DEPARTMENT OF MINERAL EXPLOITATION

UNIVERSITY COLLEGE
CARDIFF

AN EXAMINATION OF ITALIAN MINE SAMPLES AND RELEVANT POWDERS

This document represents the completion report of the Italian mine samples and other powders supplied by Johnson and Johnson, Cosham, Portsmouth, to the Department of Mineral Exploitation.

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REPORT OF INVESTIGATION OF ITALIAN MINE SAMPLES AND RELATED POWDERS

Introduction

Talc is hydrated magnesium silicate ($Mg_3Si_4O_{10}(OH)_2$) which can occur in a number of forms. In its compact form it is known as stealite or soapstone. The form normally employed for toilet purposes is soft and very friable in character. It is mined in many parts of the world including the U.S.A., Canada, France, Italy, Norway and India, as well as several other countries. It occurs in both a flaky and lath like form and the chief deposits occur in altered magnesia-rich calcareous rocks such as dolomite, marble, and magnesian limestone. The purest talc deposits occur in association with dolomite and marble. Talc also occurs in altered basic rocks such as serpentines and again as thin beds in mica schists. Commercial talcs contain a number of related mineral impurities. They may include antigorite (hydrated magnesium silicate) magnesite or members of the magnesite-chalybite series of carbonates, dolomite (calcium magnesium carbonate), tremolite and actinolite (calcium, iron magnesium silicates), chlorites (magnesium aluminium iron silicates) and other minor minerals such as the sulphides and spinels.

The hand specimens examined in this report were collected at the Italian mine and do not represent an average collection of specimens of material being produced at the mine. The specimens were collected with the intention of sampling those areas with obvious non talc mineral inclusions. Specimens were retained which showed differences in physical appearance, i.e. fibrous, flakey, massive and powdery in texture. Specimens of ore in which colour variation was observed were also collected. In general the colour of the talc ore varied from grey through white to a light green colour. Obvious inclusions in the talc ore itself were retained and a careful search at the various sample locations in the talc seam was performed for fibrous amphibole minerals.

Specimens of the hanging and footwall were also collected to assess their mineral content as these were likely sources of ore contamination, although the method of mining which consisted of hand filling methods precluded any gross contamination of the ore.

The hand specimens have been, where possible, prepared for examination by the optical microscope and both polished blocks and thin sections of material have been employed. Representative fractions of all hand specimens have been reduced to powder form and subjected to powder X-ray diffraction examination. The representative powdered samples also form the samples for morphological examination by the electron microscope.

The list of samples obtained from the Italian mine are given in Tables 1 and 2 and throughout this report the samples are referred to by the preceding code number for each specimen.

The objective of the examination has been mainly to establish the major minerals which occur in association with talc at the Italian mine. In particular to look at the association of these minerals with the talc and especially those minerals which are of the same family as the commercial asbestos minerals, i.e. the amphiboles and serpentines.

The objective of the optical examination has been to establish textural and mineral relationship and not to quantify the phases occurring in each hand specimen. X-ray work has been aimed at establishing the minerals observed by optical means and to produce reference patterns for future investigation together with computed data from pattern measurement.

Electron microscope work has been selective in nature and performed on the finer fraction of the powdered specimens. Its aim has been to describe the morphology of the particles produced by comminution of the hand specimens and to investigate any obvious structural information which might be of use in identification of individual mineral particles.

Representative data obtained from the various examinations are included in the following report.

TABLE 1

LIST OF ITALIAN MINE SAMPLES

Code No.	Description
I.1.	Talc from footwall contact
I.2.	Sorting pieces (with obvious colour differences)
I.3.	Coloured talc (green)
I.4.	Face 10 sample with obvious amphibole inclusion.
I.5.	General ore
I.6.	Suspected Quartz sample
I.7.	Mica schist specimen
I.8.	Massive talc
I.9.	Grey talc 1st face
I.10.	Granular talc sample
I.11.	Carbonate and talc
I.12.	Footwall sample? Amphibolite
I.13.	Inclusion showing passage into talc bottom transit.
I.14.	Inclusion in talc seam face 4, middle of seam.
I.15.	Talc footwall contact
I.16.	Inclusion from face 1.
I.17.	Footwall rock sample
I.18.	Face 3 carbonate/talc sample
I.19.	Tremolite/quartz/talc sample
I.20.	Amphibole sample from Gianna level 1212
I.21.	Inclusion from face 2.
I.22.	Carbonate/talc sample
I.23.	Black gneiss 2 ft below talc seam
I.24.	Talc next to carbonate face 2.
I.25.	Footwall limestone
I.26.	Talc inclusions
I.27.	Lithological inclusions face 1

Table 1 Continued

Code No.	Des ription
I.28.	Quartz/talc sample
I.29.	Sample 6 footwall
I.30.	Quartz/Carbonate/talc sample
I.31.	Black inclusion face 1
I.32.	Face 2 inclusion from base of talc
I.33.	Talc from lower left end of working
I.34.	Marble/tunnel wall
I.35.	Massive carbonate from rear end of working
I.36.	Grey talc specimen
I.37.	Carbonate in talc inclusion
I.38.	Pyrite/talc specimen
I.39.	5" - 0 pieces from crusher
I.40.	Platey talc
I.41.	Face 2, good specimen
I.42.	Face 1, coloured green (talc)
I.43.	Face 10, fibrous sample
I.44.	Face 1, pure talc?
I.45.	Face 1, good specimen
I.46.	Face 3, coloured specimen

TABLE 2

OTHER SPECIMENS EXAMINED

Code No.	Description
B1	Pure talc lst face
B2	Greenish talc lst face
B3	Talc 6 inches above footwall
B4	Talc from above inclusion
B5	Inclusion in talc
B6	Talc 2 ft above inclusion
B7	Section 2 ft above inclusion
B8	Pure talc lst face
B9	Grey talc lst face

Also examined

1) Batch shipments of ØØØØØ talc
2) Old samples of British powders.

OPTICAL EXAMINATION OF SPECIMENS I1 - I46

Thin and polished sections were prepared of the specimens of wallrock and, where possible, the talc ore.

The minerals which formed a major constituent in at least one of the sections were quartz, muscovite, talc, chlorite, (var sheridanite), calcite, garnet, and tremolite; the latter only occurred as a major constituent in section I19. Phases which were always minor or accessory were microcline, plagioclase, biotite, pennine, epidote, clinozoisite, hornblende, actinolite (section I7), rutile, and opaque constituents pyrite, pyrrhotite, and chalcopyrite.

The identification of the minerals in the sections of these specimens was based on the optical characteristics of the minerals in transmitted and reflected light, both under plane polarised light (PPL) and crossed nicols (XN), combined with the results of the X-ray diffraction study of the crushed hand specimens. In some cases material was extracted from the sections and examined in R.I. liquids as in determining that the most common chlorite mineral in these specimens is a variety called sheridanite having a R.I. ω equivalent of 1.590 ± 0.005 and a birefringence of 0.012 - 0.014. Similarly much of the muscovite was nearly uniaxial with a R.I. of 1.600 corresponding to the variety phengite, an abnormally siliceous muscovite. In the case of talc its confident determination optically is difficult since its optical properties are identical to muscovite. However, it was found that the common "feathery" form of the talc combined with the invariable occurrence of minute transparent inclusions (suspected to be silica) in the talc producing a 'dusty' appearance in thin section and a greenish colour in hand specimen, enabled talc to be distinguished from muscovite. Talc also exhibited slightly higher order interference colours in general. Where talc was only an accessory mineral to muscovite, as in some of the wallrock samples, then it could not be distinguished with certaintly.

In the following pages (no. 7 to 48) the Italian specimens are systematically described as regards their mineral composition and mode of intergrowth. Numerous photomicrographs taken under PPL and XN are provided with the description to mainly illustrate the rock textures which, it is hoped, will provide information useful in the comminution of particularly the talc ore samples, and also displays the non occurrence of asbestiform amphiboles in the talc ore.

Specimen I1

Specimen I1 consisted of several pieces of wallrock with one piece displaying the talc/footwall contact. One polished section was made of the talc/footwall contact and one thin section of the wallrock alone.

The wallrock is a schist which in thin section displayed a segregation of the main minerals into thin lenticular bands composed, as in Figure 1, of long tabular aggregates of intermixed muscovite (var. phengite) and chlorite (var sheridanite), and granular quartz exhibiting a polygonal grain boundary structure. Accessory rutile occurs as orientated inclusions in the chlorite and muscovite, and also opaque constituents which in polished section were identified as dominantly pyrite metacrysts with minor pyrrhotite. Some subhedral porphyroblasts of plagioclase also occur.

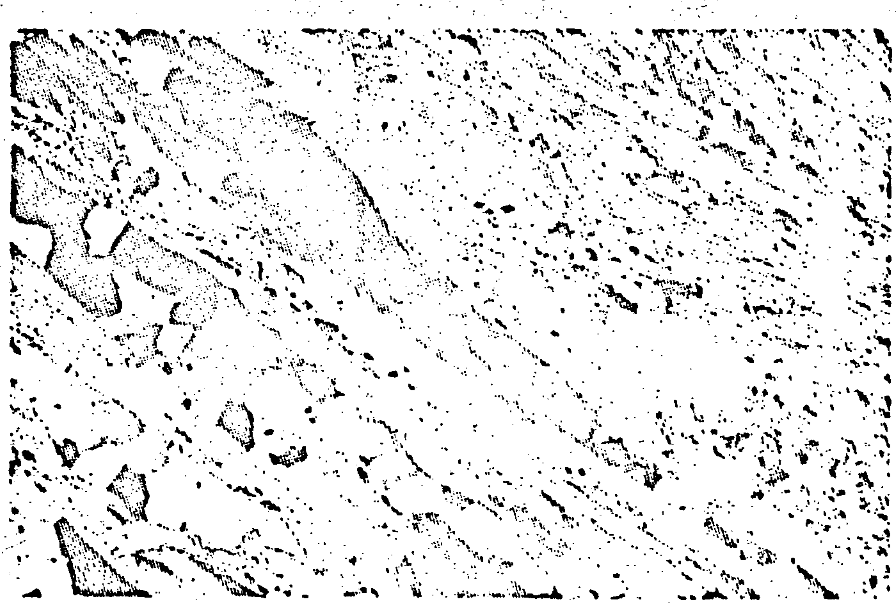


Fig. 1. Photomicrograph, X 40, of thin section of wallrock I1 under crossed nicols. A schist of quartz (granular white-black), muscovite (lamellar yellow-blue), and chlorite (lamellar white-blueish grey).

Specimen I3: 'coloured talc'

The minerals composing this specimen are major talc and chlorite (var sheridanite) with the talc content much greater than chlorite, together with accessory garnet, rutile, and an unidentifiable finely dispersed phase occurring as minute transparant inclusions along the cleavage planes and grain boundaries of the talc and imparting a dusty brown appearance to the talc in thin section and a greenish colour in hand specimen. The talc occurs as medium grained feathery aggregates which are in places 'dusty' and grade into 'clean' transparant aggregates which are free of any inclusions. It appears that some retrograde metamorphic process has caused the inclusions to be removed or incorporated into the talc minor chlorite is dispersed in the talc matrix as small lenticular and globular fibrous aggregates. Rare garnet, possibly a member of the ugrandite series because of its anisotropy, occurs as subhedral porphyroblasts.

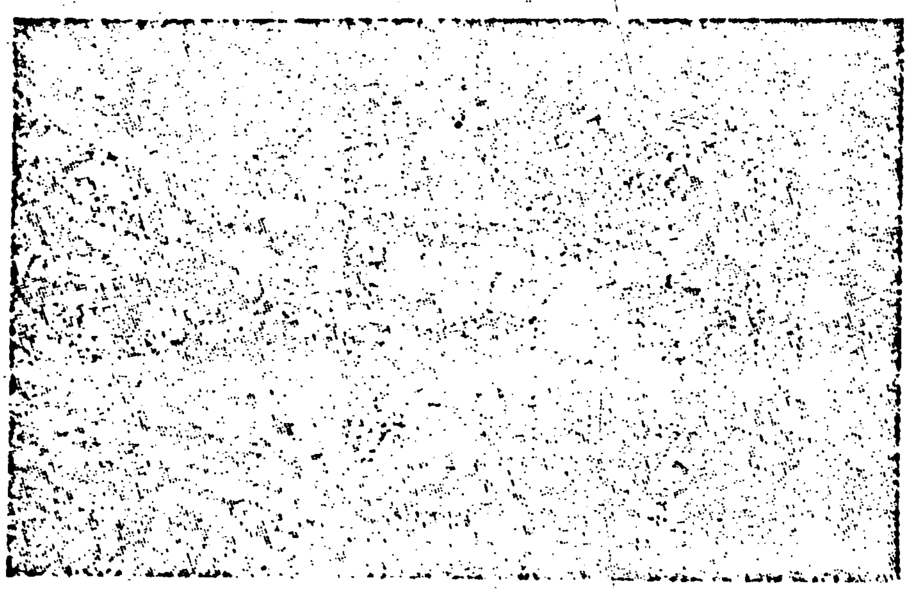


Fig. 2. Photomicrograph, X 24, of thin section of 'coloured talc' specimen I3 under crossed nicols. Dominantly talc (yellow-blue interference colours) showing murky brownish black patches due to presence of fine unidentifiable inclusions.

Specimen I5: general ore

A coarse aggregate of curving foliaceous and feathery crystals of talc displaying evidence of shearing and translation twinning. As in specimen I3, dusty inclusions of a transparent mineral with a general prismatic habit occurs dispersed in the talc. As before, but to a lesser extent, the talc is cleansed of these inclusions along zones associated with deformation and translation twinning, and it appears that the inclusions have either been converted to talc (as in the conversion of tremolite to talc by low temperature CO_2 metasomatism) or incorporated into the talc structure as a result of retrograde deformation metamorphism. Rare small subhedral garnet porphyroblasts also occur.

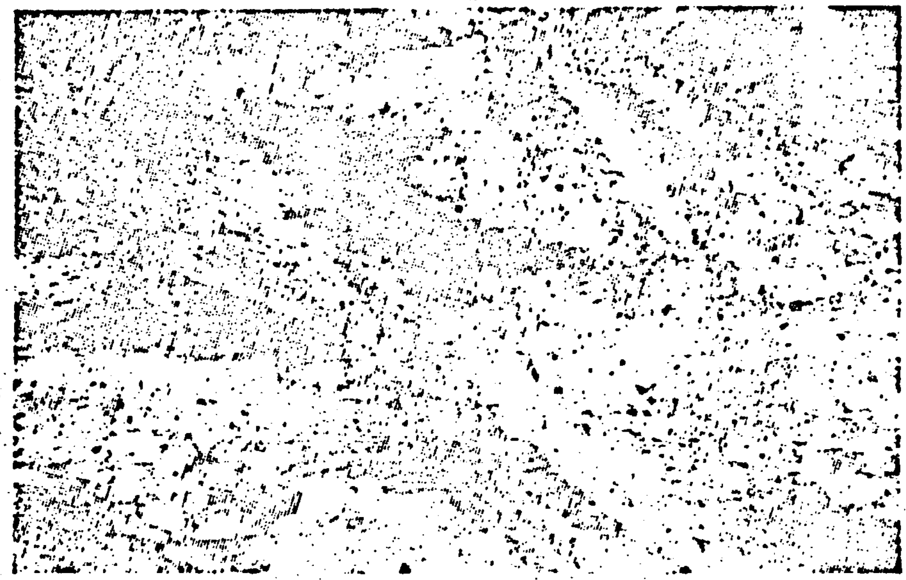


Fig. 3. Photomicrograph, x 24, of thin section of 'general ore' specimen I5 under crossed nicols showing the texture of the talc, and the 'murky' inclusion-rich talc compared to the clear inclusion-free talc.

Specimen I6

Specimen I6 consists of a very coarse aggregate of interlocking anhedral magnesite grains which exhibit strongly irregular and angular penetrating grain boundaries. The magnesite is characterised in thin section, Fig. 3a, by its marked change in relief and perfect rhombohedral cleavage in plane polarised light, and very high order interference colours, Fig. 3b, under crossed nicols.

Intergranular pockets of fine grained foliaceous and radiating prismatic crystals of talc together with rare chlorite (var. sheridanite) occur. In places the prismatic clusters of talc appear to have formed at the expense of the magnesite, perhaps as a result of a retrograde thermal metamorphism with its formation being ascribed to a reaction between the magnesite and silica. One subhedral porphyroblast of plagioclase felspar occurs in the thin section.

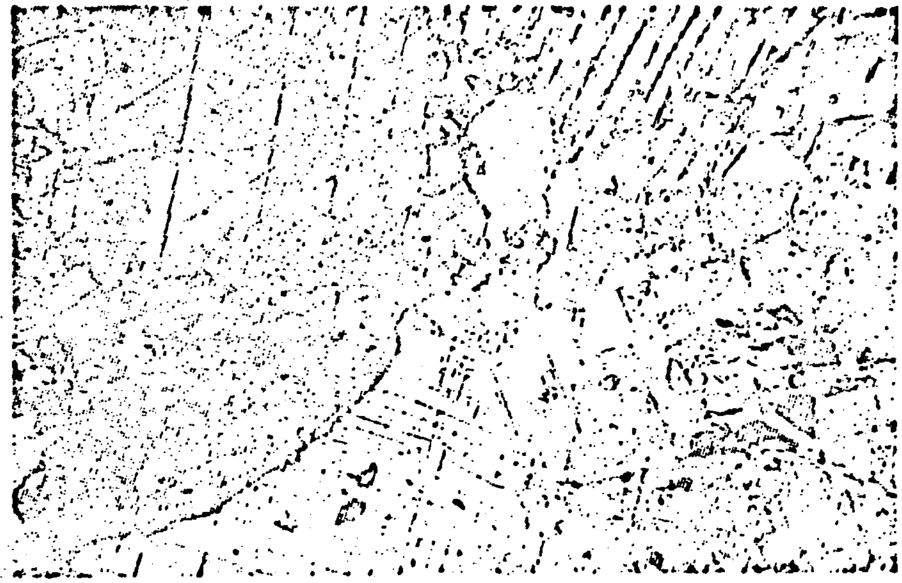


Fig. 3a. Photomicrograph, x 24, of thin section of specimen I_6 under plane polarised light, consisting dominantly of magnesite with minor talc and rare chlorite.

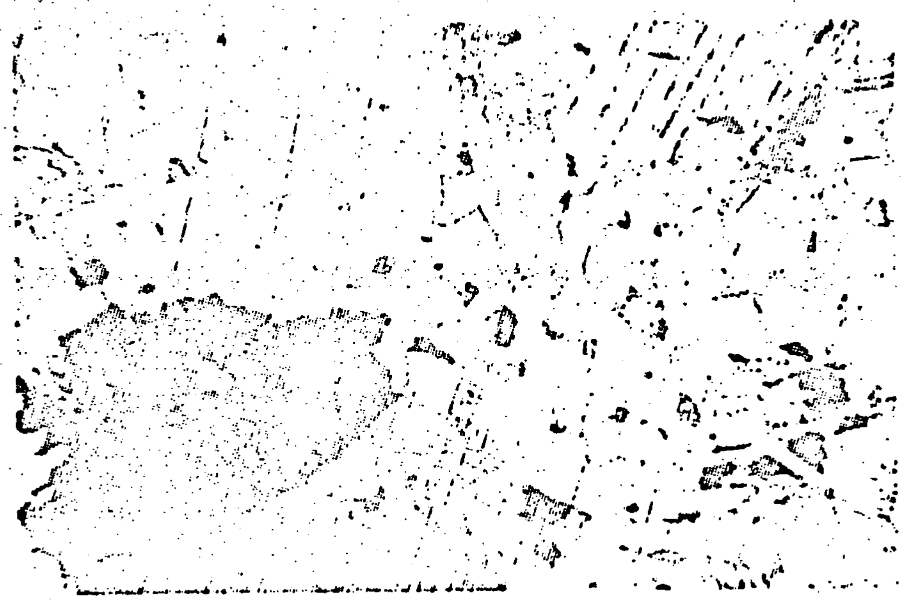


Fig. 3b. Photomicrograph of thin section of specimen I_6, mag x 24, under crossed nicols showing the occurrence of small equigranular and prismatic crystals of talc penetrating and interstitial to coarse anhedral magnesite.

Specimen I7

This specimen of wallrock is a quartz-muscovite-garnet schist (Figs. 4a, 4b, and 4c) containing some accessory actinolite, brown hornblende, talc and rare biotite.

The muscovite (var. phengite) forms long lenticular bands showing a preferred orientation in a matrix of interlocked equigranular quartz grains displaying strongly irregular grain boundaries. Large euhedral porphyroblasts of garnet, forming one of the major phases, are dispersed throughout the rock.

Accessory subhedral tabular and rhombic sections of actinolite (colourless to bluish green pleochroism) occur orientated parallel to the schistosity. The actinolite also occurs as rims to euhedral grains of rhombic and tabular outline which may have originally been brown hornblende but now are pseudomorphed by what appears to be a mixture of talc, chlorite and residual hornblende. Some talc is present as small pockets within the muscovite layers but this identification is based on the form, the lower refractive index and the occurrence of dusty inclusions. The colour, birefringence etc. of the talc is otherwise the same as muscovite.

In polished section the main opaque accessory mineral is pyrrhotite occurring as subhedral laths lying parallel to the schistosity. Traces of chalcopyrite also occur, and some rutile rods mainly as inclusions in the garnet porphyroblasts.

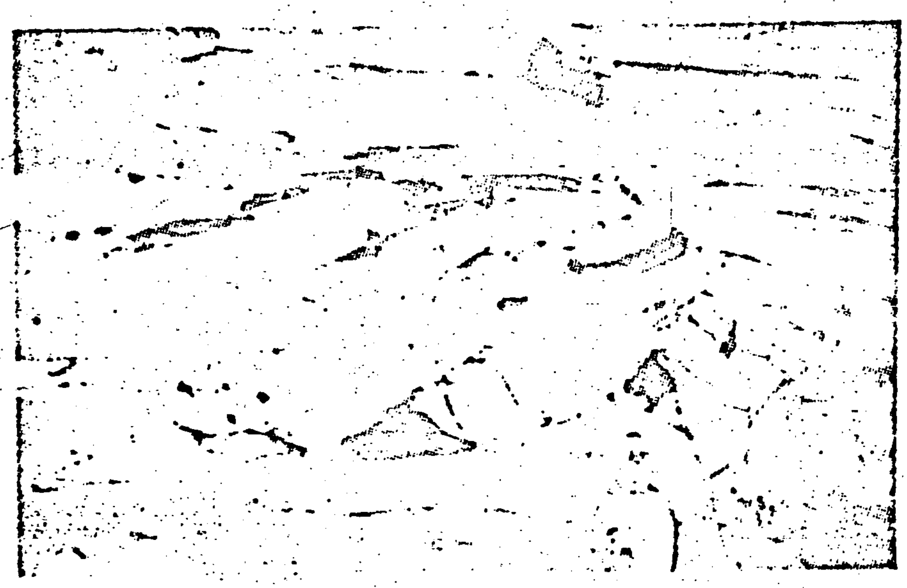


Fig. 4a Photomicrograph of polished section of I7 showing pyrrhotite (white), garnet (light grey), and muscovite-quartz (darker grey). Very dark to black areas are pits in the surface.

