a lung may contain more free silica than sericite but not be affected so much by quartz as by the countless fibres of sericite in the alveoli. In other words, he states that the mechanical action of sericite fibres causes silicosis and that the amount of free silica, as quartz, is out of all proportion to the silicotic action it exerts. It will be remembered, too, that he stated that the bulk of the mineral residue (by nitric acid) from every silicotic lung he had examined, gold-miners, coal-miners, stone-masons, potters, etc., consisted of sericite.

Our results are quite at variance with this. Watkins-Pitchford and Moir (1916) in 1916 were very alive to the fact that the majority of the doubly refractile particles seen in lung sections of Rand silicosis were sericite. This was at first surprising, but the results of their experiments and examination of the lung residues and mine dust made the explanation apparent. We have repeated their work in Lancashire mine-drillers, stone-masons, etc. Pl. IV, fig. 2, shows a section of a driller's lung, taken between crossed nicols. As they point out in their sections, there are three prominent features in this photomicrograph. The first is the birefringence of the fibrous tissue. (Moir in 1910 was the first to publish a photomicrograph of a lung section under polarised light.) The second, the great majority of particles seen are sericite, and the third that in the advanced fibrotic part few particles are apparent whilst in the newly establishing fibrosis they are very numerous.

On examination by a higher power (Pl. IV, fig. 3), it is seen that some of the particles are quartz flakes on edge. A fibrotic part of a section such as this is marked, the coverslip removed and the section passed through xylol and alcohol and dried; the part is ringed with paraffin wax after removal of the rest of the tissue. The slide is then placed level in an incubator, and two or three drops of strong nitric acid are placed on the selected portion. The process is repeated for three days and the slide allowed to dry. On examination, it will be seen that there are a hundred times more birefringent particles than at first appeared in the section, and the greater number of these are not sericite but quartz. Watkins-Pitchford's and Moir'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 birefingent 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 peri-bronchial 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 edgeways, are quite invisible n sections.

These minute quartz plates, 0·1–5μ 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 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 pneumonoconiosis, 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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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*.)

PLATE I (*continued*)

Figs. 16, 17. Two asbestos bodies. **16,** 130μ long; **17,** 120μ 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. ×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. ×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*. ×500.

Fig. 3. Chrysotile asbestos fibre showing black particles within fibre. ×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. ×400.

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

PLATE III

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

Fig. 2. The same body photographed between crossed nicols. ×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 20·8μ. Maximum 23μ, minimum 16μ. ×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 orthoclare 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 320μ, maximum 510μ, minimum 76μ. No fine needles of sericite are present. ×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. ×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. ×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 2μ in length and 5μ in breadth. The refractive index of the brilliant little needles being so much greater than quartz makes them very prominent in sections and digests.

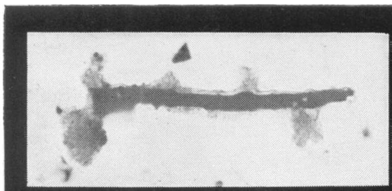
Fig. 2. Photographed between crossed nicols: a mine-driller's lung. Such men use compressed air drills and work in shale, mudstone and free silica containing rock. The prominent features are described in the text (p. 213). ×80.

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. ×500.

PLATE IV (*continued*)

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

(*MS. received for publication* 9. III. 1935.—Ed.)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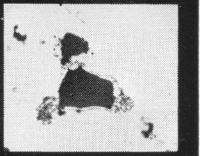
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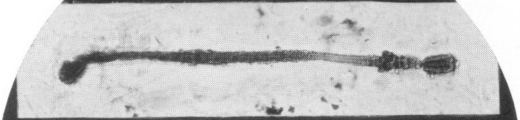

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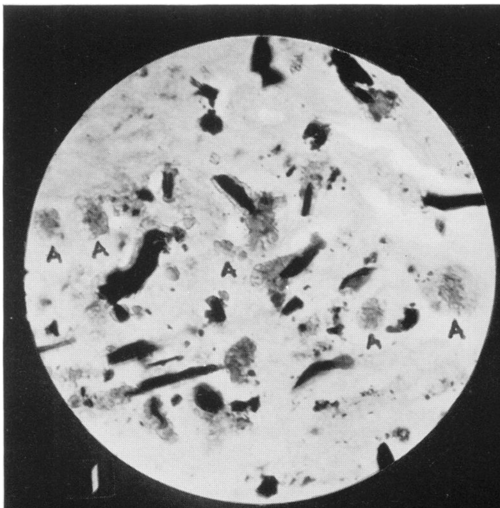
PLATE II



