THE INCIDENCE OF QUARTZ AND SERICITE PARTICLES IN SILICEOUS RESIDUES IN SILICOTIC LUNGS

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(With Plate III)

It is now 6 years since Jones (1933) suggested that the mineral sericite, a secondary white mica, might be the cause of silicosis rather than silicon dioxide.

First, Jones claimed that petrographical examination of the mineral residues from silicotic lungs showed quartz to be present mainly in large fragments, whereas the majority of the smallest particles consisted of sericite fibres. Secondly, he adduced the high aluminium fraction in the residues as shown by chemical analysis as further evidence that much of the siliceous matter commonly expressed as free silica was actually present in the combined form of potassium aluminium silicate, i.e. as sericite. Thirdly, he claimed that silicosis only occurred where sericite was associated with quartz, while in mines free from sericite silicosis was absent even though the rock worked was almost pure quartz. Especially, he contrasted the South African gold-mining area where silicosis was rife and sericite abundant with the Kolar gold mines of India where silicosis was absent and where there was no sericite.

Since then a number of papers on every aspect of this controversy have appeared, and the question is still not definitely settled. Such authorities as E. H. Kettle and A. Policard have lent their support to Jones' theory.

Hurlburt & Beyer (1934) reported that the dust from a foundry with a high silicosis rate contained more sericite than the dust from a foundry with a low silicosis rate, thus supporting the sericite theory. They also pointed out, as has Jones, that the percentage of sericite in the air-borne dust of a foundry may be higher than that in the sand giving rise to it, because the size and shape of sericite fibres tend to favour their continued suspension in the atmosphere, whereas quartz particles tend to settle more rapidly.

On the other hand, Rao (1934) disputed the accuracy of Jones' statement that silicosis is unknown in the Kolar gold mines.

Cooke (1935) pointed out that silicosis was rare among Lancashire coal-miners although sericite fibres were abundant in the rock they worked, while silicosis did occur when they drilled quartz rock.

Again, Feil (1935) found no silicosis in 251 workers quarrying slate containing abundant sericite but little free silica.

Oller (1936) found a high incidence of silicosis amongst the Rodalquir miners in Spain, although sericite was absent from the rock mined.

Fowweather (1936) found that although silicosis was equally common in two sand-blasting works, yet the air-borne dust of one was practically completely free from sericite and the dust from the other contained nearly 20 % of sericite.

Jephcott (1935) found equal amounts of sericite and silica in the lung residues of nine gold-miners from the Porcupine area, but on the other hand no sericite at all in the lungs of a sand-blaster dying of uncomplicated silicosis.

Cooke (1935), studying the minerals present in sections from silicotic lungs, found predominantly quartz particles, sericite being comparatively rare.

Geisler (1935), by the petrographical examination of incinerated sections from sixty silicotic lungs, found mainly quartz particles and concluded that sericite played no role in silicosis.

Koppenhöfer (1935) in the same year examined a smaller series of lungs by a similar technique and was unable to identify sericite fibres in the mineral residues, and pointed out that the most marked cases of silicosis came from mines where there was little or no sericite.

Burke & Kerr (1938) found no sericite in the mineral residues of silicotic lungs, using an X-ray diffraction method.

Using the experimental approach Drinker *et al.* (1934) found that the lymph nodes in dogs reacted similarly to injected silica and to sericite, but did not prolong the experiment beyond 12 days.

Policard (1934), on the basis of inhalation experiments with mica dust, lent his support to the view that sericite was the cause of silicosis.

Kettle (1934) found that kaolin (aluminium silicate containing numerous sericite fibres), introduced with dead tubercule bacilli, produced extensive fibro-necrotic lesions, and in the same paper stated his belief that Jones had put forward a strong case for sericite being the factor in silicosis.

On the other hand, Fallon & Banting (1935*a*) found the reaction of rabbit tissues to sericite was essentially similar to that to an innocuous foreign body, and they found no evidence of fibrosis after 6 months, whereas quartz showed typical lesions.