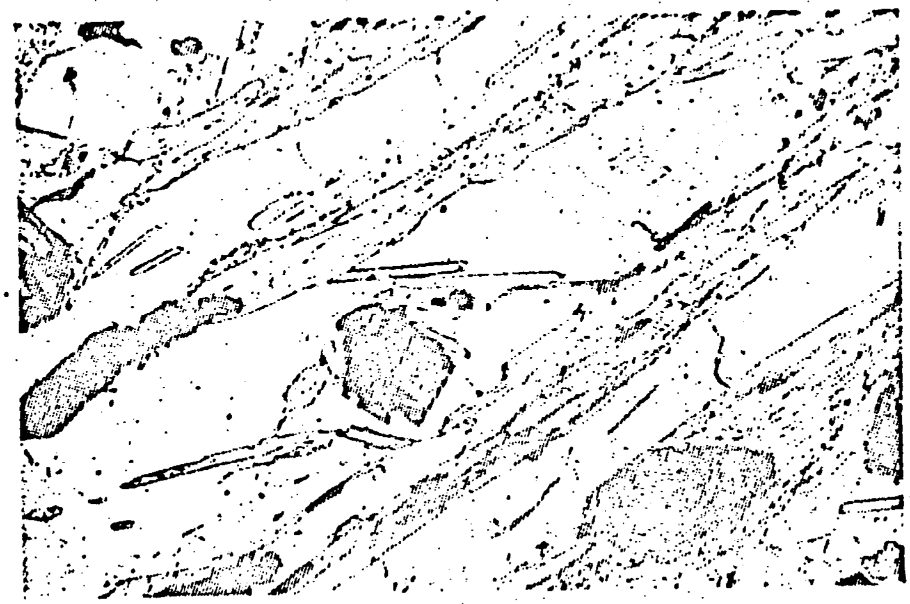


Fig. 4b. Photomicrograph, mag. x 40, of thin section of I7 consisting of garnet, muscovite and quartz under plane polarised light.

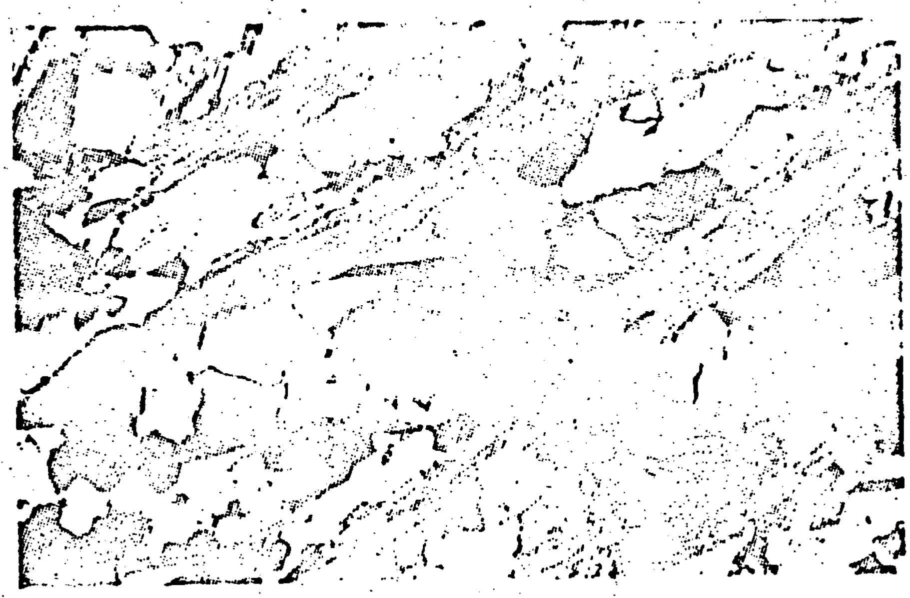


Fig. 4c. Photomicrograph, mag. x 40, of thin section of I7 under crossed nicols showing subhedral garnet (black), anhedral interlocking quartz (white-grey-black), and lamellar muscovite (coloured).

Specimen I_8

In hand specimen I_8 appears as a coarse aggregate of foliaceous talc varying in colour from white to greenish white. The general texture in thin section is of coarse foliated talc preferentially orientated and alternating with long lenses of a finer talc in which a preferred orientation appears to be absent as a result of shearing parallel to the schistosity. Minor chlorite (var. sheridanite) occurs as orientated laths intimately intergrown with the coarse talc and as fibrous aggregates in the finer talc lenses. Rare anhedral garnet, possibly pyrope, occurs.

In thin section the talc which appears greenish in hand specimen is seen to be crowded with minute inclusions of a pinkish mineral occurring as rounded to thin tabular grains and having a lower refractive index than the talc. A grey-brown amorphous material is also present. This material together with the granular inclusions is presumably responsible for the greenish colouration of the talc in hand specimen. As in I_3 and I_5 the greenish talc has been cleansed of inclusions along planes parallel to the schistosity by some later metasomatic process or retrograde metamorphic process. This 'absorbtion' of the inclusions by the talc or removal of the inclusions does not effect the form of aggregation of the talc crystals. Boundaries between the clean transparent and 'murky' talc often transgress the schistosity and there is no change in the coarseness or mode of aggregation of the talc across such boundaries. X-ray diffraction of the transparent white talc and the translucent greenish talc revealed no differences and the composition of these inclusions is at the moment unknown. Figure 5, under crossed nicols, shows such a transgressive boundary between the clear and 'murky' or dusty talc.

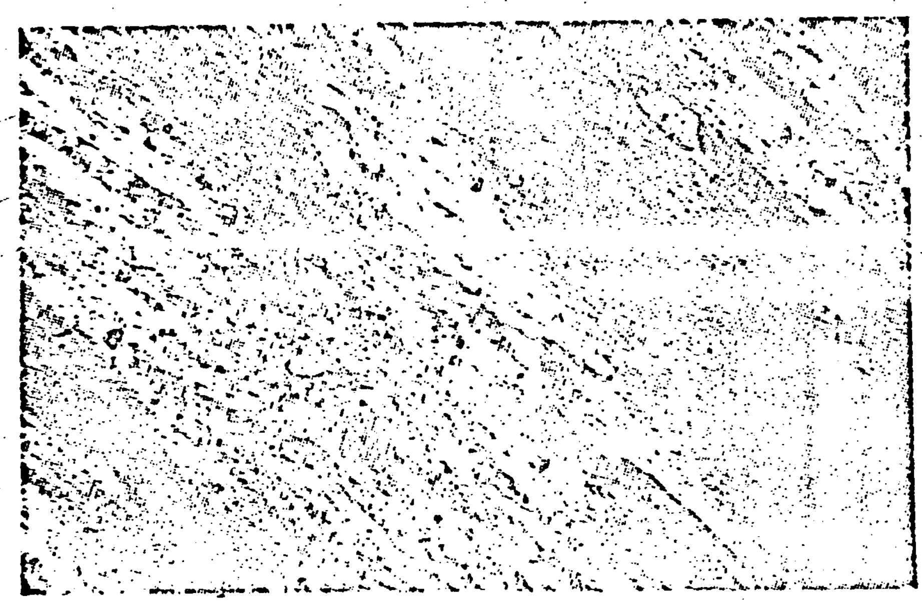


Fig. 5. Photomicrograph, mag x 24, of thin section I_8 showing the nature of the talc intergrowth under crossed nicols, and the transgressive boundaries between clear transparent talc and the inclusion-rich 'murky' talc which appears greenish white in hand specimen.

Specimen I_9: 'Grey talc 1st face'.

In specimen I_9 talc and chlorite (var. sheridanite) are the main constituents. They occur intimately intergrown as long orientated foliaceous aggregates alternating with finer platy aggregates in which the talc and chlorite fibres are randomly orientated and which form lenses elongated parallel to the schistosity of the coarser foliaceous talc (Figs. 6a and 6b). As in previous sections the talc appears murky in parts due to the presence of minute unidentifiable inclusions.

The talc is also crowded with small irregular and rod-shaped grains of rutile . Rarc subhedral porphyroblasts of garnet (possibly pyrope) also occur.

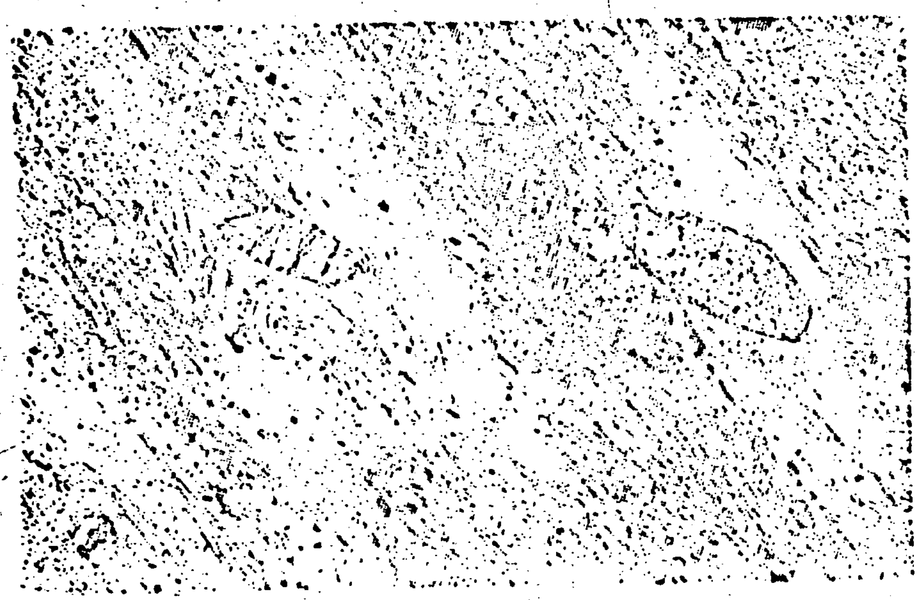


Fig. 6a Photomicrograph, x 40 mag, of thin section I_9 under plane polarised light showing subhedral garnet grains in an orientated foliaceous aggregate of talc and chlorite.

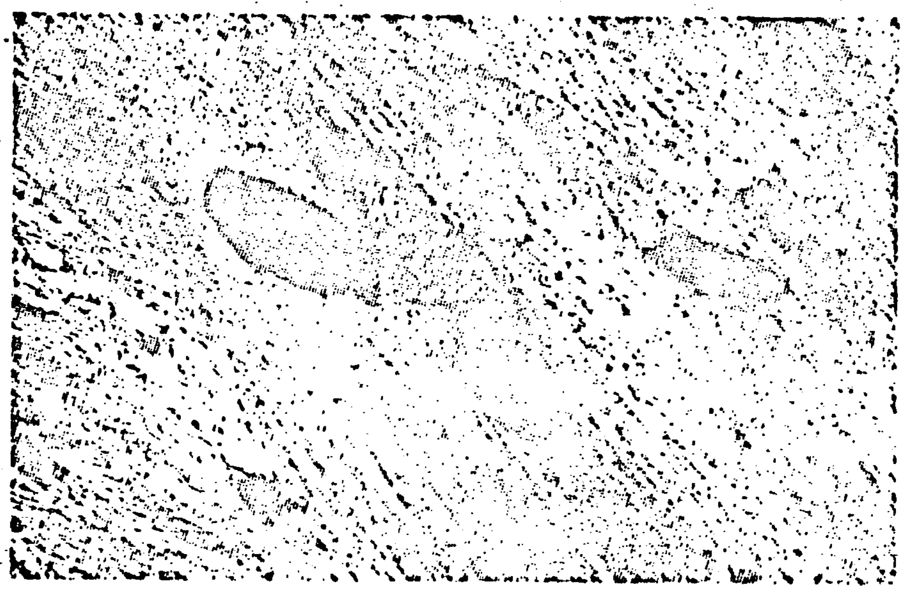


Fig. 6b. Photomicrograph, x 40 mag., of thin section I_9 under crossed nicols showing garnet (black) in a coarse matrix of foliaceous talc (bright interference colours) and chlorite (white to blue-grey interference colours).

Specimen I_{10} and I_{10A}: 'granular talc'

Both I_{10} and I_{10A} consist of an intergrowth of medium grained and randomly orientated major talc with minor chlorite (var. sheridanite) (Fig. 7). Some small porphyroblasts of garnet also occur scattered in the talc/chlorite ground mass. In this specimen the talc is not crowded with inclusions as is the case in most of the other samples.

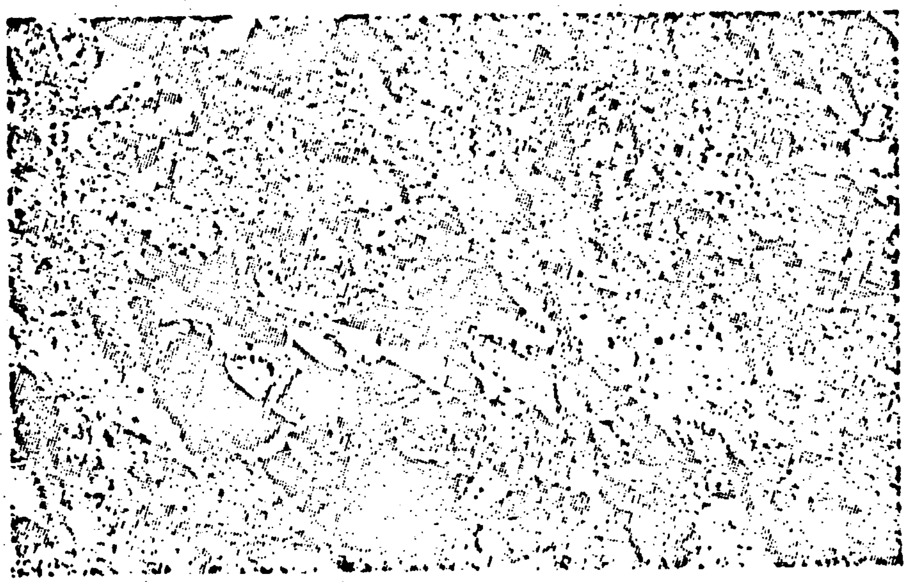


Fig. 7. Photomicrograph, x 40 mag., of thin section I_{10}, under crossed nicols, consisting of talc (blue and yellow interference colours), chlorite (white and greys), and garnet (black).

Specimen I_{11} : 'carbonate and talc'

Specimen I_{11} consists dominantly of a mosaic of coarse to fine grained anhedral interlocking magnesite grains with interstitial pockets of coarse to medium grained foliaceous aggregates of talc (Figs. 8a and 8b). The talc is crowded with near sub-microscopic inclusions of a transparant phase together with a brown amorphous material which causes the talc to appear dusty or turbid in thin section. Some fibrous chlorite (var. sheridanite) occurs as small pockets intergrown with the talc. Traces of rutile and pyrite occur.

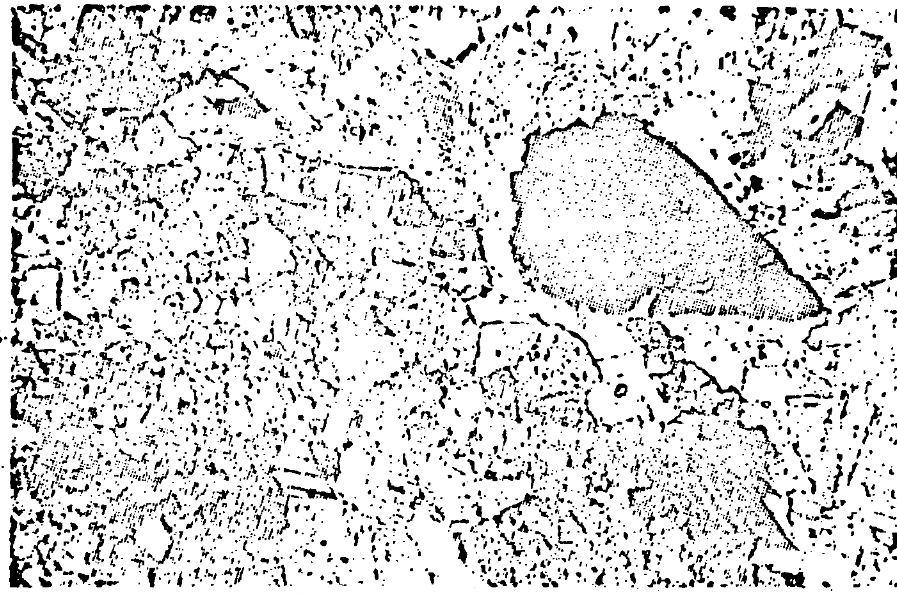


Fig. 8a. Photomicrograph, x 24 mag., of thin section I_{11} under plane polarised light showing a subhedral pyrite metacryst (black) in a matrix of compact granular magnesite with interstitial foliaceous talc (top centre).

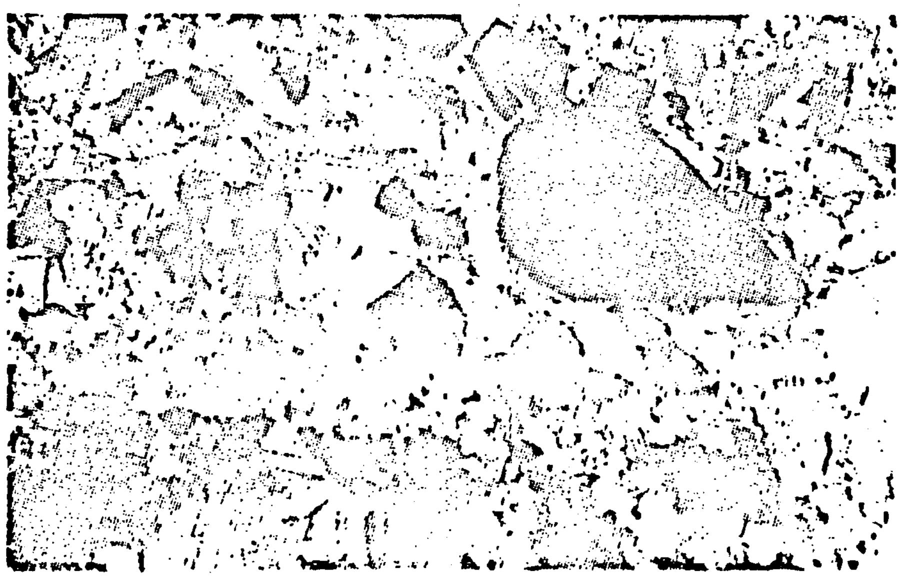


Fig. 8b. Photomicrograph, x 24 mag., of thin section I_{11} under crossed nicols showing a pyrite metacryst (black) in a granular magnesite matrix, with a foliaceous interstitial aggregate of talc (top centre).

Specimen I_{12}

An aggregate of anhedral quartz as the main constituent with minor interstitial muscovite and green chlorite (var. pennine) Fig. 9. The long muscovite laths show a preferred orientation. Chlorite occurs in interstitial pockets as randomly orientated platy grains. Some epidote is present and a trace of magnesite.

The chlorite displays a pleochroism from light green to brownish-cream, and anomalous blue interference colours in some cases. However, most of the chlorite grains display lower second order to upper first order interference colours. Thus a range of chlorite composition is probably represented in the section.

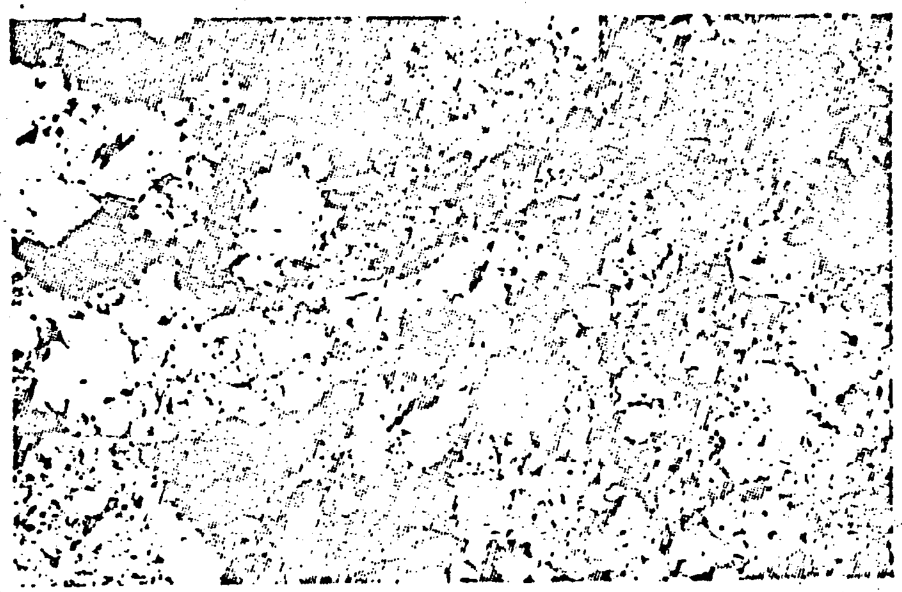


Fig. 9. Photomicrograph, x 40 mag., of thin section I_{12} under crossed nicols.

Specimen I_{13}

This specimen consists of an aggregate of mainly medium grained platy to fibrous chlorite (var. sheridanite) and equigranular quartz. These two enclose ragged replacement residuals of calcite and subhedral metacrysts of pyrite with rare chalcopyrite.

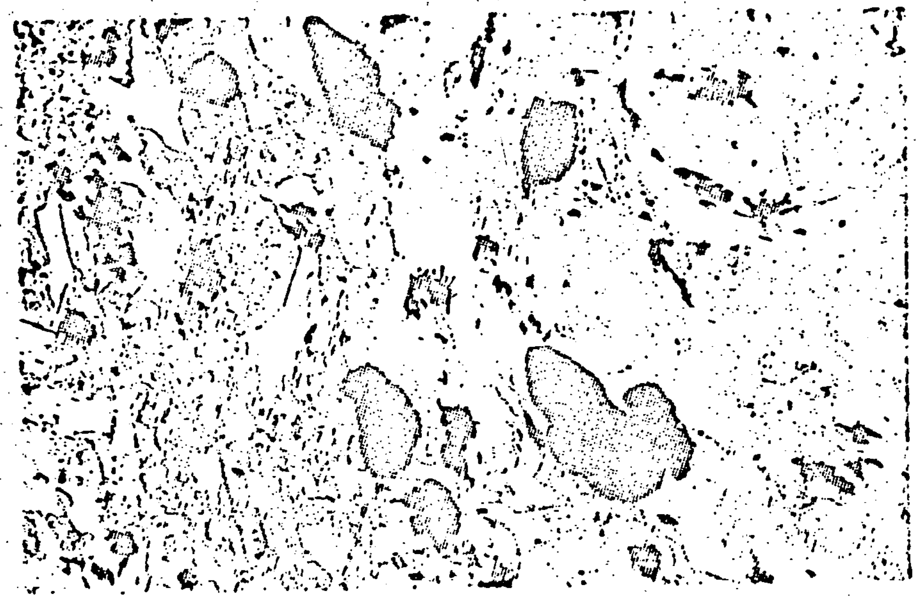


Fig. 10a Photomicrograph, x 40 mag., of thin section I_{13} under PPL showing subhedral pyrite metacrysts (black) in a matrix of dominantly chlorite and quartz with minor calcite.