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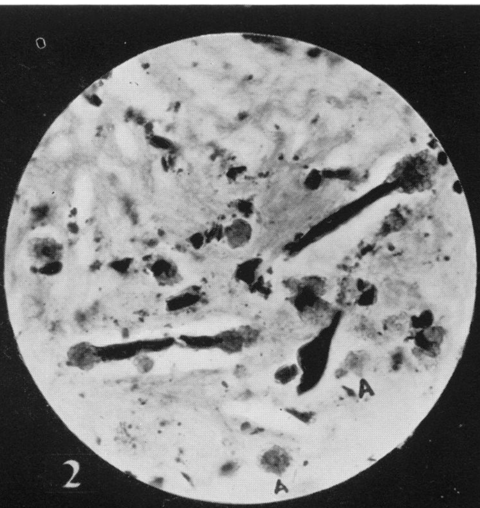

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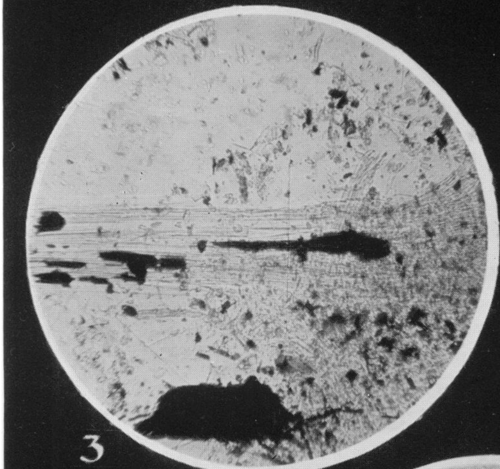

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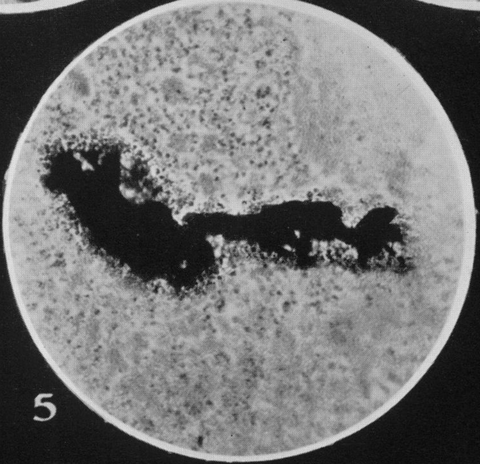