Similarly Lemon & Higgins (1935) found that sericite injected intratracheally into rabbits gave a diffuse irregular pulmonary fibrosis, but never produced lesions resembling silicosis, whereas in previous experiments they had produced typical silicotic lesions with silica.

More recently, Cummins (1937) found that in rabbits sericite led to nodules of mononuclear phagocytes and giant cells but fell behind quartz in the production of fibrosis; but he also found that sericite and dead tubercle bacilli together led to a more destructive necrosis than silica and dead tubercle bacilli, and concluded that sericite could by no means be regarded as an inert dust.

Weiland (1937) found lesions resembling those seen in human silicosis in the lungs of guinea-pigs exposed to sericite inhalation for 10 months.

From this account of the work done since Jones originally suggested sericite as the active cause of silicosis, it is evident that the balance of evidence does not support his theory. Accounts of direct mineralogical examinations of incinerated sections from silicotic lungs have, however, been few, and the results of Koppenhöfer (1935), Geisler (1935), and Cooke (1935), reporting the absence of sericite fibres in such preparations, appear to have received relatively little attention.

It was therefore thought that, since the question was not definitely settled, further petrographical examination of sections from silicotic lungs was necessary.

MATERIAL

The material consisted of portions of lungs from thirty-one cases of unequivocal silicosis, collected from a wide range of sources, and which comprised chiefly stone-masons and dressers, and machine tool-grinders. There was only one miner.

No case has been included unless there were both unequivocal naked eye and histological evidence of silicosis, nor unless the appearances after micro-incineration conformed with those described as characteristic for silicosis by Irwin (1934).

TECHNIQUE

From each case two blocks of tissue containing aggregations of silicotic nodules were embedded for paraffin section, and three consecutive sections were obtained from each block. The first section was stained by haematoxylin and eosin, the second and third were incinerated according to the technique described by Irwin (1934).

Both incinerated slides were treated when cold with concentrated hydrochloric acid for 30 min., then washed in distilled water, then in absolute alcohol, and then dried. One was covered immediately and the cover-slip ringed round with melted paraffin wax. The other was mounted in Euparal, a mounting medium with refractive index 1·483. Both slides were first examined by dark-ground illumination, and the presence of silicosis confirmed. A definite silicotic nodule was next identified in the Euparal preparation and marked with an ink ring for further examination under the petrological microscope.

Illumination was provided by a 6 V. 5 amp. high-intensity lamp with coil filament, and "Polaroid" attachments fitted to a Watson research microscope were used for the petrological examinations.

Counts were made with the oil-immersion lens, magnifications up to 1000 times being obtained. Separate counts were made for particles above and particles below 2μ.

Results

Quartz particles possess a low double refractility, and when thin and small may easily be overlooked, especially if canada balsam be used as a mounting medium. This point has especially been emphasized by Cooke (1935), who recommends the use of Euparal, and it has been noted also by Geisler (1935), and by Green & Watson (1935). Quartz particles can be recognized by their shape, forming irregular flakes with straight edges and sharp angles; by polarized light they appear in shades from grey to white. According to Jones (1933) they never appear as fibres.

Sericite can usually be distinguished from quartz by its shape, which is fibre-like, by its high birefringence, and by its property of giving straight extinction. The readier recognition of sericite compared with quartz had been stressed by Williams (1937), Green & Watson (1935), and by Cooke (1935).

According to Udluft (1935), other fibrous minerals which occur naturally include andalusite, talc, tremolite, asbestos, gypsum, kaolinite, apatite and serpentine, and so the possibility exists that fibres of these minerals may have been included in the sericite estimations recorded below, since all particles with a fibrous structure that were highly birefringent were recorded as sericite. Hence the sericite figures may be inaccurately high.

Several fields were counted in each slide, and an average obtained for each case. Some variation between fields in the same slide was found, and the quartz and sericite counts have been expressed as percentage ratios approximated to the nearest fifth integer in order to avoid suggesting an accuracy which was not obtained by this method of counting.

In general it was found that, whereas in many cases under the lower powers the sericite fibres present appeared to dominate the picture by reason of their high birefringence, yet, when the oil-immersion count was made the actually larger number of quartz particles could be recognized.