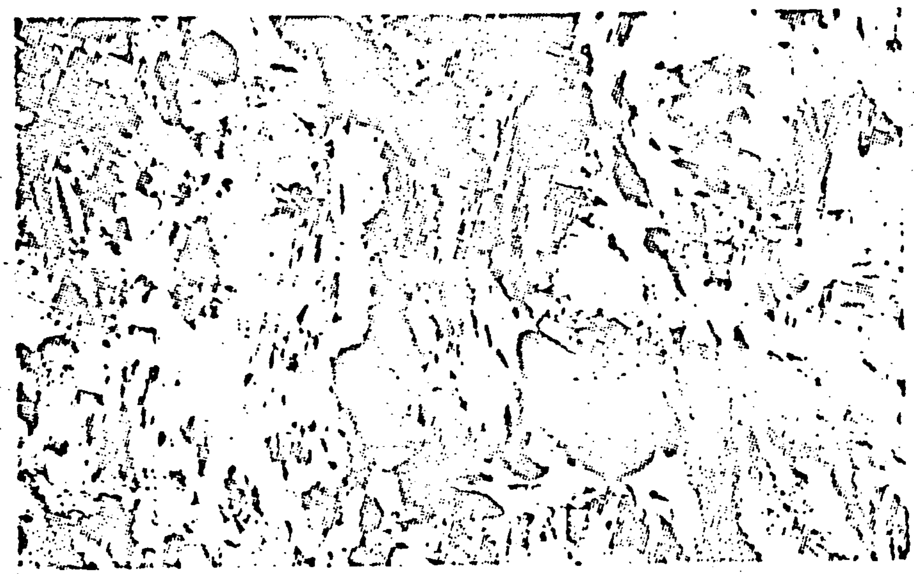


Fig. 10b Photomicrograph, x 40 mag., of thin section I_{13} under XN showing chlorite (fibrous white and greenish-grey) and calcite (coloured) enclosing subhedral grains of pyrite (black). Equigranular grey grains are quartz.

Specimen I_{14}

This specimen is dominantly composed of very coarse grained magnesite enclosing minor amounts of talc and very minor chlorite (var. sheridanite). The talc and chlorite form pockets of radiating lamellar and foliaceous crystals as in Figs. 11a, 11b.

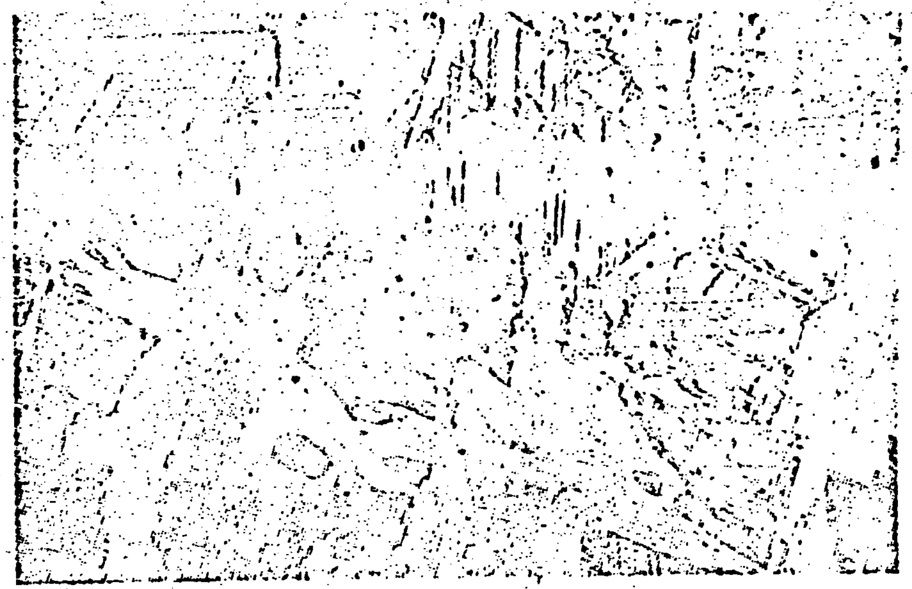


Fig. 11a Photomicrograph, x 24 mag., of thin section I_{14} under PPL of coarse magnesite and intergranular pockets of 'dusty' and 'clear' talc.

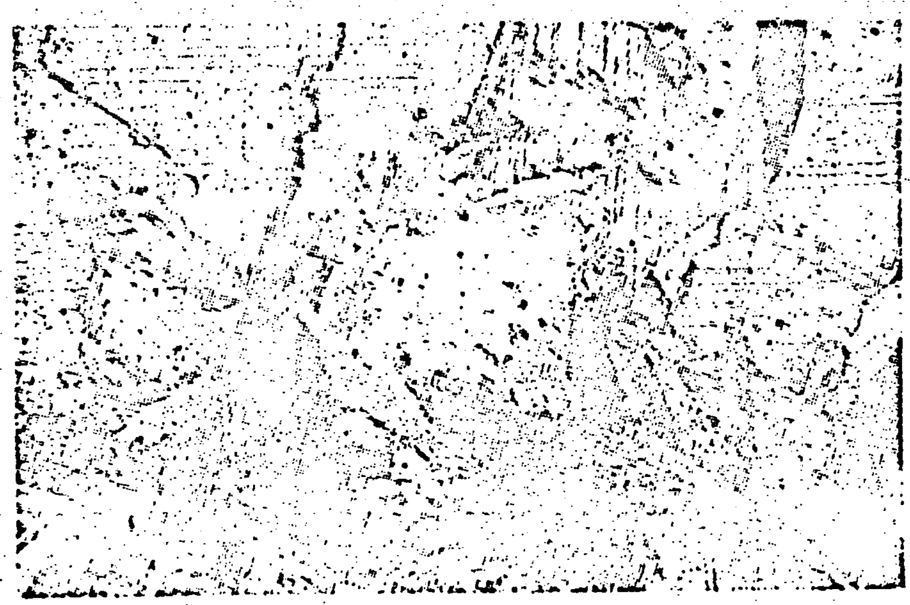


Fig. 11b Photomicrograph, x 24 mag., of thin section I_{14} under XN of magnesite (greenish) and pockets of radiating lamellar talc (blue, purple, yellow).

Specimen I_{15A}

This specimen of wallrock is a garnet-muscovite-quartz schist with minor green chlorite, biotite, and rare talc and feldspar (Figs. 12a and 12b).

The garnet occurs as large (1-3mm diam.) porphyroblasts altered along irregular fractures to a mixture of greenish chlorite, biotite, and some feldspar, and enclosed in a matrix composed of orientated tabular grains of muscovite, forming elongated lenses, and alternating with 'mosaic' granular quartz containing randomly dispersed biotite and chlorite flakes.

Fig. 12a Photomicrograph, x 24 mag., of thin section I_{15A} UNDER PPL showing a large altered porphyroblast of garnet in a matrix of dominantly muscovite with minor quartz.

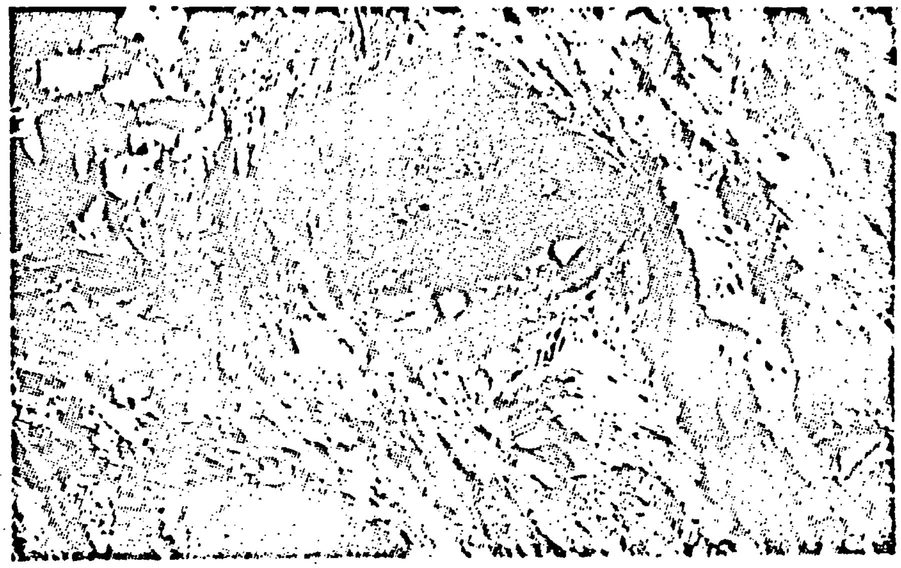


Fig. 12b. Photomicrograph, x 24 mag., of thin section I_{15A} under crossed nicols. Garnet (black). Muscovite (dominantly purple interference colours). Quartz (white and greys).

Specimen I_{15}

This specimen is dominantly composed of chlorite (var. sheridanite) and quartz as orientated aggregates producing a schistosity. Very minor amounts of magnesite and talc occur. The talc occurs as thin laths intergrown with the chlorite (Fig. 13b).

Fig. 13a Photomicrograph, x40 mag., of thin section I_{15} under PPL showing the irregular but preferred elongation of granular quartz segregations in a matrix of fibrous chlorite (var. sheridanite).

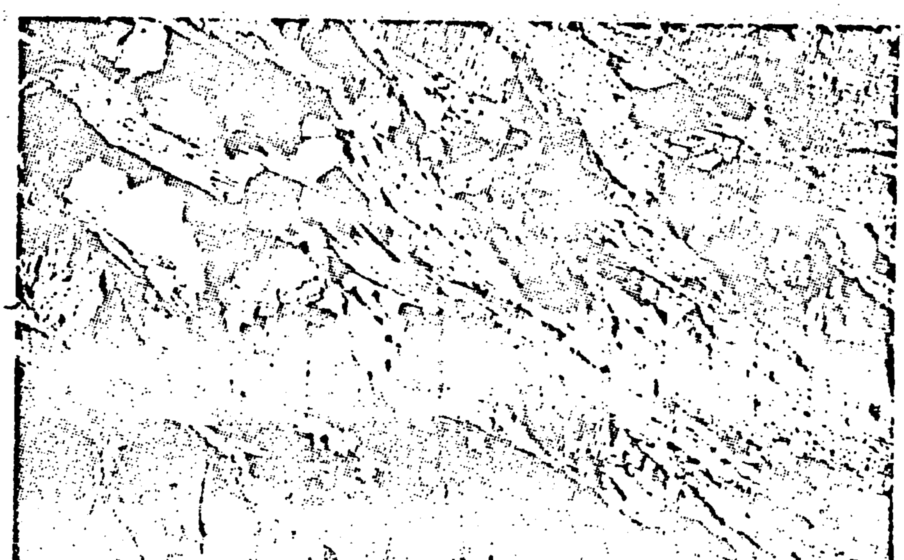


Fig. 13b Photomicrograph, x 40 mag., of thin section I_{15} under XN, composed of chlorite (fibrous white, greenish grey, black), quartz (granular white-grey-black), and talc (blue, red, and yellow interference colours).

Specimen I_{16}: 'first face inclusion'

This specimen is composed of a medium grained aggregate of dominantly chlorite (var. sheridanite) and quartz, with minor magnesite, clinozoisite, talc, and muscovite, and displaying a poor schistosity. Scattered euhedral to subhedral pyrite metacrysts occur as well as medium grained crystal aggregates of rutile associated with clinozoisite forming 'stringers' parallel to the general schistosity of the rock.

In the photomicrograph of figure 14a the brownish speckled areas are dominantly chlorite although in Figure 14b talc and muscovite are more apparent because of their interference colours.

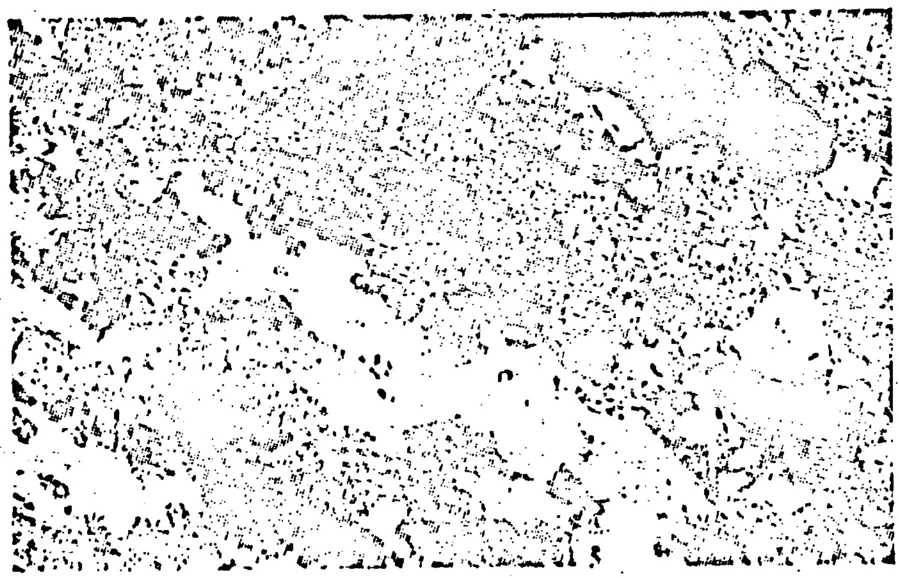


Figure 14a Photomicrograph, x 40 mag., of thin section I_{16} under PPL.

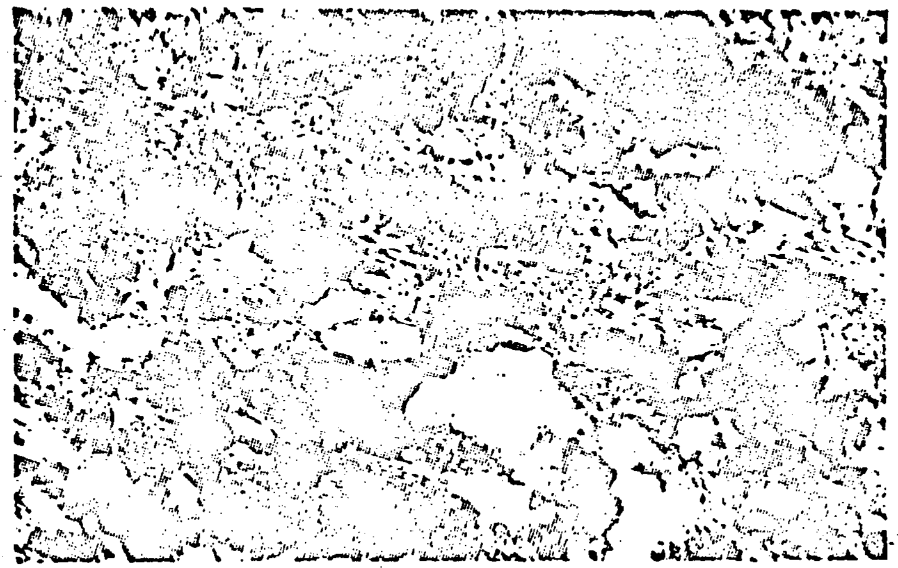


Fig. 14b Photomicrograph, x 40 mag., of thin section I_{16} under crossed nicols. A chlorite - quartz rock with minor talc and muscovite, and accessory magnesite, clinozoisite, rutile and pyrite.

Specimen I_{17}: 'footwall'

This specimen of footwall rock is a muscovite-quartz-garnet schist consisting of long lenticular anhedral quartz aggregates. Both are enclosing fractured and altered euhedral porphyroblasts of garnet. Accessory sphene also occurs as well as serpentine-quartz pseudomorphs after a mineral displaying rhombic and tabular sections.

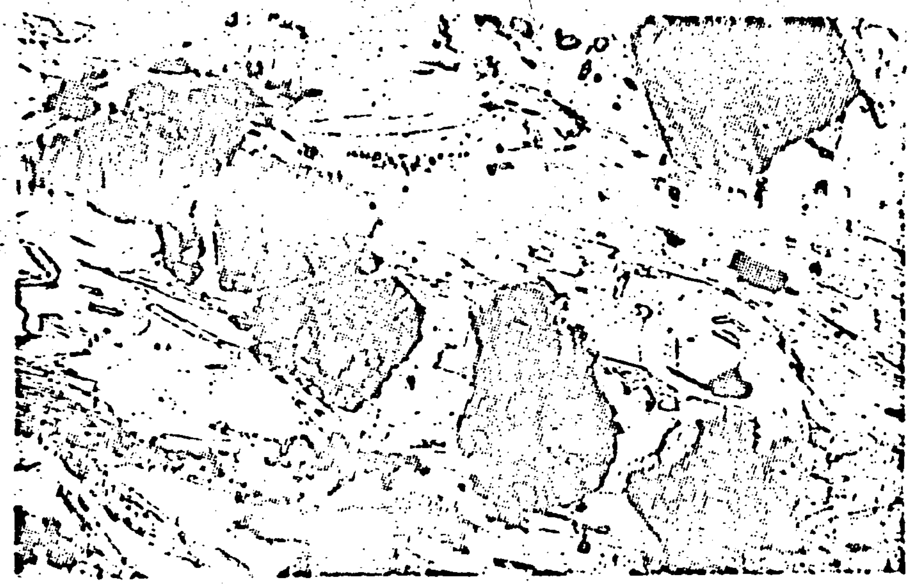


Fig. 15a Photomicrograph, x 24 mag., of thin section I_{17} under PPL showing garnet euhedra in a matrix of segregated quartz and muscovite.

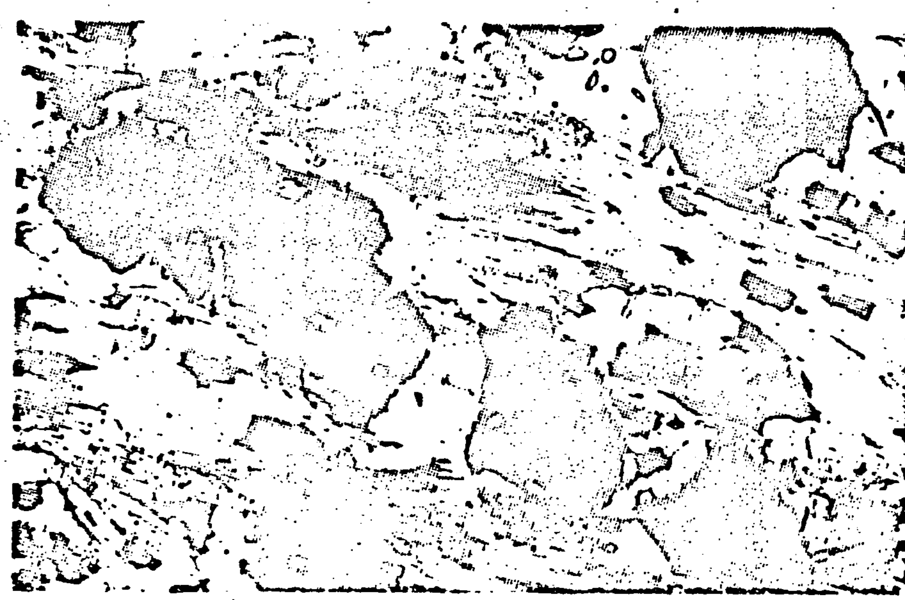


Fig. 15b Photomicrograph, x 24 mag., of thin section I_{17} under XN. Garnet (black), quartz (white to grey), and muscovite (lamellar and coloured).

Specimen I_{18}: 'Face 3, carbonate/talc'

A coarse to medium grained aggregate of subhedral interlocking grains of magnesite with minor talc occurring as scattered small interstitial clusters associated with rare chlorite (var. sheridanite) and muscovite (Figs. 16a, 16b).

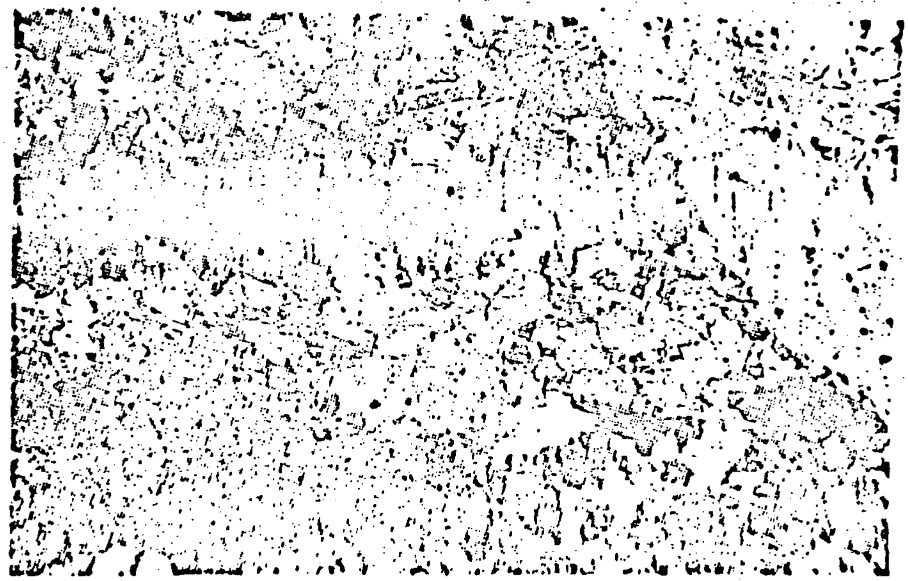


Fig. 16a Photomicrograph, x 24 mag., of thin section I_{18} under PPL of granular magnesite with scattered tabular crystals and clusters of talc.

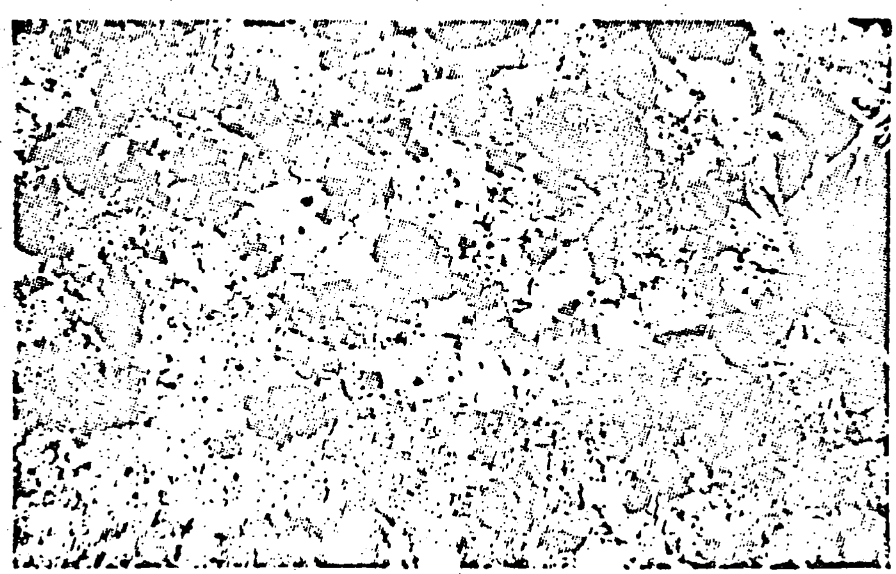


Fig. 16b Photomicrograph, x 24 mag., of thin section I_{18} under XN of granular magnesite (high order interference colours, and scattered tabular crystals and clusters of talc (top right, coloured) and rare chlorite (white to blue-grey colours).