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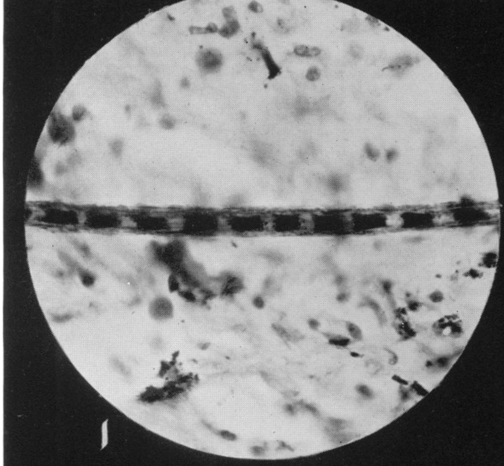
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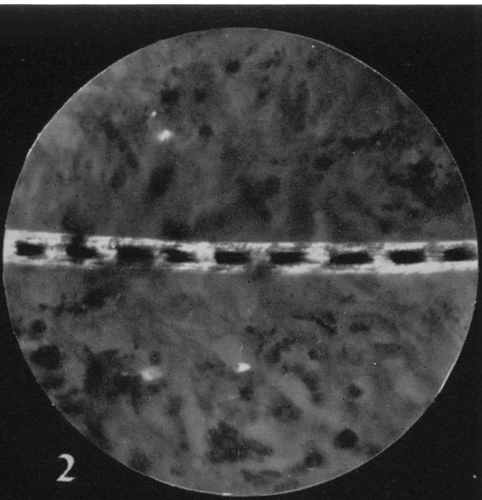
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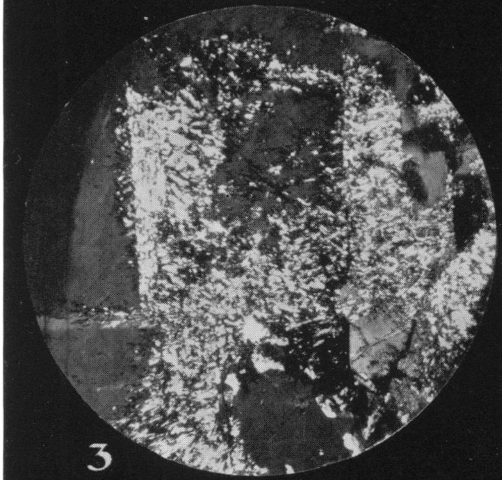
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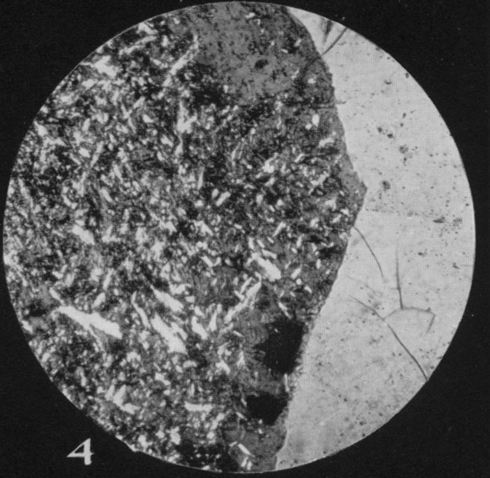
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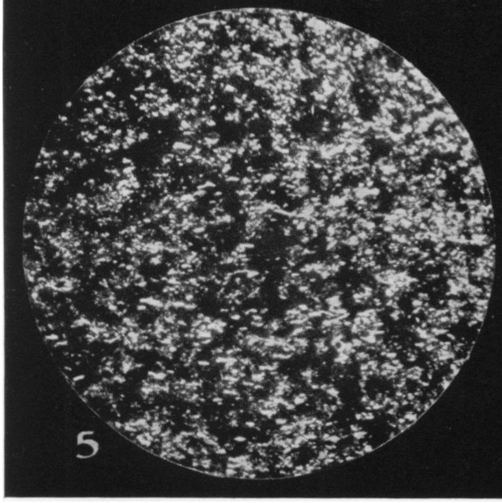
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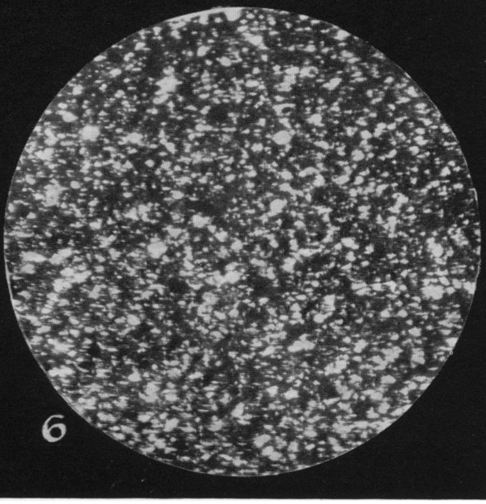
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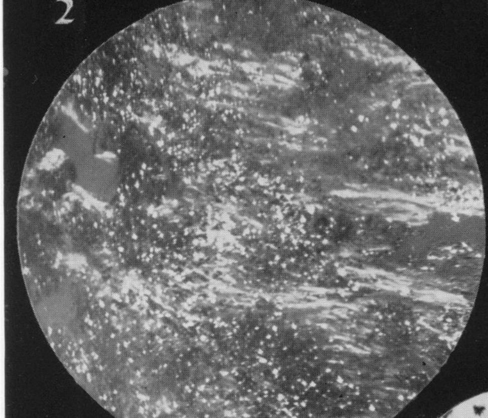

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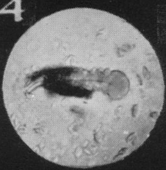

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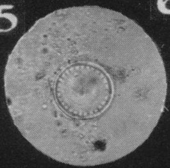

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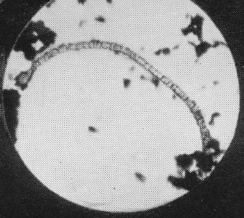

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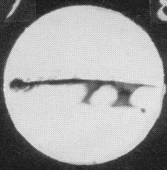

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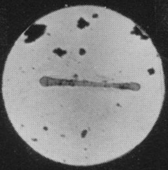

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