The great majority of the particles were less than 2μ. The counts for particles below 2μ have been regarded as the more important figures for each case, since it has generally been accepted that the smallest particles are the most significant from the point of view of pathogenicity, owing to their relatively high surface area weight for weight.

As will be seen from Table I, of the thirty-one cases examined, twenty-five showed sericite counts of less than 35 % for particles less than 2μ, although in no case were sericite particles entirely absent.

The sericite counts above 2μ are shown in Table II, and it can be seen that the bulk of the cases show lower percentages than those for below 2μ.

It is evident, then, that in the majority of cases of this series the sericite particle percentages both above and below 2μ are considerably smaller than the quartz particle percentages.

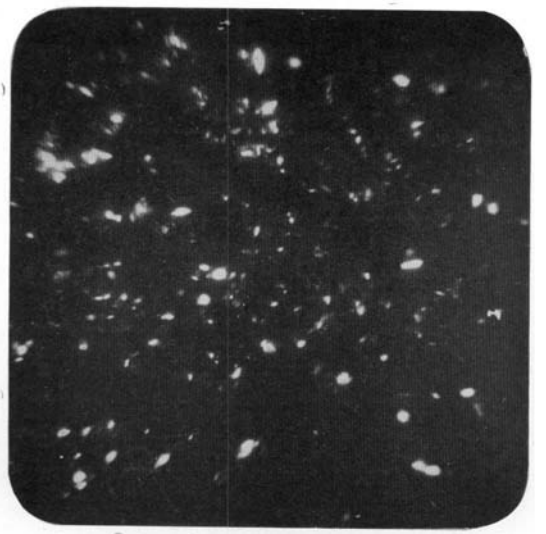

Fig. 1. Incinerated section as seen by polarized light. Numerous prominent sericite fibres are present together with many less obvious quartz particles. ×800.

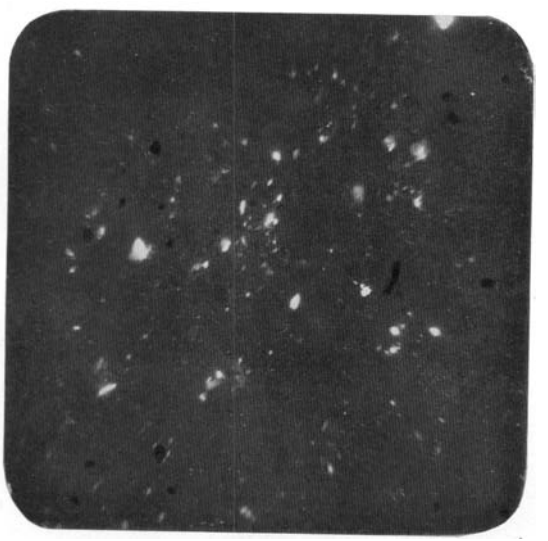

Fig. 2. Incinerated section showing mainly quartz particles of varying size with a few bright sericite fibres. ×800.

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Table I. *Particles below* 2μ