Specimen I_{19}:

This specimen consists of an aggregate of coarse grained anhedral magnesite intergrown with solitary bladed crystals and crystal aggregates of tremolite associated with minor amounts of fine fibrous talc and rare anhedral grains of quartz (Figs. 17a, 17b).

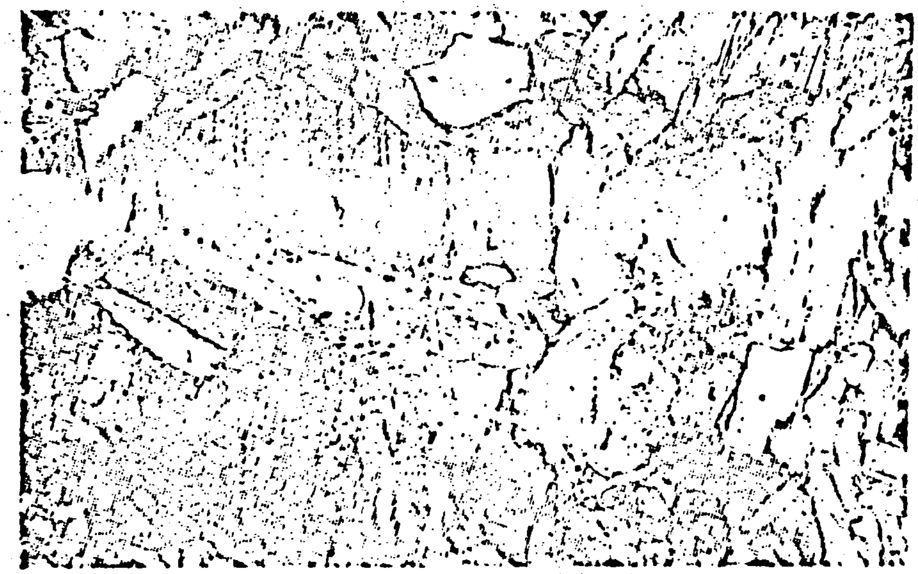


Fig. 17a Photomicrograph, x 24 mag., of thin section of I_{19} under PPL, showing coarse bladed tremolite intergrown with very coarse grained magnesite.

Fig. 17b Photomicrograph, x 24 mag., of thin section I_{19} under crossed nicols showing coarse bladed tremolite and anhedral coarse-grained magnesite with minor small fibrous aggregates of talc (top left)..

Specimen I_{21}: 'Inclusion, face 2'.

Specimen I_{21} is composed of a fine grained interlocking aggregate of anhedral magnesite, as the major constituent, associated with scattered laths and interstitial fine-grained fibrous aggregates of very minor talc (Figs. 18a and 18b).

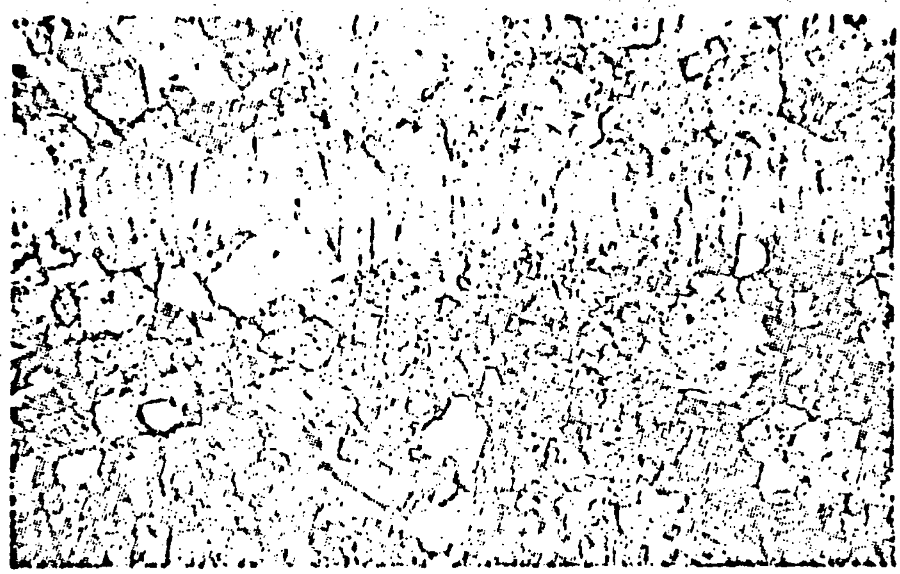


Fig. 18a Photomicrograph, x 24 mag., of thin section I_{21} under PPL. Magnesite with rare talc.

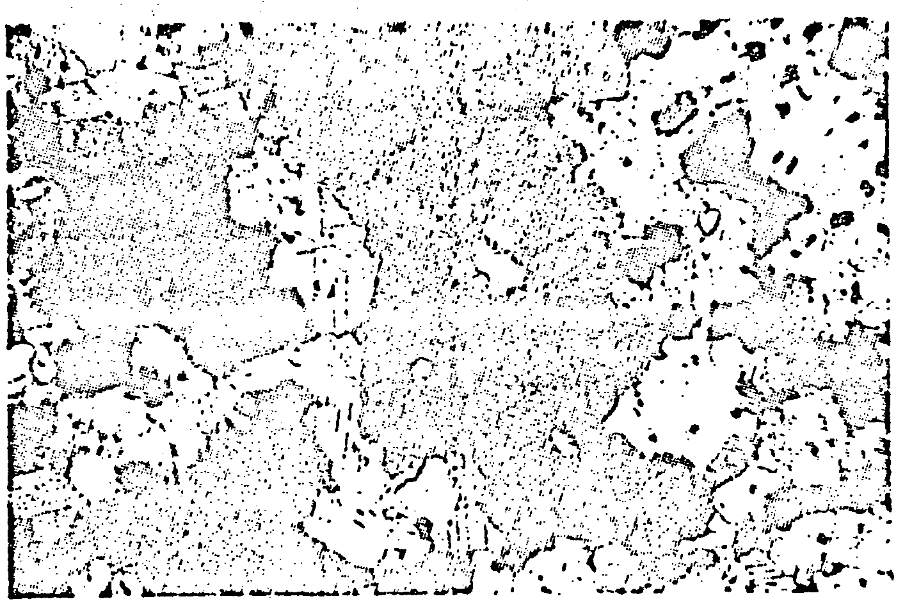


Fig. 18b Photomicrograph, x 24 mag., of thin section I_{21} under crossed nicols. Magnesite with rare talc.

Specimen I_{22}

This specimen is dominantly composed of coarse subhedral to euhedral interlocking grains of magnesite associated with intergranular fibrous clusters of talc which often enclose smaller euhedral magnesite grains (Fig. 19).

Fig. 19 Photomicrograph, x 24 magnification, of thin section I_{22} under plane polarised light. Magnesite and interstitial aggregates of talc.

Specimen I_{23}: 'Black Gneiss 2' below talc vein'

Specimen I_{23} consists dominantly of medium grained anhedral interlocking quartz as orientated bands enclosing large microcline anhedra and anhedral aggregates. Scattered platy aggregates of muscovite occur orientated parallel to the general direction of the quartz banding. Minor epidote and chlorite also occur (Figs. 20a and 20b).

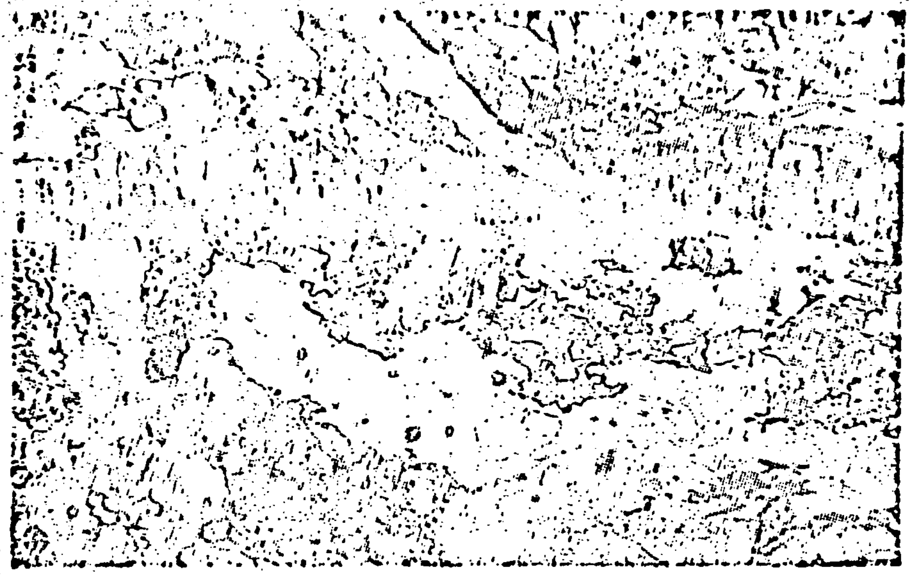


Fig. 20a Photomicrograph, x 24 mag., of thin section I_{23} under PPL. Quartz-muscovite-microcline gneiss.

Fig. 20b Photomicrograph, x 24 mag., of thin section I_{23} under XN. Quartz-muscovite-microcline gneiss.

Specimen I_{24}: 'Face 2, Talc next to carbonate'

This specimen of talc ore consists dominantly of coarse fibrous talc with minor chlorite (var. sheridanite) occurring as small lenticular fibrous aggregates within the main mass of talc (Figs. 21a and 21b). A few small subhedra of garnet are present. As in previous specimens there are two forms of talc present: (1) a talc that in thin section appears brown (Fig.21a) under plane polarised light due to finely dispersed dusty inclusions of a transparant mineral and a brown amorphous material, (2) a clear transparant talc free of inclusions which appears to have been formed at the expense of the other by some metasomatic 'cleansing' process. Talc crystals in optical continuity can be seen to change sharply from 'dusty' brown talc to the clear talc.

Fig.21a Photomicrograph, x 24 mag., of thin section I_{24} under PPL. 'Dusty' and clear talc enclosing small lenticular aggregates of chlorite.

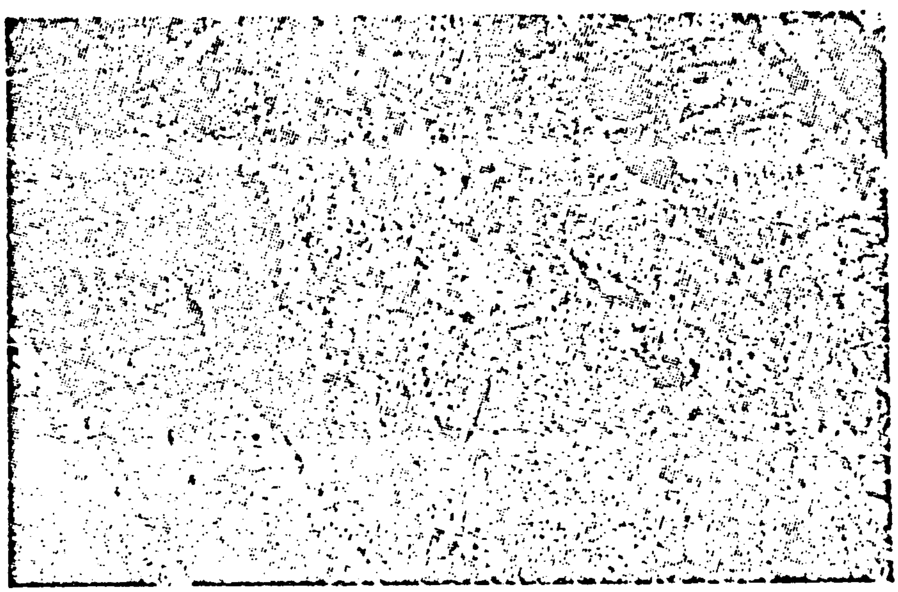


Fig.21b Photomicrograph, x24 mag., of thin section I_{24} under XN.

Specimen I_{25}

This specimen of footwall rock consists of an interlocking aggregate of medium grained anhedral quartz enclosing occasional large anhedra of microcline feldspar (Figs. 22a,22b). Minor magnesite occurs as pockets interstitial to the quartz, and also scattered laths of muscovite. Green chlorite (pennine) and epidote occur in trace amounts.

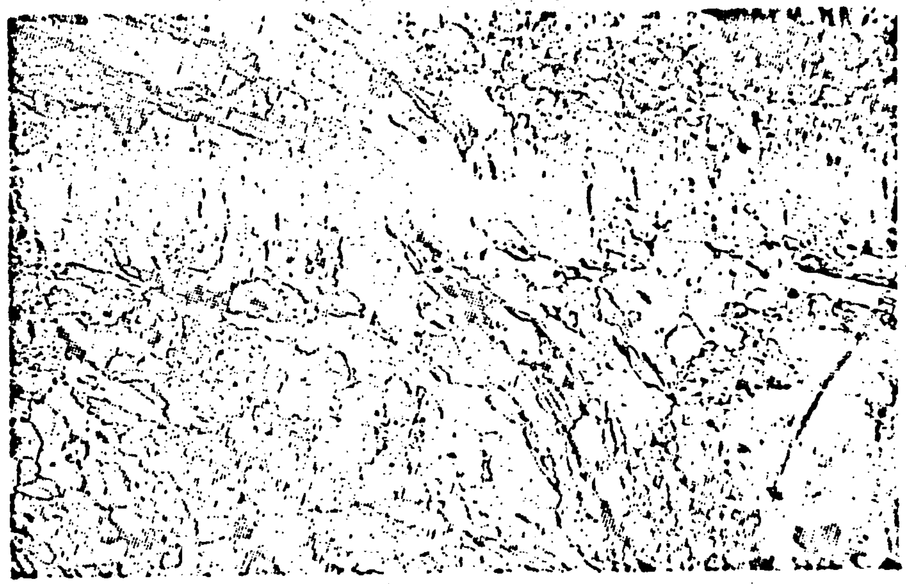


Fig. 22a Photomicrograph, x 24 mag., of thin section I_{25} under PPL; dominantly a quartz-microcline rock with minor muscovite and rare pennine and epidote.

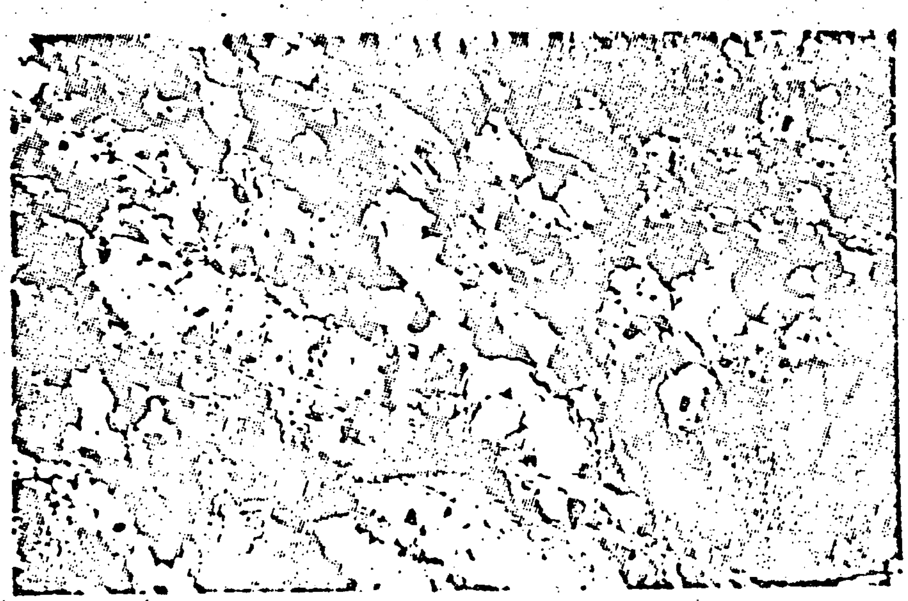


Fig. 22b Photomicrograph, x 24 mag., of thin section I_{25} under XN.

Specimen I26

This specimen contains chlorite, talc, magnesite and rutile. One part of the thin section consisted of a massive coarse fibrous and feathery aggregate of talc enclosing pockets of coarse magnesite. This texture graded into one which was dominantly fine grained chlorite (var. sheridanite) intimately intergrown with minor quantities of fibrous and platy talc (Fig. 23) as well as scattered small equigranular and rod-shaped rutile crystals.

Fig. 23. Photomicrograph, x 40 mag., of thin section I26 under crossed nicols showing minor talc (coloured) intimately intergrown with major chlorite.

Specimen I_{27}

Specimen I_{27} is dominantly composed of quartz, chlorite (var. sheridanite) and talc (Figs. 24a and 24b). Thin lenticular bands of coarse feathery talc and chlorite alternate with anhedral granular interlocking aggregates of quartz. Scattered inclusions of rutile and epidote occur, as well as occasional large microcline anhedra.

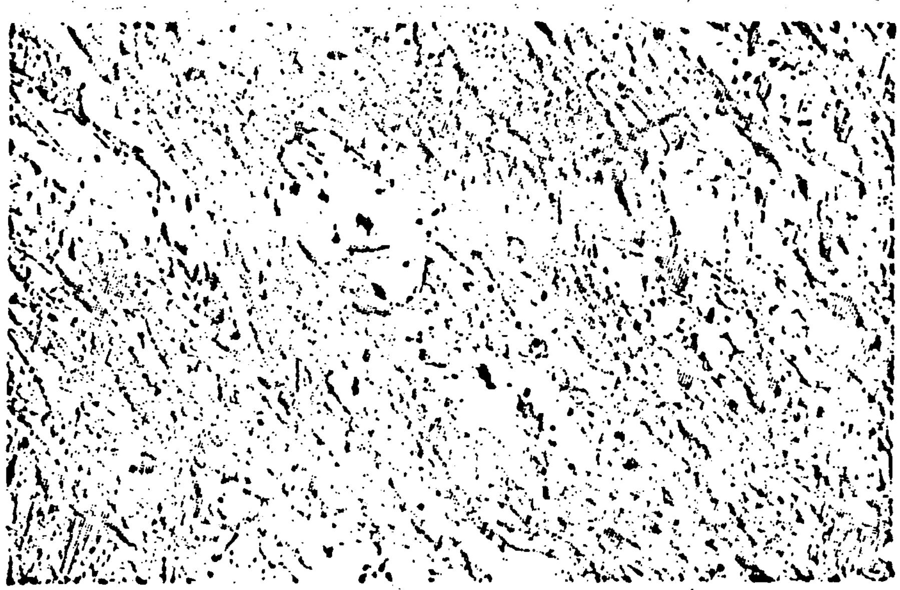


Fig. 24a Photomicrograph, x 40 mag., of thin section I_{27} under PPL, showing a fibrous and feathery aggregate of talc and chlorite enclosing anhedral segregations of quartz.

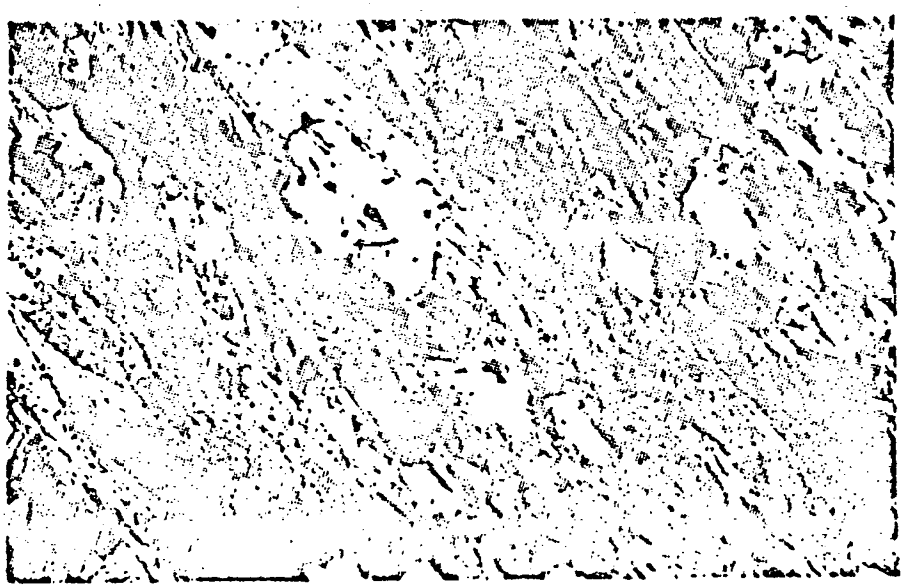


Fig. 24b Photomicrograph, x 40 mag., of thin section I_{27} under XN.

Specimen I_{29}

Specimen I_{29} is a gneissic rock consisting of segregated bands of medium to fine interlocking nhedral quartz grains alternating with minor muscovite as orientated platy clusters and enclosing large microcline anhedra. Some rare pennine and very rare epidote occur intergrown with the muscovite.

Fig. 25a Photomicrograph, x 24 mag., of thin section I_{29} under PPL; quartz, muscovite, and microcline (top left)

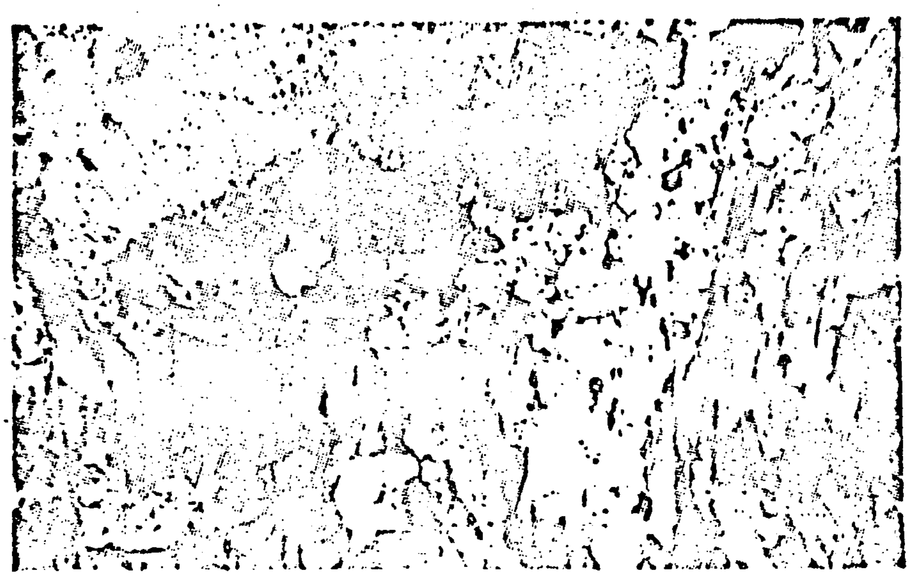


Fig. 25b Photomicrograph, x 24 mag., of thin section I_{29} under XN.

Specimen I_{31}

Specimen I_{31} is a muscovite-quartz schist containing minor pennine, sphene and tremolite.

The rock is dominantly made up of coarse orientated lamellar segregations of muscovite intergrown with flakes of minor greenish brown chlorite (pennine) and enclosing euhedral to subhedral grains of sphene. Minor interlocking fine to medium grained quartz segregations occur alternating with the muscovite bands. Hexagonal sections of an amphibole, probably tremolite, occur dispersed in the muscovite matrix.

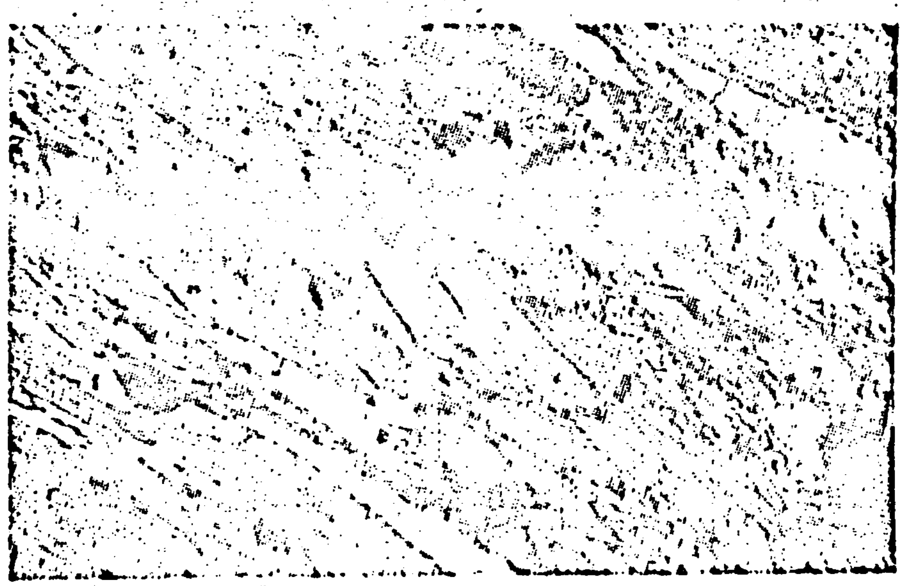


Fig. 26a Photomicrograph, x 40 mag., of thin section I_{31} under PPL; muscovite-quartz schist.

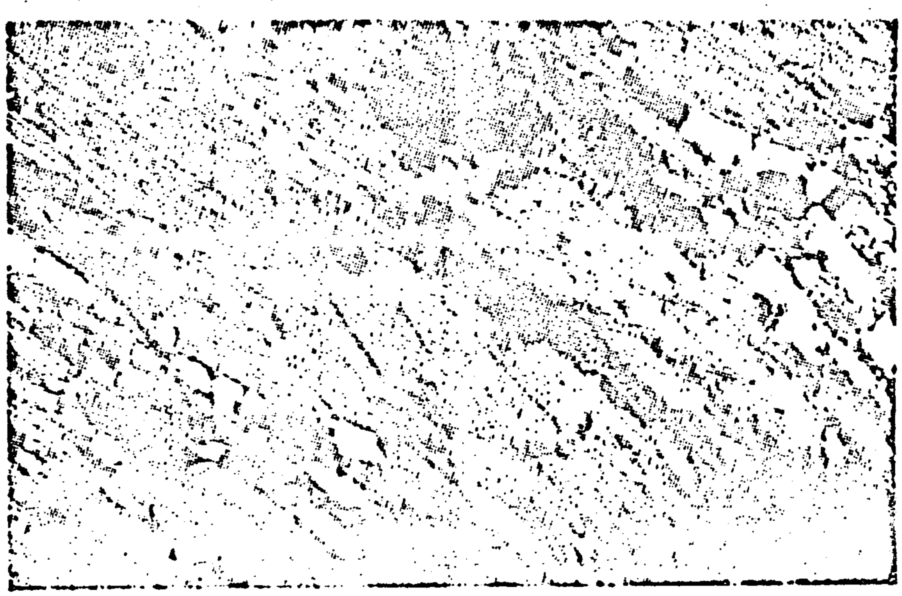


Fig. 26b Photomicrograph, x 40 mag., of thin section I_{31} under XN; muscovite-quartz schist.

Specimen I_{32}

This specimen consists of coarse feathery lenticular aggregates of dominantly chlorite (var. sheridanite) intimately intergrown with minor amounts of talc (Figs. 27a and 27b).

Small inclusions of rutile occur along the boundaries (shear planes) between the chlorite aggregates and also along chlorite cleavage planes. Finely dispersed submicroscopic dusty inclusions of an unidentified phase similar to that found in talc occur in the chlorite.

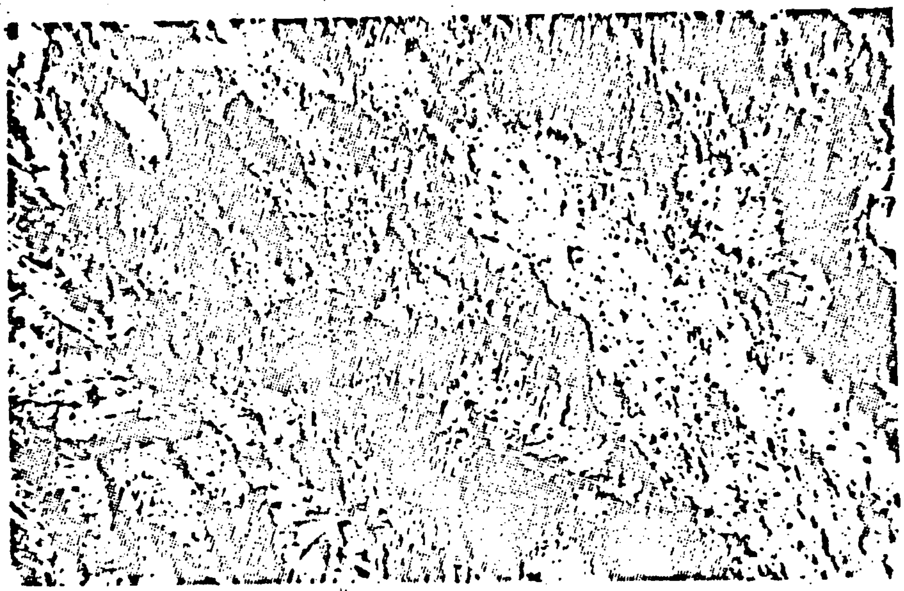


Fig. 27a Photomicrograph, x 24 mag., of thin section I_{32} under XN. Feathery aggregates of sheared chlorite (white to greenish grey to black) with minor talc (coloured).

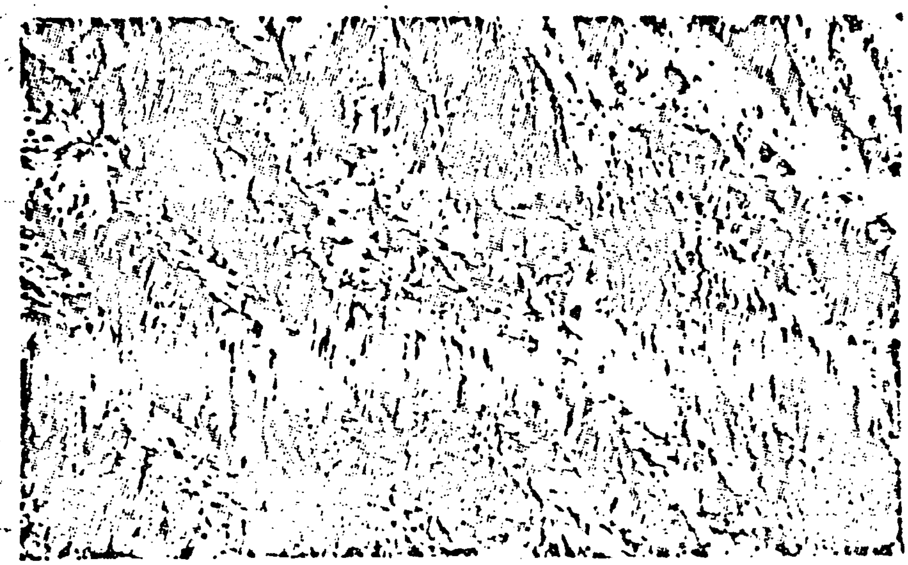


Fig. 27b Photomicrograph, x 24 mag., of thin section I_{32} under XN. Finer grained chlorite-talc mixture.

Specimen I_{33}

This specimen of talc ore consists of a medium to fine grained randomly orientated intergrowth of dominantly talc with minor chlorite (var. sheridanite). The chlorite is intimately mixed with the talc (Fig. 28). Some pockets of coarse interlocking anhedral magnesite grains occur enclosed by the talc-chlorite matrix.

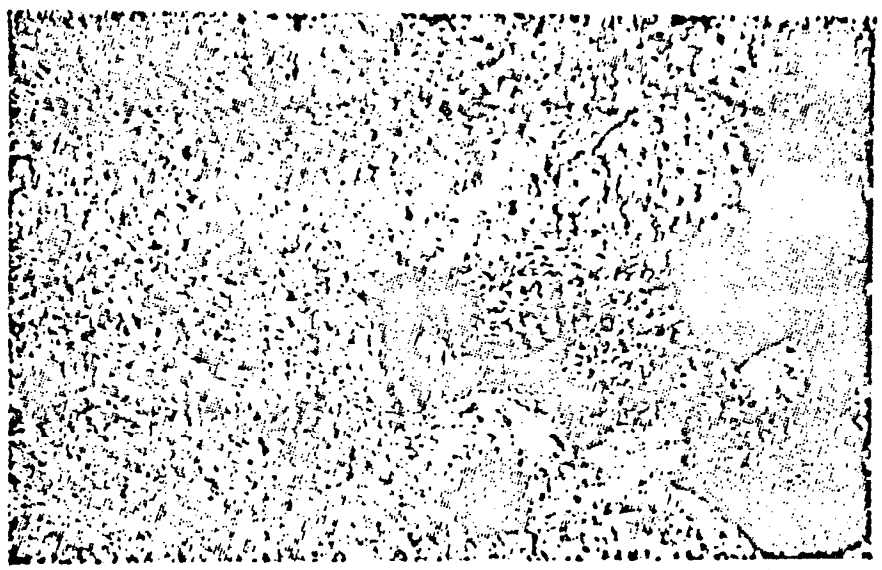


Fig. 28 Photomicrograph, x 24 mag., of thin section I_{33} under XN.

Specimen I35

This specimen consists dominantly of magnesite as a very coarse to medium grained interlocking aggregate of euhedral to subhedral grains. Minor tremolite occurs as long prismatic crystals forming interstitial clusters, and as solitary crystals penetrating the magnesite and along the grain boundaries of the magnesite. Minor chlorite (var. sheridanite) and rare talc occur associated with the tremolite segregations. (Figs. 29a, 29b).

Fig. 29a Photomicrograph, x 24 mag., of thin section I35 under PPL. Magnesite-tremolite-chlorite-talc rock.

Fig. 29b Photomicrograph, x 24 mag., of thin section I35 under XN. Prismatic tremolite in magnesite in the extinction position.

Specimen I37

This specimen consists dominantly of magnesite with minor talc. The magnesite occurs as an aggregate of very large magnesite anhedra enclosed by finer grained subhedral magnesite which is intergrown with feathery intergranular clusters of talc (Fig. 30).

Fig. 30 Photomicrograph of thin section I37, x 24 mag., under XN showing the finer intergranular magnesite associated with small laths of talc (fibrous and coloured).

Specimen I_{39}

This specimen is dominantly composed of talc forming coarse feathery aggregates intimately intergrown with minor finer grained chlorite (var. sheridanite) and containing fine disseminated inclusions of rutile. Occasional fine grained quartz as well as larger oval-shaped augen of quartz and rare garnet occur scattered throughout the talc matrix. The talc is for the most part crowded with inclusions, as in previous sections, but elongate areas of 'clean' talc occur as in Fig. 31a.

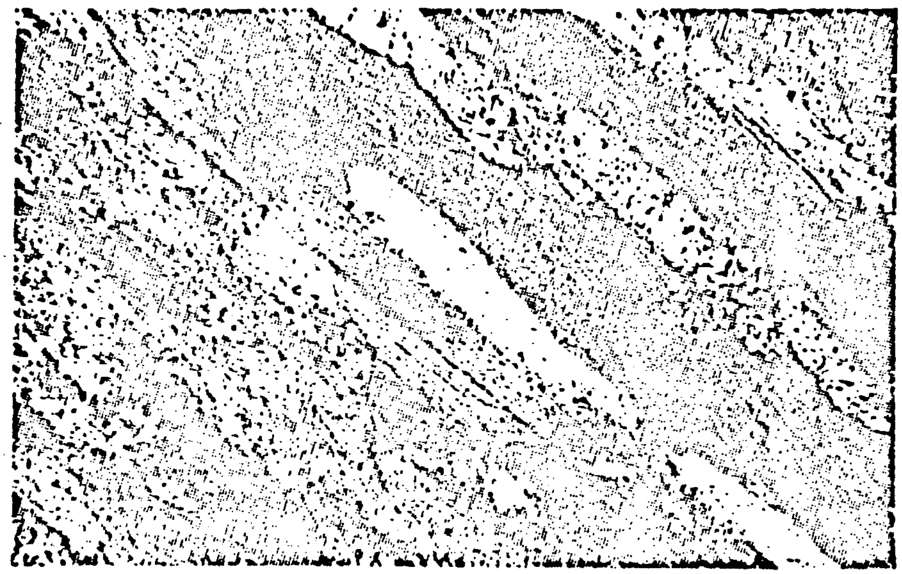


Fig. 31a Photomicrograph, x 24 mag., of thin section I_{39} under PPL.

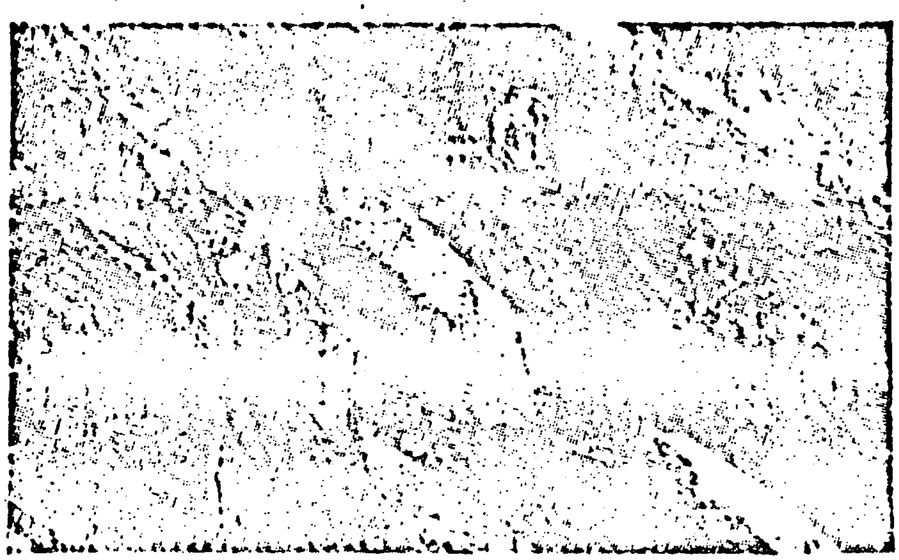


Fig. 31b Photomicrograph, x 24 mag., of thin section I_{39}, under XN

Specimen I_{41}

This specimen of talc ore consists of a coarse aggregate of feathery talc intimately intergrown with minor chlorite (var. sheridanite), and enclosing rare large porphyroblasts of subhedral garnet which occasionally contain long prismatic inclusions of tremolite (Fig.32a).

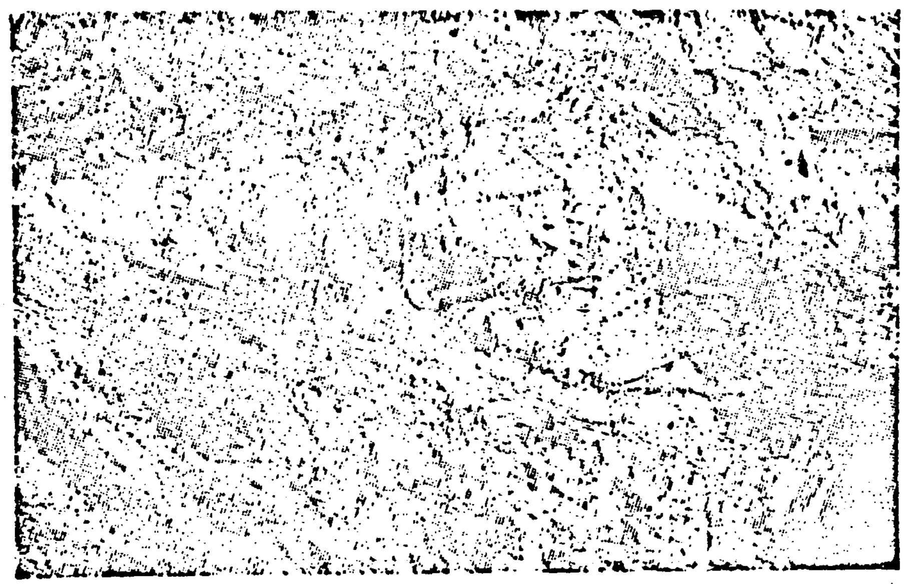


Fig. 32a Photomicrograph, x 24 mag., of thin section I_{41} under XN. Feathery aggregate of talc with garnet porphyroblast (bottom right, black).

Specimen I42: 'No.1 Face, green coloured'

Specimen I42 consists dominantly of an aggregate of fine grained fibrous chlorite (var. sheridanite) intimately intergrown with minor very fine grained talc as in Fig. 33.

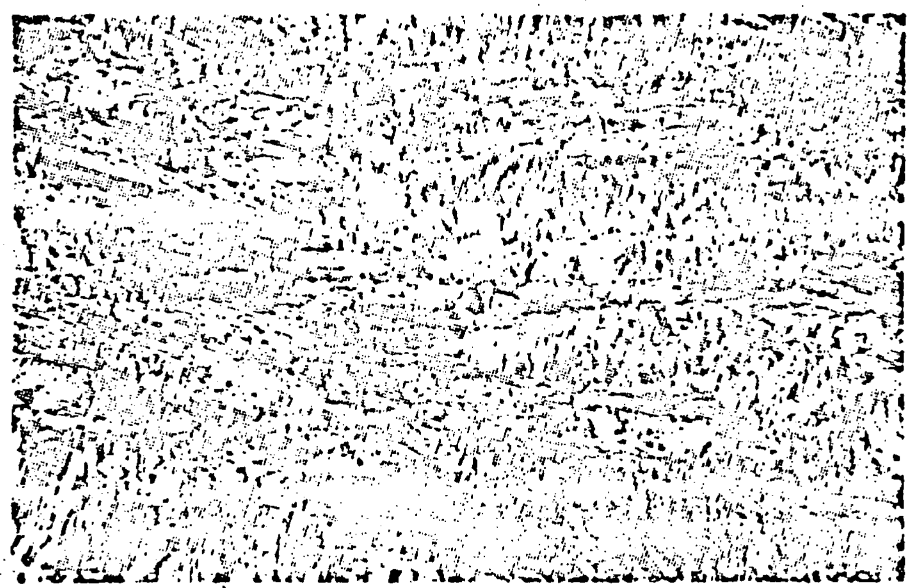


Fig. 33 Photomicrograph, x 24 mag., of thin section I42 under crossed nicols of chlorite (white, greenish grey, black), and fine grained talc (yellow).

Specimen I43: 'Face 10 fibrous sample'

Specimen I43 consists dominantly of chlorite (var. sheridanite), occurring in the form of a coarse sheared fibrous aggregate intimately intergrown with very minor talc as in Figure 34.

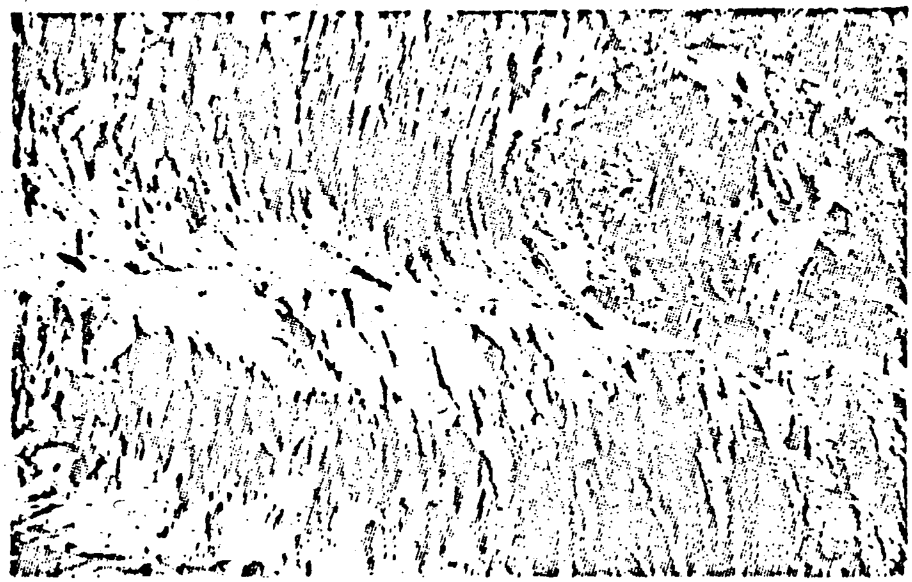


Fig. 34 Photomicrograph, x 40 mag., of thin section I43 unde crossed nicols showing deformed fibrous chlorite (white-greenish grey-black) intergrown with platy and prismatic crystals of talc (coloured).

Specimen I43A

As for I43 the specimen consisted dominantly of chlorite (var. sheridanite) with very minor talc. The 'cross fibre' type texture found in I43 and produced by shearing at right angles to the schistosity was absent in specimen I43A.

Specimen I_{44}: 'First face pure talc"

A coarse aggregate of lamellar talc showing a preferred orientation and enclosing augen of what appears to be an intimate intergrowth of quartz and serpentine (Fig. 35). Both talc crowded with fine unidentified inclusions and 'clear' talc are present. See also description for I_{45}.