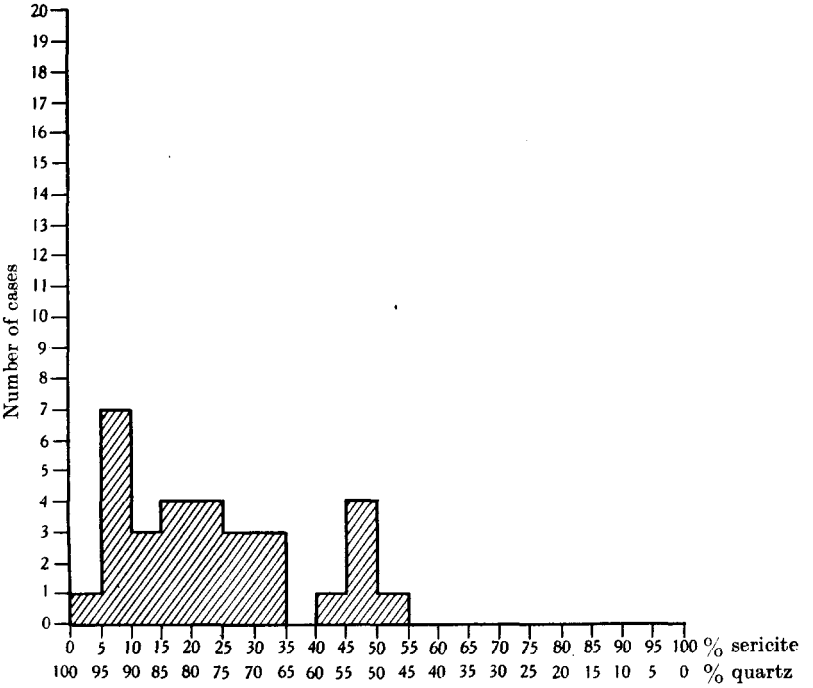
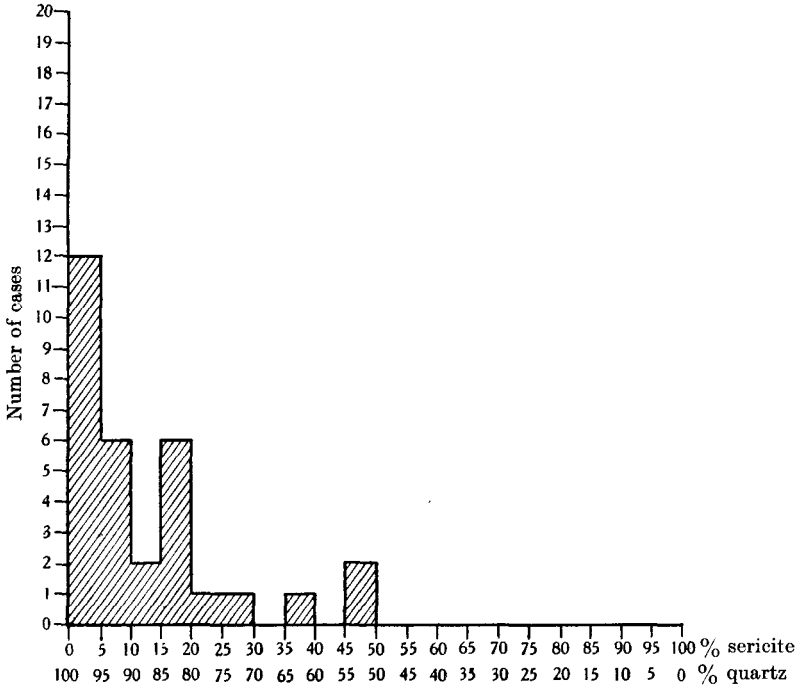


Table II. *Particles above* 2μ



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Relation to age

Unfortunately all the ages were not available in this series, so that no definite correlation could be drawn between either a high quartz count or a high sericite count and the age at death from silicosis. It is perhaps suggestive, however, that high quartz and low sericite counts were present in the three youngest cases in which, presumably, the course of the disease had been rapid, while in the three oldest cases the reverse was obtained, the sericite counts being high.

Relation to occupation

No definite relation was found between sericite counts and the nature of the work. As there was only one miner no inference could be drawn concerning differences between sericite counts of miners and of stone-masons. It may, however, be noted that this one miner actually showed a high sericite count.

Relation to tuberculosis

It is notoriously difficult to exclude the presence of tuberculosis in the presence of silicosis, and since the complete sets of lungs were not always available, no great importance can be assigned to the following results, the cases being divided into those in which tuberculosis or silico-tuberculosis (11) was present, and those in which evidence of tuberculosis was absent (20). On this basis it was found that sericite counts tended to be higher in the tuberculous group than in the non-tuberculous group, averaging 30 % compared with 22 %.