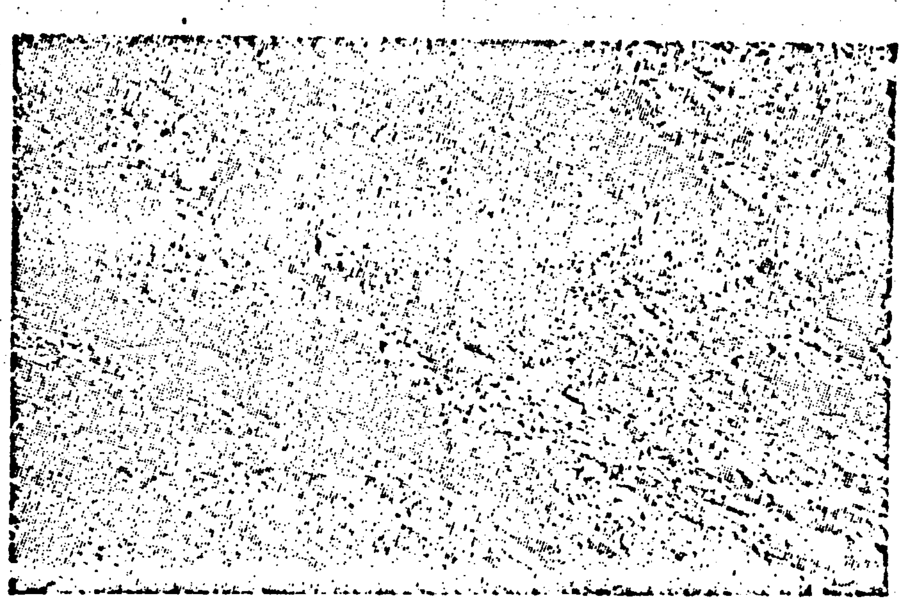


Fig. 35 - Photomicrograph, x 24 mag., of section I_{44} under crossed nicols showing coarse lamellar talc enclosing rare anhedral segregations of probable serpentine-quartz composition.

Specimen I45: 'No.1 good specimen'

This specimen of 'talc ore' consists nearly wholly of talc occurring in the form of a randomly orientated 'matted' aggregate of fibrous talc enclosing minor quartz-serpentine augen. As in previous sections the talc is rendered murky or dusty by fine inclusions of a brown amorphous material and an unidentified transparant phase. In places the talc has been cleansed of these inclusions along zones which appear to be independent of any intergrowth or crystallographic features of the talc (Fig. 36).

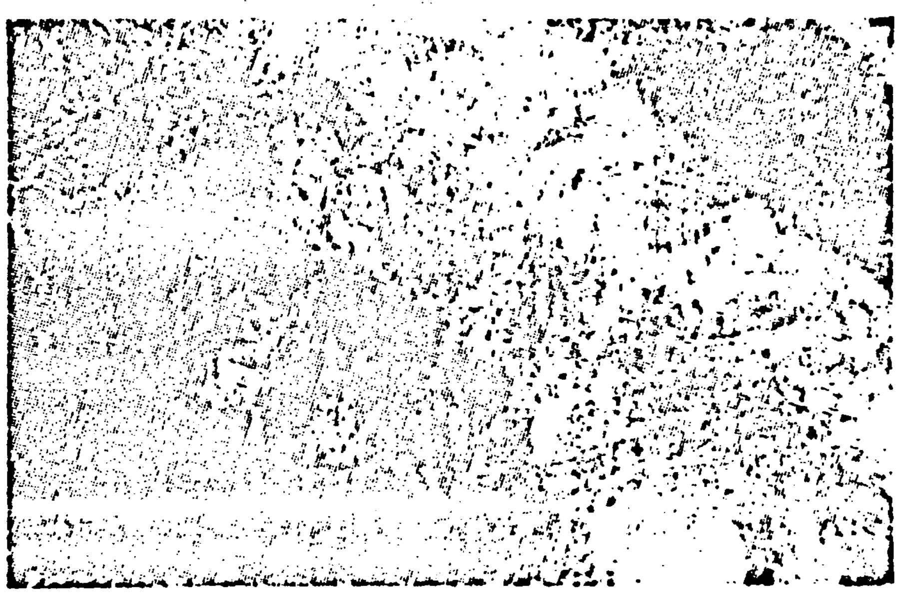


Fig. 36 Photomicrograph, x 24 mag., of thin specimen I45 under crossed nicols showing the form of aggregation of the talc and the difference between the 'murky' talc and the linear transgressive zone of 'clear' talc.

Specimen I_{46}: 'No.3 face, coloured'

This specimen consists of very coarse lenticular aggregates of long fibrous and feathery talc crystals enclosing rare anhedral porphyroblasts of garnet.

DIGESTIVE TESTS

To confirm the presence of acid soluble carbonate material and also to help identify the type of carbonate present in the rock specimens collected,each powder specimen was subjected to a digestive test.

Half gram quantities of each of the powders were treated with normal hydrochloric acid for several hours at approximately 70^{o}C. The residues were reweighed and the filtrates were analysed for their calcium and magnesium content using the EEL, 240 Atomic Absorption Spectrophotometer. The aim of the digestion was not to estimate the total acid soluble fraction only to help establish the carbonate minerals present and to estimate roughly their quantity to help interpret the X-ray powder photographs obtained from the samples.

The results are present under three headings, namely 'Rock Types', 'Carbonate Specimens', and 'Talc Specimens'.

It can be seen that only small quantities of carbonate material are present in the talc specimen group, similarly in the rock specimens with the exception of the marble specimen which is practically 100% calcite. The carbonate group of specimens appear to be mixtures of calcium and magnesium carbonate with a number of specimens being possible dolomites.

ROCK TYPES

Specimen No.	% Weight Loss	% Calcium	% Magnesium
I1	<0.2%	<0.2%	<0.2%
I7	3.0%	<0.2%	<0.2%
I12	<0.2%	<0.2%	<0.2%
I13	4.2%	1.0%	0.4%
I15	6.0%	<0.2%	0.4%
I16	4.8%	2.0%	0.4%
I17	6.0%	<0.2%	<0.2%
I20	11.2%	<0.2%	<0.2%
I23	1.4%	<0.2%	<0.2%
I25	22.4%	<0.2%	<0.2%
I27	9.0%	<0.2%	<0.2%
I29	3.6%	<0.2%	<0.2%
I31	9.6%	<0.2%	<0.2%
I34	92.2%	>20.0%	<0.2%

CARBONATE SPECIMENS

Specimen No.	% Weight Loss	% Calcium	% Magnesium
I4	22.8%	3.0%	1.1%
I6	48.0%	6.0%	1.15%
I11	21.6%	3.0%	6.4%
I14	44.2%	7.0%	5.0%
I18	75.2%	14.0%	24.0%
I19	37.8%	5.0%	4.0%
I21	61.8%	8.4%	8.0%
I22	91.2%	16.0%	15.2%
I30	15.0%	1.9%	1.6%
I35	50.8%	6.6%	13.4%
I37	51.0%	4.4%	24.0%

TALC SPECIMENS

Specimen No.	% Weight Loss	% Calcium	% Magnesium
I2	3.6%	<0.2%	0.4%
I3	1.6%	<0.2%	<0.2%
I5	5.4%	<0.2%	<0.2%
I8	6.0%	<0.2%	<0.2%
I9	<0.2%	<0.2%	<0.2%
I10	4.2%	<0.2%	<0.2%
I24	8.0%	<0.2%	<0.2%
I26	<0.2%	<0.2%	<0.2%
I28	12.6%	<0.2%	<0.2%
I32	1.2%	<0.2%	0.4%
I33	5.6%	0.34%	<0.2%
I36	4.6%	<0.2%	<0.2%

/Continued....

TALC SPECIMENS (Continued)

Specimen No.	% Weight Loss	% Calcium	% Magnesium
I38	1.0%	<0.2%	<0.2%
I39	<0.2%	<0.2%	<0.2%
I40	7.0%	<0.2%	<0.2%
I41	<0.2%	<0.2%	<0.2%
I42	0.8%	<0.2%	<0.2%
I43	6.2%	<0.2%	<0.2%
I44	<0.2%	<0.2%	<0.2%
I45	8.0%	<0.2%	<0.2%

Electron Microscope Examination of Italian Mine Samples and Imported Batch Shipments of Italian Powder

The main purpose of the electron microscope examination of mine samples and also representative fractions of the Italian powder has been to establish whether or not any particles corresponding to the commercial forms of asbestos were present. The electron microscope is an instrument which is most usefully employed in the examination of particles less than ten microns in size. It has been used in this investigation therefore to examine only the finer particulate portion of the Italian samples. It may be argued that only a small fraction of each of the powdered samples was examined and that this was not representative of the total sample. However, we can assume that the fraction examined was representative of the dust formed from each sample and that it is this finer fraction which is the most important from a biological standpoint. Also as the size of the biologically active commercial asbestos particles fall entirely within the particle size range examined we can consider the main aim of the examination to be entirely satisfied by only looking at the finer fractions from each of the Italian samples.

To acquaint ourselves with the type of particles formed by the commercial asbestos minerals, Figs. A-D have been included. They represent samples of Amosite, Crocidolite, Anthophyllite and Chrysotile asbestos. Also Figs. E-F have been inserted to demonstrate typical single particle electron diffraction patterns which can be obtained from the four asbestos types for comparison with patterns obtained from the Italian samples.

Sample Preparation

Small portions of the powdered rock samples and imported powder specimens were placed in 15cc centrifuge tubes to which distilled water was added. The powders were then dispersed first by hand shaking and then with the aid of a small ultrasonic bath. The concentration of suspended material in the tubes was adjusted by eye using dilutions of distilled water. The tubes containing suspended solids were then allowed to stand for 20 minutes to allow the larger particles of mineral to sediment to the bottom of the tubes.

Electron microscope grids coated with carbon films were prepared and small drops of the particulate material from each of the specimen tubes were mounted on specimen grids and allowed to dry. The specimens were inserted into an A.E.I. E.M.6. electron microscope and examined for particles resembling commercial asbestos fibres. Where suitable particles were observed, selected area electron diffraction patterns were taken and compared with those produced by the commercial asbestos minerals. In all cases photomicrographs representative of the type of particles found in each sample were taken while interesting diffraction patterns were also recorded.

Particle Morphology

The carbonate rich materials were found to produce compact particles which were very electron dense. On the whole they were finer particles than those obtained after crushing talc rich specimens. No fibrous material whatsoever was found when carbonate material only was comminuted. The morphology of particles produced from the footwall rocks i.e. limestone, marble, gneiss and the amphibolites were also very compact, although in the gneiss specimen platey particles were present probably representing the muscovite content of the specimen. Again in the footwall rock specimens fibrous particles were very scarce. Those lath like particles detected resembled the amphibole minerals rather than chrysotile. Selected area diffraction patterns which were obtained from the lath like particles in no way resembled the typical amphibole fibre diffraction pattern. They were generally very distorted patterns containing streaks rather than spots indicating a rather stressed and deformed material.

The specimens which were composed of talc together with other mineral associations, presented a very different picture, as far as particle shape was concerned. In the main particles were flat and plate-like, some being very thin and translucent in the electron beam. Particle sizes varied from very small to quite large plates some with very sharp discrete edges, others with rather ragged outlines. Comparing particles from those samples of talc which varied in bulk morphology in hand specimens, no observable difference could be drawn between them. Similarly, a comparison of particles produced from talc specimens of varying colour revealed no differences in the overall particle shape. Similarly those specimens rich in chlorite did not form particles with any distinctive features.

There were, however, observable differences in particle morphology between individual powder specimens. In the main most produced good plate like particles, however, one or two specimens were found to contain considerable numbers of lath like particles, these being very thin in character. These particles resembled the amphibole asbestos type particle being less regular and also very much larger in projected diameter. Diffraction patterns from these particles matched those obtained from the platy particles with which they were associated and in no way resembled the typical amphibole diffraction pattern obtained from single amphibole asbestos fibres.

Other fibrous particles were observed in the mainly talc specimens which to some extent resembled chrysotile asbestos fibres rather than amphibole minerals. They often had a somewhat textile appearance but were, however, crystalline. Diffraction patterns from these fibres were very distorted and in no way matched typical chrysotile or amphibole patterns.

The only group of specimens in which amphibole fibres were confirmed were in those specimens with known amphibole composition. However, even the fibres found in these specimens barely resembled the fibres formed by the commercial amphibole asbestos minerals. To assess the particles produced from the pure amphibole mineral (Tremolite), found in three of the specimens, small crystals of the mineral were taken from the hand specimens and crushed separately. An examination of the finer particles produced revealed stubby electron dense fibres associated with irregular lumps of the same mineral. Diffraction patterns from these fibres were similar to those obtained from the commercial amphibole minerals, although they were more difficult to obtain because of the greater thickness of these particles. Other specimens in the group, which did not contain talc but were composed of sheet silicate minerals mainly muscovite, were also practically free of fibrous particles. There appeared to be no general tendency for these other minerals to form fine fibrous particles. A number of very fine short fibres were observed on grids prepared from several of the talc specimens, these were, however, chance small pieces torn from the edges of talc plates. They appeared in those samples which had a tendency to form copius numbers of very fine particles when subjected to comminution.

The specimens examined can be grouped into four categories on the basis of particle morphology and they are as follows:

(a) Talc specimens with impurities of carbonate and chlorite.

(b) Rock type specimens, i.e. footwall limestone etc.

(c) Those specimens composed mainly of carbonates.

(d) Amphibole specimens with carbonate and talc.

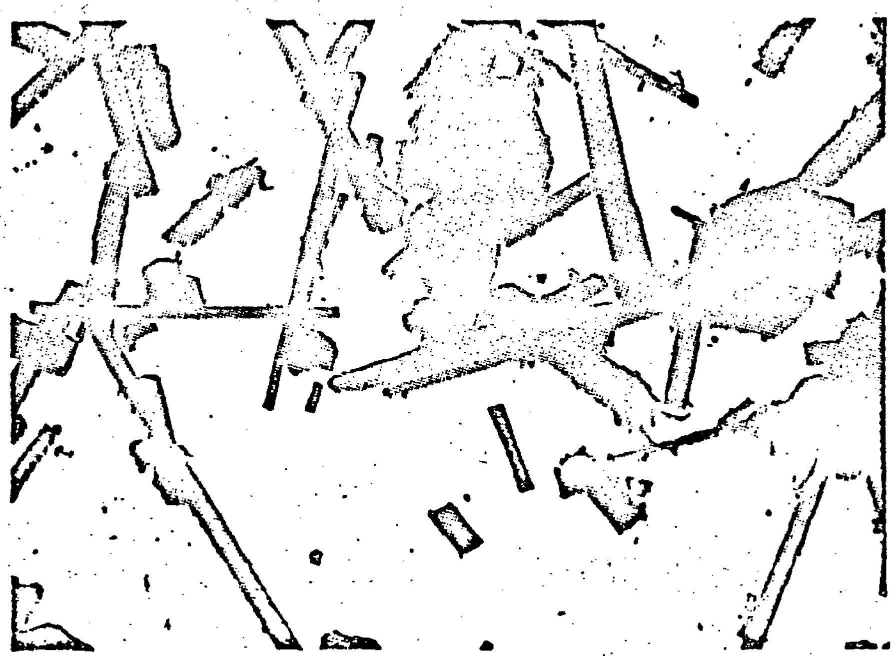
The talc specimens were characterised by the large number of plate like particles often translucent in the electron beam. Rock specimens varied from specimens which were composed mainly of compact electron dense particles to those with some sheet silicate content in which plate like particles become apparent. Those specimens composed mainly of carbonate material produced compact rounded particles, often very small and grouped together in aggregates. Finally the specimens containing amphibole were characterised by the compact nature of the particles with evenly distributed fibres and very few translucent plates. The groups of particles described are illustrated by the following micrographs which illustrate the various forms.

Selected area electron diffraction patterns obtained from single particles of the amphibole mineral are also presented showing the similarity of these patterns to those obtained from commercial asbestos fibres. Also included are single crystals patterns and polycrystalline patterns, from talc, chlorite and muscovite rich specimens. It can be seen that they are very different in character to those obtained from the amphibole mineral. However, patterns from the sheet silicate minerals mentioned above are all very similar and it is impossible to identify each of these minerals from their electron diffraction patterns or to tell them apart without applying a more sophisticated approach to the diffraction procedure. With specimen tilt facilities enabling the particle to be rotated through more than 45° discrimination is possible between certain of these minerals.

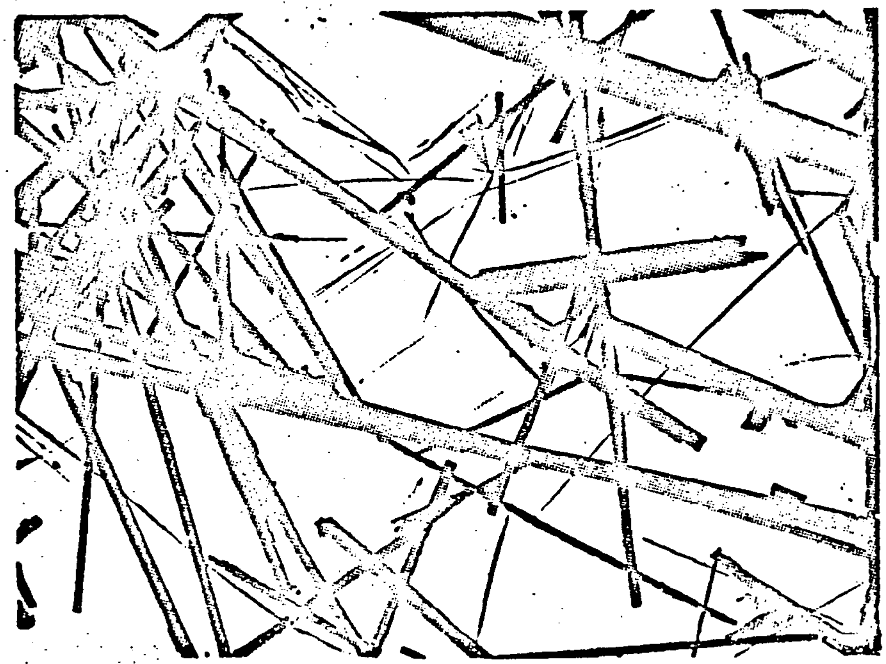
As mentioned earlier, patterns obtained from lath like particles found in the talc specimens were identical to those observed from general plate like forms. Those fibres with a textile like appearance often only gave very streaked patterns but in one or two cases these also resembled very closely the normal talc pattern.

Examples of Commercial Amphibole and Chrysotile asbestos particles together with typical selected area electron diffraction patterns.

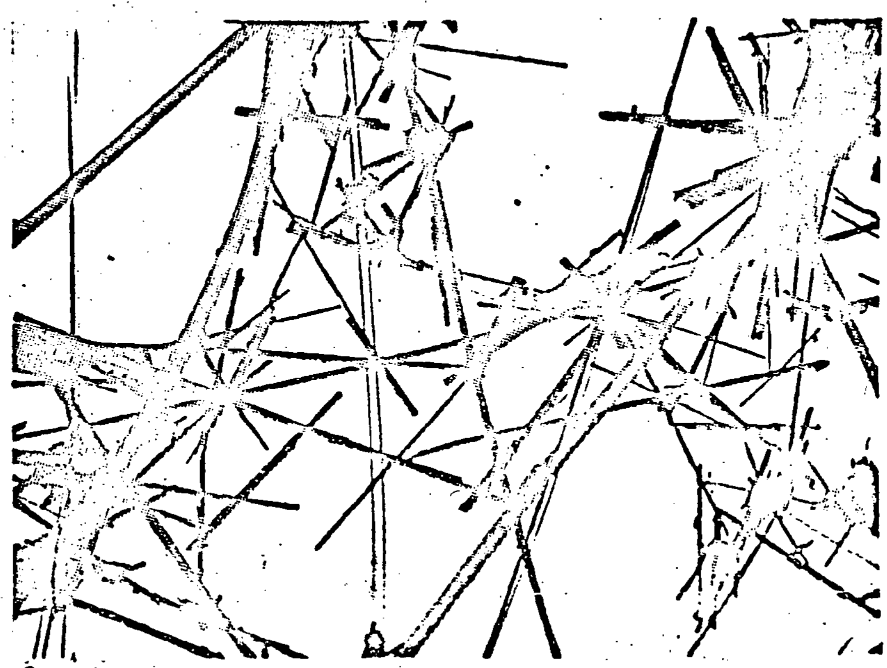
Chrysotile asbestos particles x 3000



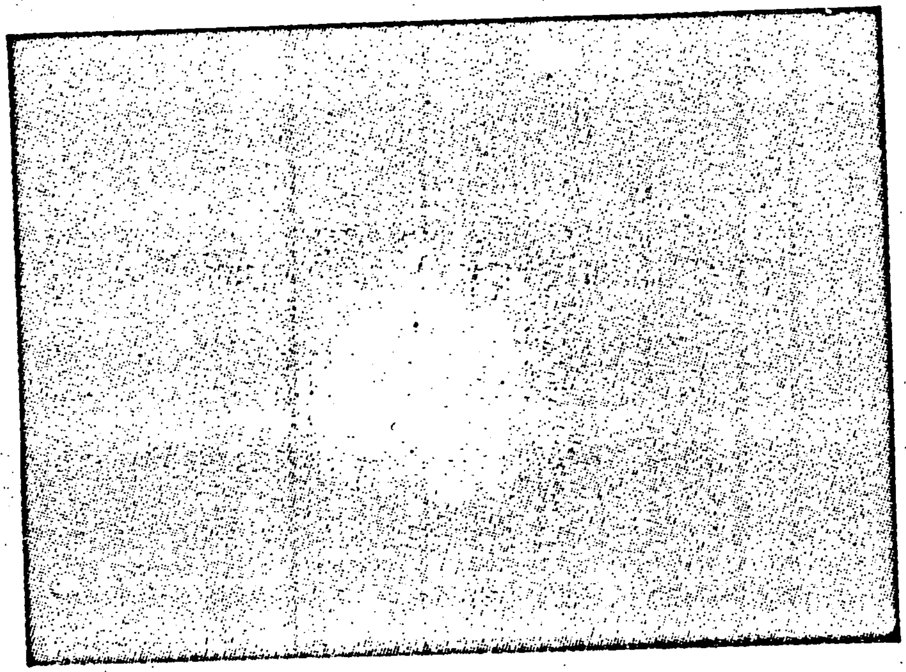
Anthophyllite asbestos particles x 3000



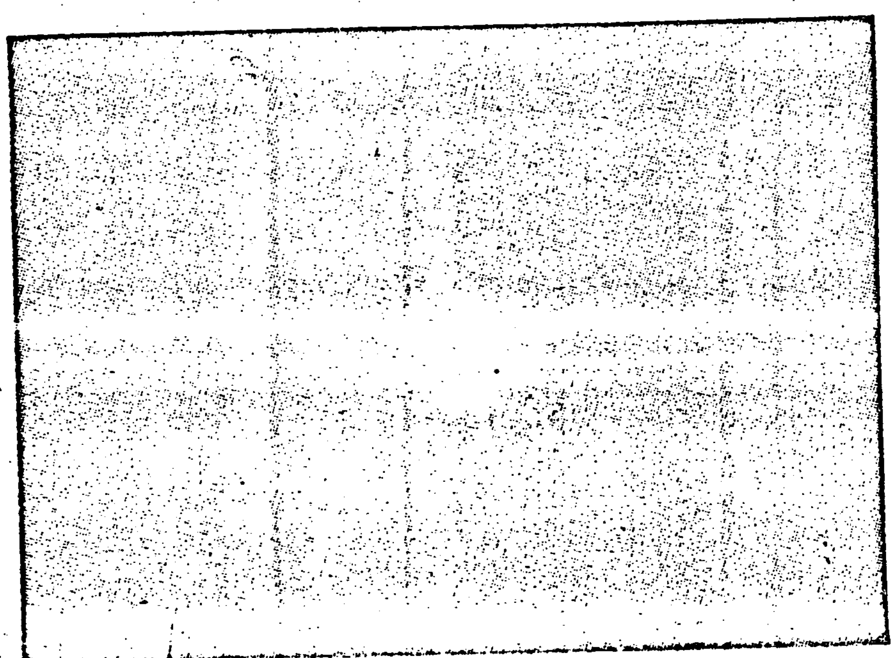
Amosite asbestos particles x 3000



Crocidolite asbestos particles x 3000



Amphibole asbestos selected area
electron diffraction pattern.



Chrysotile asbestos selected area
electron diffraction pattern.

Electron micrographs of particles produced from specimens which have been classified as rock types.

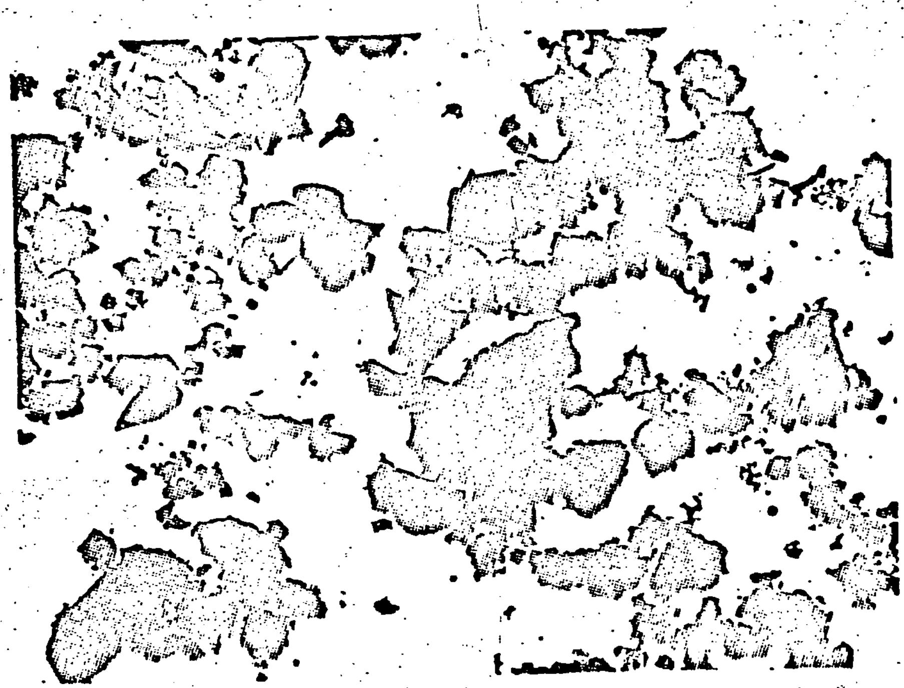


Fig. 1. Specimen I13 seam inclusion showing passage into talc x 3000. The particles are mainly compact and electron dense. A few flakes, no fibres present.

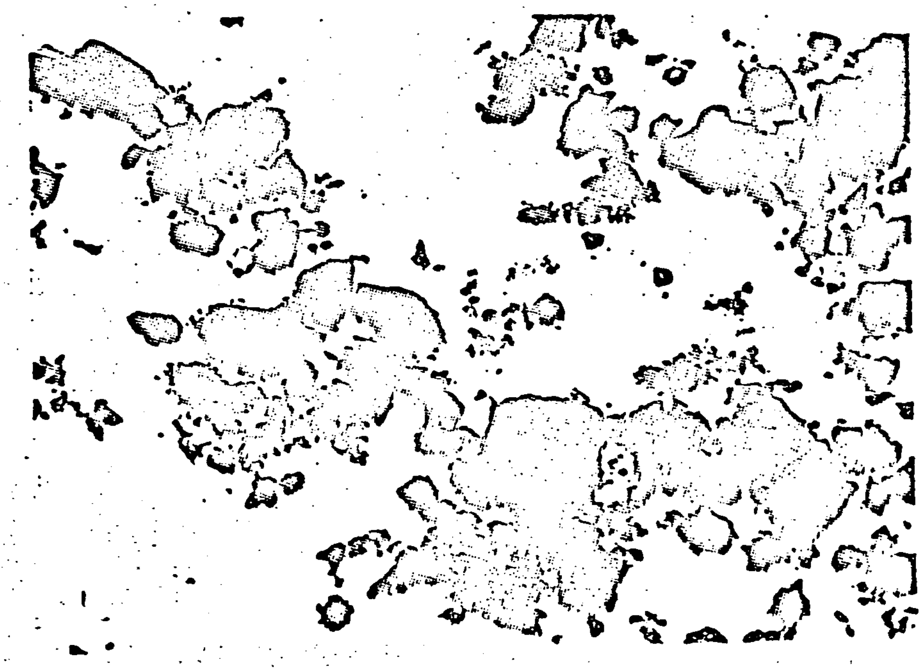


Fig. 2. Specimen I15. Talc footwall contact. x 3000. Compact particles with a few small flakes. No fibres present.

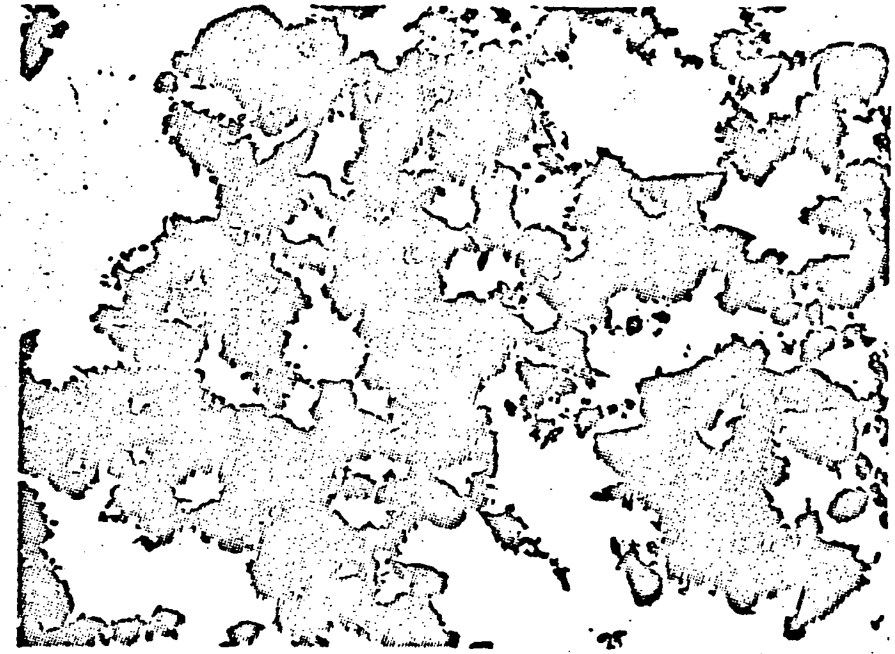


Fig. 3. Specimen I_{16}. Lithological inclusion from Face 1. x 3000. Compact electron dense particles. No fibres present.

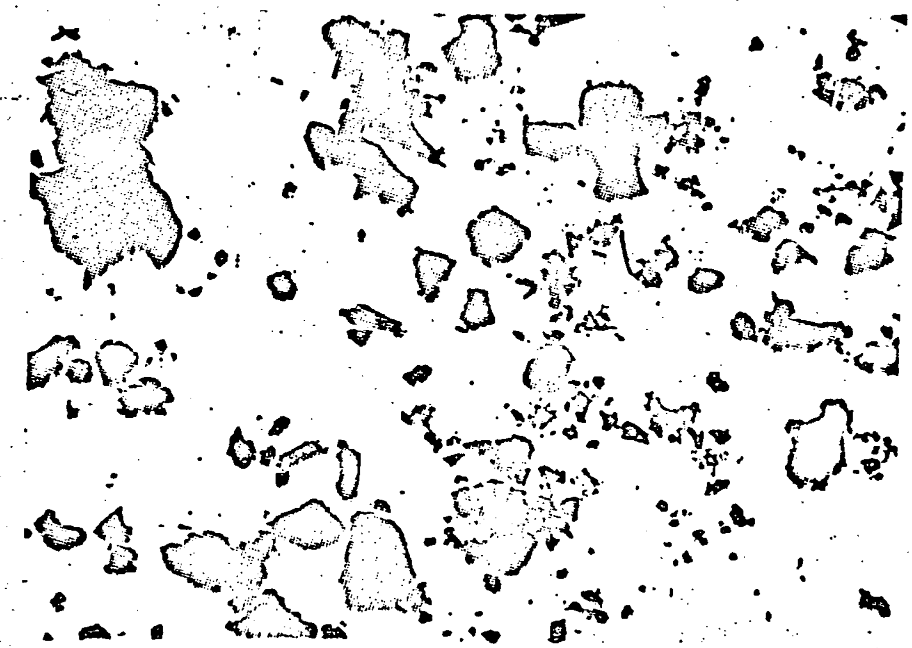


Fig. 4. Specimen I_{17}. Footwall rock sample, x 3000. Mainly compact particles produced with a few plate like forms.

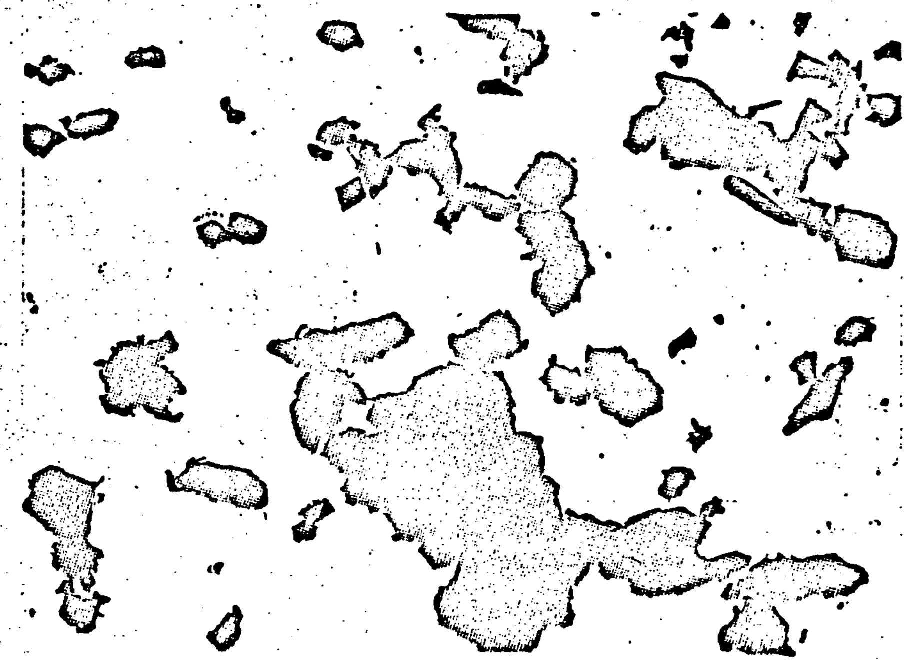


Fig. 5. Specimen I23. Black gneiss, 2ft below talc seam. x 3000. Compact electron dense particles produced.

Fig. 6. Specimen I25. Footwall limestone. x 3000. Compact electron dense particles.

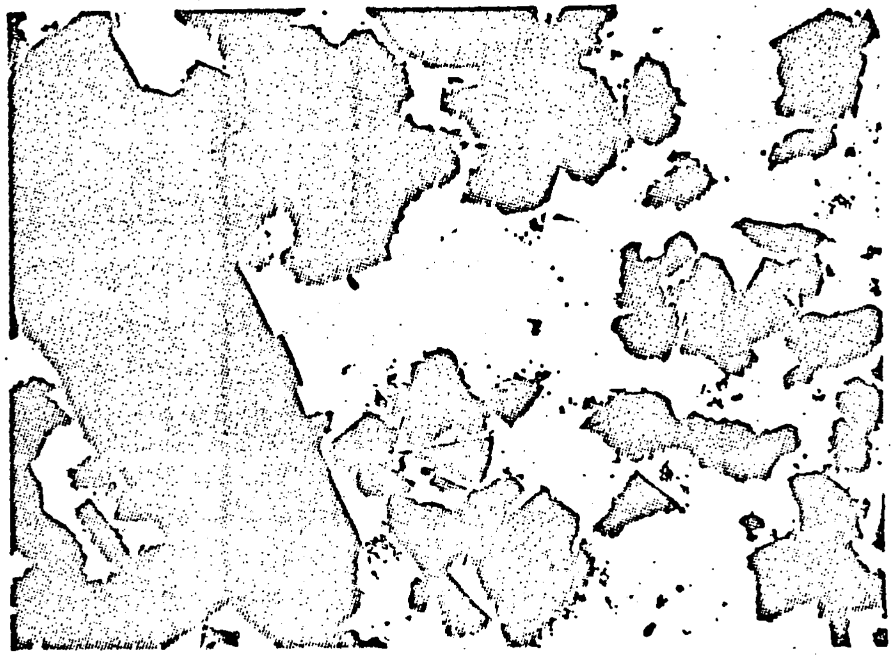


Fig. 7. Specimen I27. Lithological inclusion face 1. x 3000. Platey electron dense particles. No fibres.

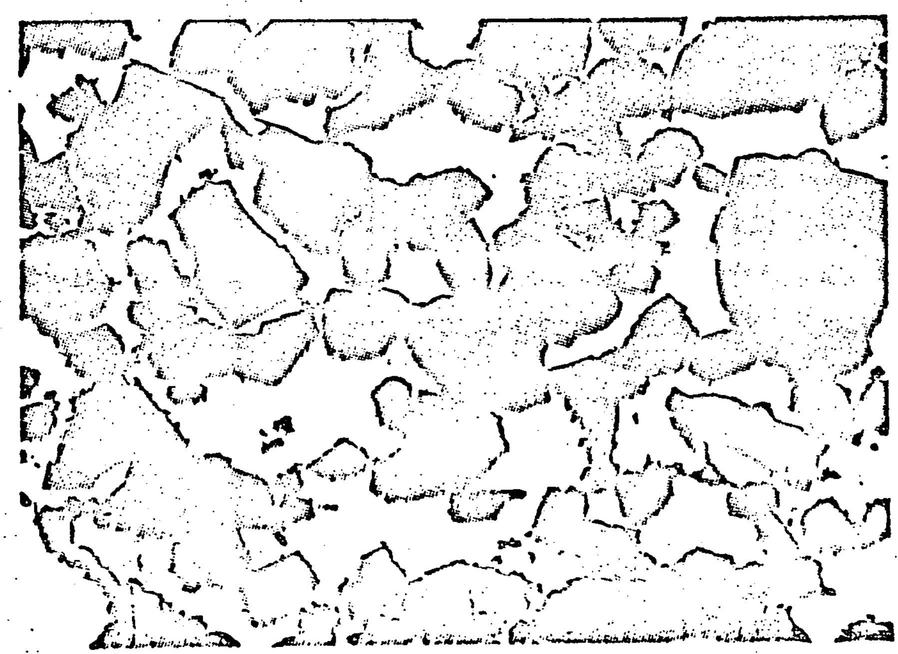


Fig. 8. Specimen I29. Sample 6 Footwall. x 3000 Compact electron dense particles with a few

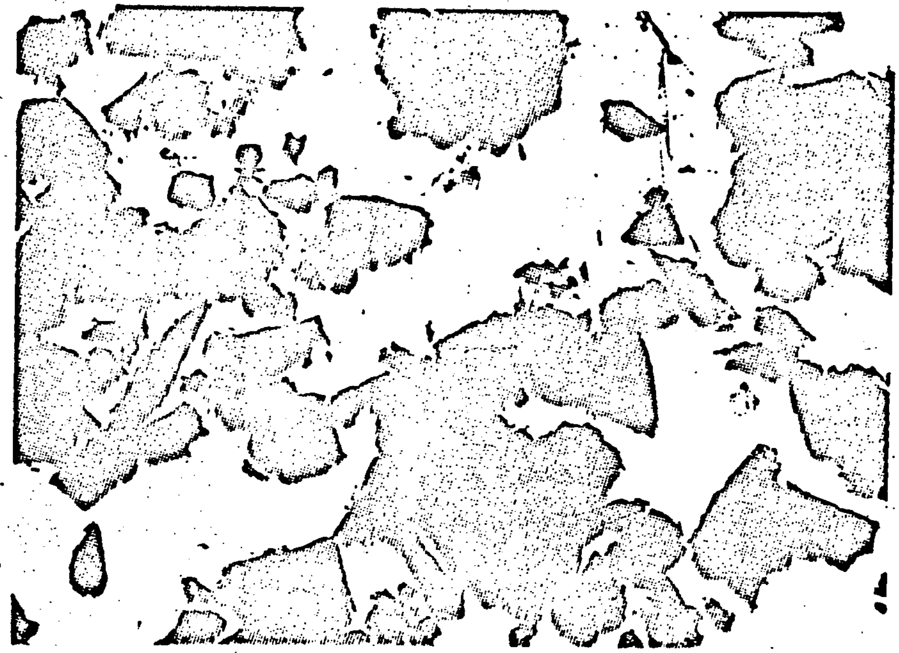


Fig. 9. Specimen I31. Black inclusion face 1. x 3000
A mixture of plate-like and compact forms mainly electron dense in character.

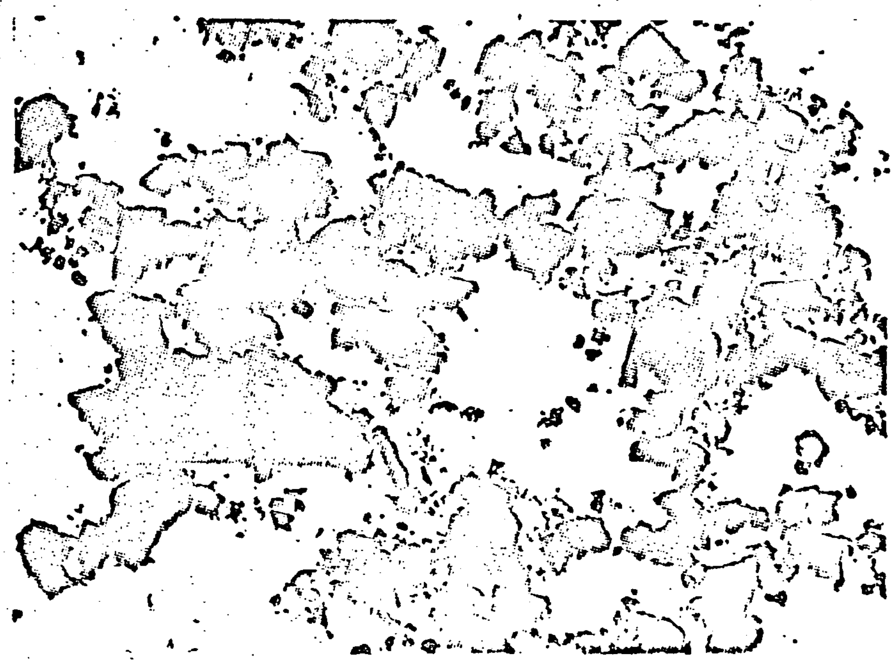
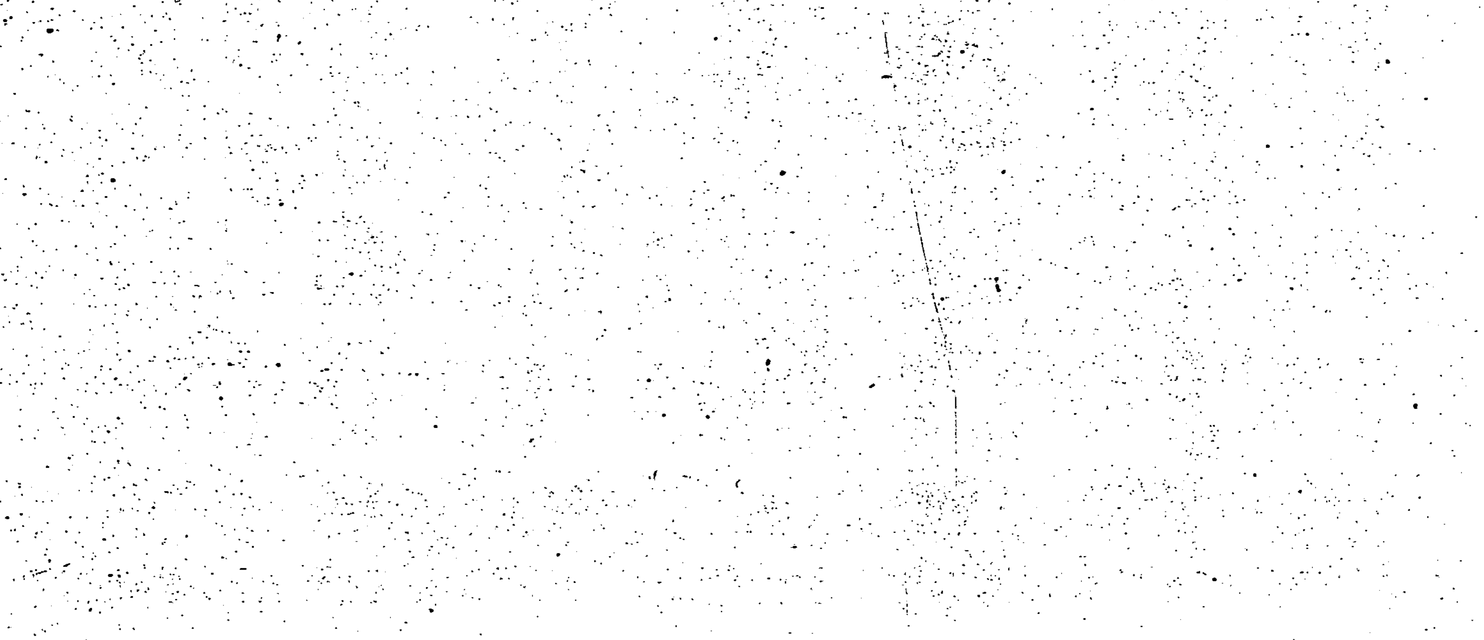


Fig.10. Specimen I34. Marble from tunnel wall. x 3000
Mainly compact electron dense particles with a few plate-like forms.



Electron micrographs of particles produced from those specimens mainly composed of carbonate minerals.