Discussion

It may be stated at the outset that these results do not confirm the observations of Jones (1933) that sericite is by far the most abundant mineral present in the lower particle size ranges in the mineral residues in silicosis. On the other hand, they do confirm the observations of Koppenhöfer (1935), Geisler (1935) and Cooke (1935), that quartz particles are present in silicotic nodules in numbers greater than sericite fibres up to the limit of particle identification by optical methods.

The difficulty in seeing small quartz particles by polarized light when they are mounted in canada balsam has been emphasized by numerous observers, and it is probable that this difficulty, together with the obvious brightness of sericite fibres, has led to more attention having been paid to these fibres than to quartz particles in estimating the relative incidences. However, by the use of an optimum lighting source, and of Euparal, with its lower refractive index than balsam (1·483 compared with 1·540), this difficulty has been largely overcome, although considerable patience and experience have admittedly been necessary before the distinction between the smaller particles has been achieved.

In Jones' method it was not possible to be certain that the particles examined petrographically actually came from parts of the lung where there

were silicotic lesions, since a small sample from the residue of a large portion of lung was examined. By the technique used in the present investigation the particles actually present in a silicotic nodule were examined.

It must be admitted that no case was found in which sericite fibres were completely absent, so that an absolute proof that silicosis can occur without sericite has not been supplied.

Sericite occurs naturally in rock arranged in the form of multitudes of closely packed minute fibres; when disrupted these fibres, owing to their small size and shape, tend to remain longer in air-borne dust than quartz particles, as has been pointed out by Jones (1933), and Hurlburt & Beyer (1934), and since sericite is commonly associated with quartz in nature it would actually be surprising if sericite fibres were not found in large numbers in the lungs of all workers in quartz. Therefore no definite inference can be drawn from their apparent ubiquity in silicotic lungs. In the majority of cases the sericite count was smaller, and often much smaller than the quartz count, and if sericite actually were the cause of silicosis it would have to be, as Fowweather (1936) points out, a vastly more active substance than quartz in the production of silicosis. Yet animal experiments have shown that the contrary obtains, quartz being more active than sericite (Fallon & Banting, 1935*b*; Lemon & Higgins, 1935; Cummins, 1937).

The higher sericite content in the lungs examined by Jones may perhaps be partly accounted for by the fact that his cases were mainly miners, whose working conditions would have been less adequately ventilated than those of stone-masons, etc., which formed the majority of the cases of this series, with the result that the differential rate of deposition between quartz and sericite would operate more in his series, the air respired by the miners being relatively richer in sericite fibres than that inhaled by the stone-masons. Yet stone-mason's silicosis differs in no way from that of rock-miners, and any theory of the aetiology of silicosis that holds good for miners and not for masons must be abandoned. In this connexion it is interesting to recall that in this series the only miner showed a high sericite particle count.

The majority of the accounts of the experimental work with sericite record a failure to produce typical silicotic nodules, whereas these have been produced by pure silica (Fallon & Banting, 1935*b*; Lemon & Higgins, 1935; Gardner, 1934). However, since Cummins (1937) has shown that sericite with dead tubercle bacilli can produce lesions resembling silico-tuberculosis, it is evident that sericite may yet be proved to be a potentially dangerous dust even though it is not the chief causal factor in the majority of cases of silicosis.

On the other hand, in a communication to the Pathological Society of Great Britain and Ireland, on 6 January 1939, King stated that the presence of silicates such as sericite appeared to diminish the solubility of quartz in water and in serum. This suggests that sericite might have a protective action, a suggestion which finds further support from the observations of Whitehouse (1938), who found that the presence of stone dust and shale dust, both con-

taining abundant silicates, reduced the solubility of silica in 1 % sodium carbonate.

In conclusion, it may be stated that the theory that silica is the cause of silicosis still rests on a firm body of evidence, and the results of this investigation have failed to support the alternative view that sericite is the active cause.

SUMMARY

1. Preparations for petrographical examination were obtained by micro-incineration of sections from silicotic nodules from thirty-one cases of unequivocal silicosis.

2. Particle counts above and below 2μ showed, in the majority of cases, a preponderance of quartz.

3. Jones' claim that sericite particles predominate in the lower size range of particles in silicotic lungs is not confirmed.

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