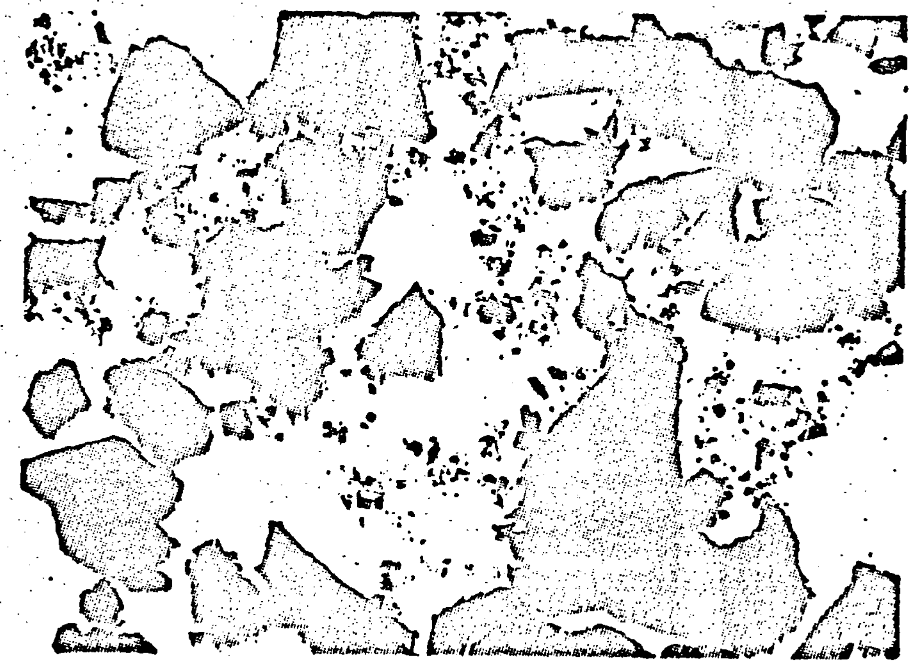


Fig. 1. Specimen I_{11}. Carbonate inclusion with some talc. x 3000. Particles consist of a mixture of compact and plate-like forms.

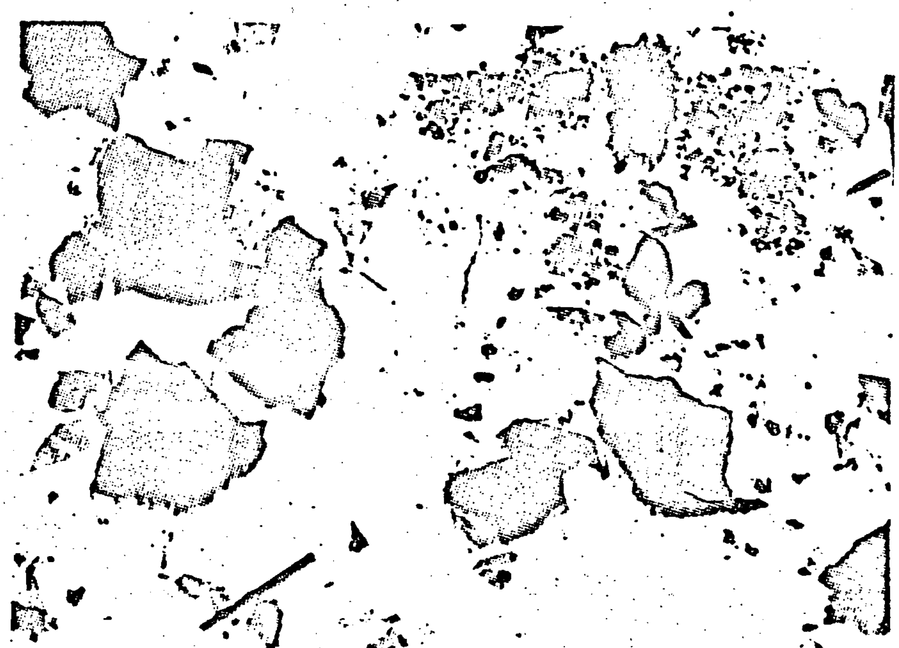


Fig. 2. Specimen I_{14}. Inclusion in talc seam Face 4, middle of seam. x 3000. Granular particles with plate-like types and lath-like forms.

Fig. 3. Specimen I_{18}. Carbonate/talc sample, x 3000. Particles compact and electron dense. A few plate-like forms.

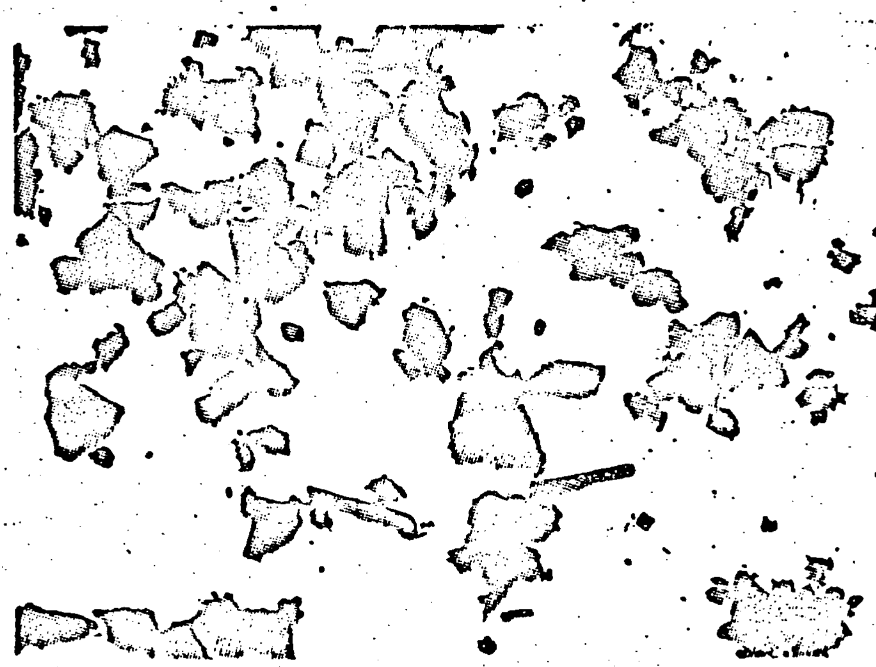


Fig. 4. Specimen I_{21}. Inclusion from Face 2. x 3000. This specimen produced plate-like and compact particles with some lath-like forms.

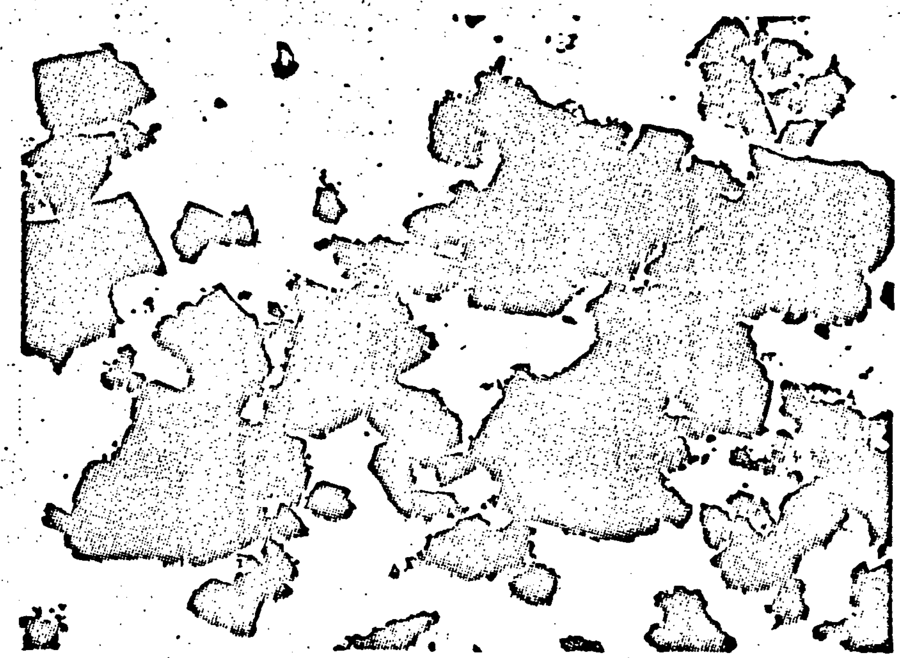


Fig. 5. Specimen I35. Massive carbonate from rear end of working, x 3000. Compact electron dense particles with some plate-like talc particles.

Fig. 6. Specimen I37. Carbonate in talc inclusion x 3000. Compact particles together with some plate-like forms and rolled talc sheets.

Electron Micrographs of specimens of talc with carbonate and other mineral inclusions.

Fig. 1. Specimen I3. Coloured talc (Green) x 3000. Particles plate-like. Few fibres, rolled sheets and shords.

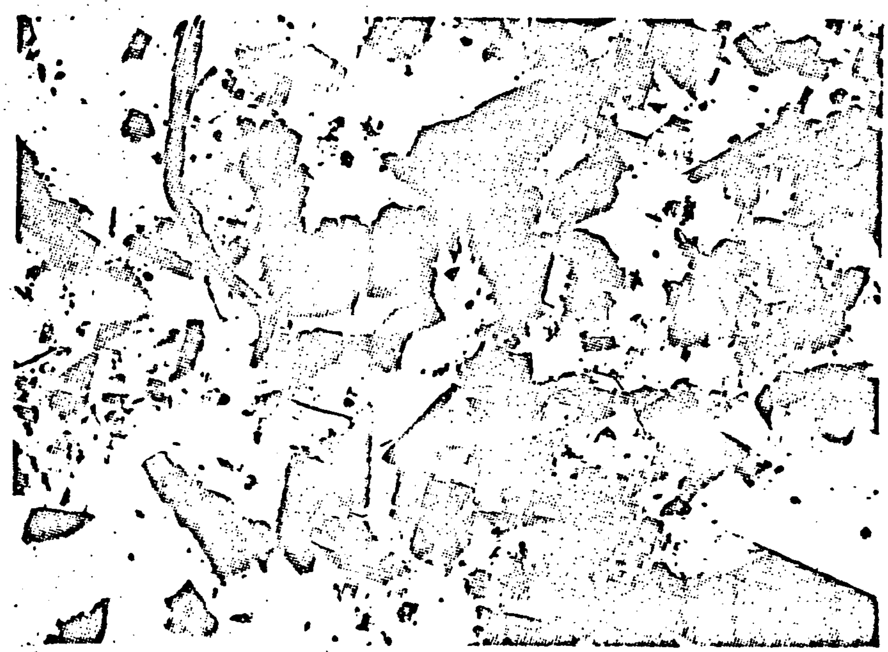


Fig. 2. Specimen I5. General ore, x 3000. Plate-like particles together with short lath-like particles, also a typical example of textile type fibre.

Fig. 3. Specimen I_8. Massive talc, x 3000. Plate-like particles with a few lath- forms also typical textile type long fibre.

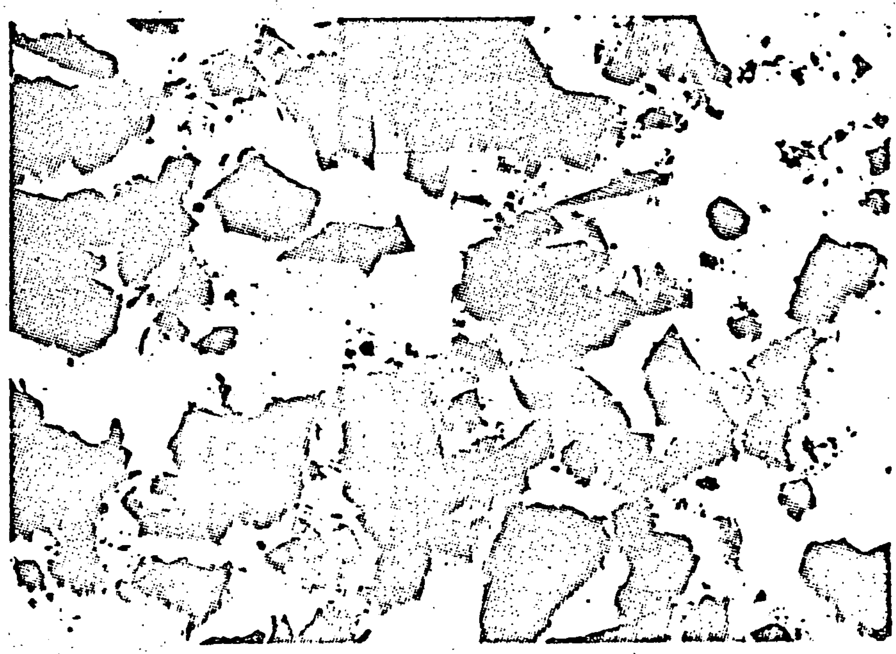


Fig. 4. Specimen I_9. Grey talc First Face, x 3000. Practic ally all plate-like with a few lath forms.

Fig. 5. Specimen I_{10}. Granular talc, x 3000. All plate-like particles.

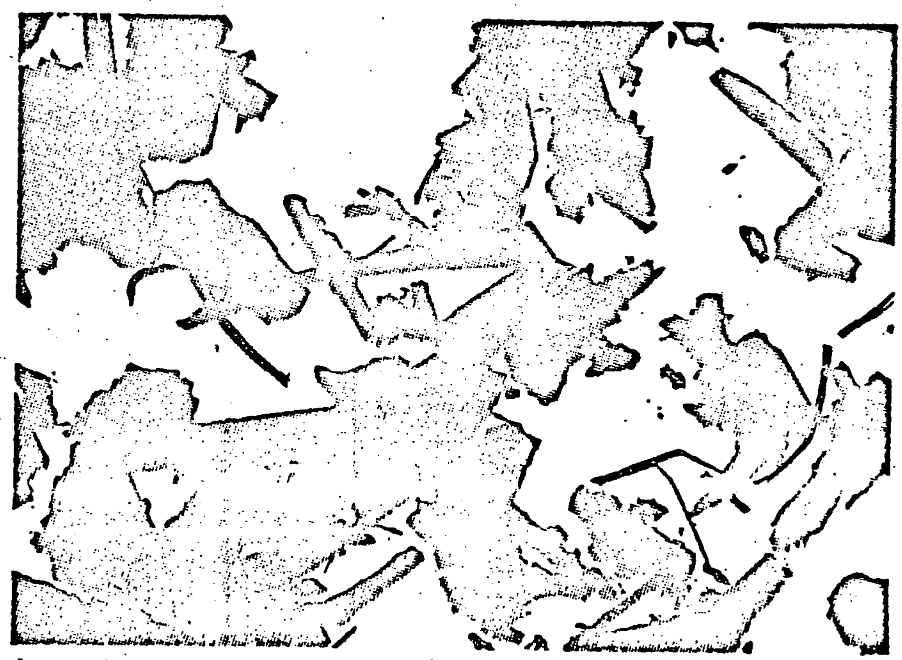


Fig. 6. Specimen I_{24}. Talc next to carbonate inclusion, x 3000. This specimen was found to contain a large number of lath-like particles, as can be seen from the micrograph above. No diffraction pattern corresponding with an amphibole fibre was obtained from a selection of the elongated particles.

Fig. 7. Specimen I26. Coloured talc inclusions, x 3000. The particles produced from the various coloured inclusions in the talc were found to be mainly plate-like with a few lath forms.

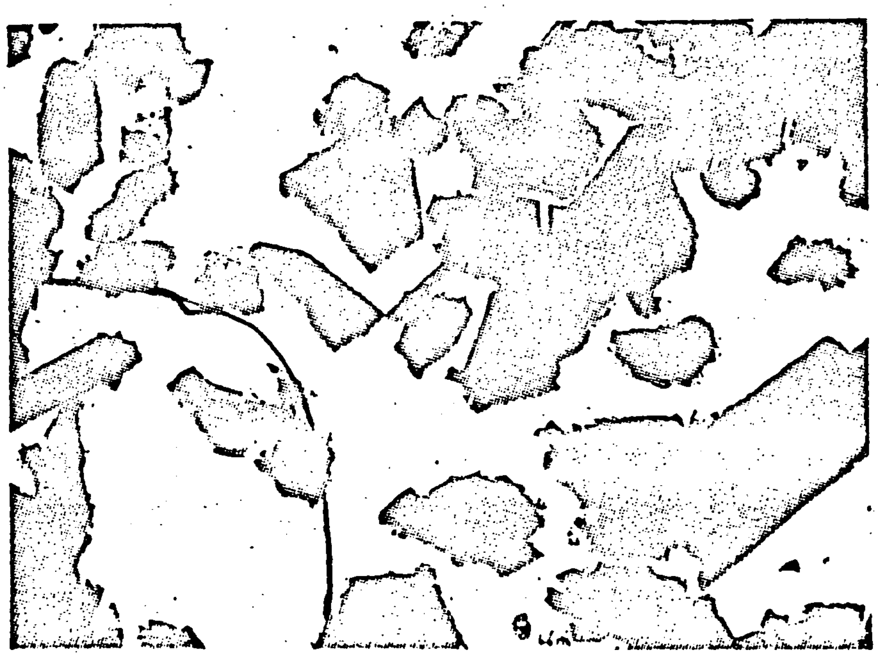


Fig. 8. Speçimen I28. Talc/Quartz specimen, x 3000. Particles from this specimen were mainly plate-like but accompanied by more compact opaque particles. A few textile type fibres were observed.

Fig. 9. Specimen I32. Face 2 inclusion from base of talc seam, x 3000. The specimen produced a mixture of irregular particles varying from compact to plate-like in form with a few lath like particles.

Fig.10. Specimen I33. Talc from lower left end of working x 3000. Particles mainly plate-like with some lath forms.

Fig. 11. Specimen I38. Pyrite/Talc specimen, x 3000. Plate-like particles with some rolled tubes of talc.

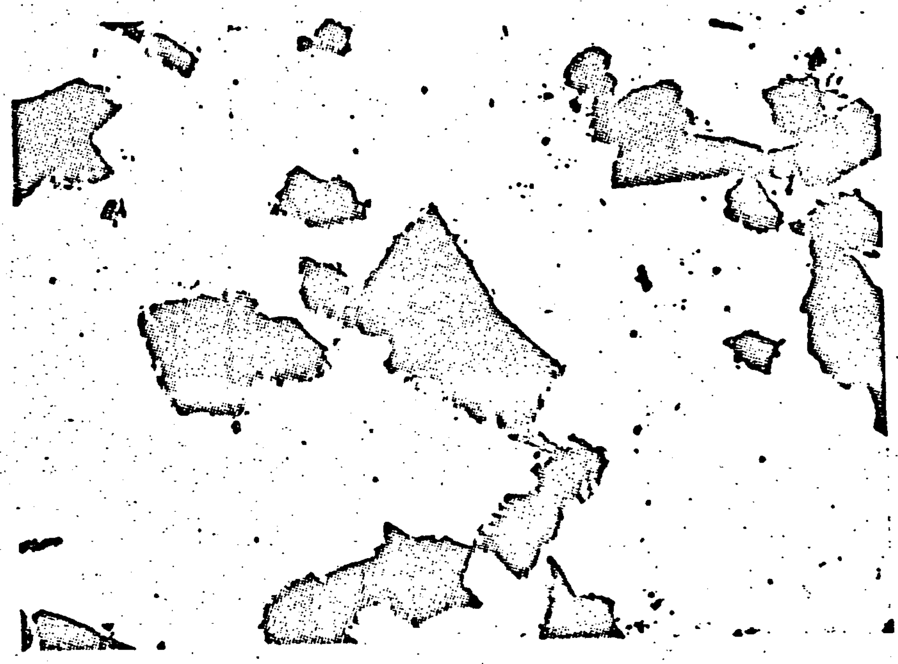


Fig. 12. Specimen I39. 5" - 0 coloured pieces from the crusher, x 3000. These various coloured talc pieces produced only plate-like particles.

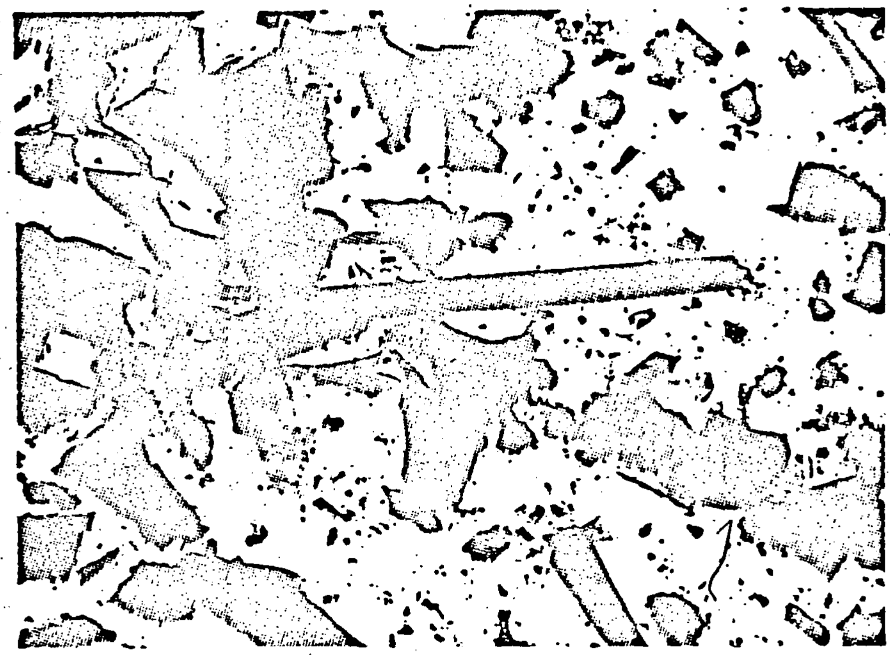


Fig. 13 Specimen I41. Face 2, good talc specimen x 3000. Plate-like particles together with rolled talc sheets lath forms and textile type fibres.

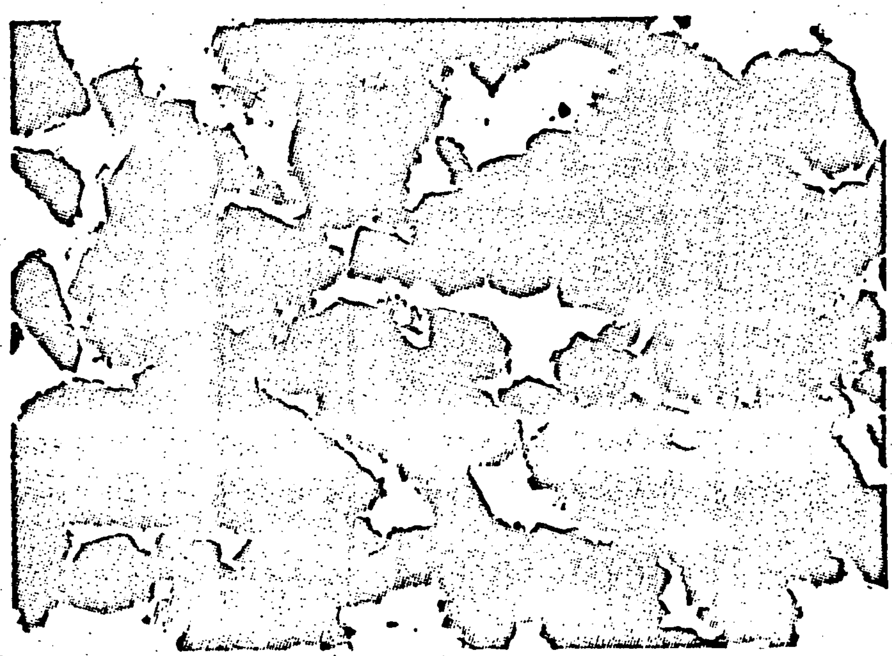


Fig. 14. Specimen I42. Face 1, green coloured talc, x 3000. This coloured specimen produced plate-like particles which were rather more electron dense.

Fig. 15. Specimen I43. Face 10. Fibrous looking hand specimen, x 3000. This sample was found to be practically all plate-like in form.

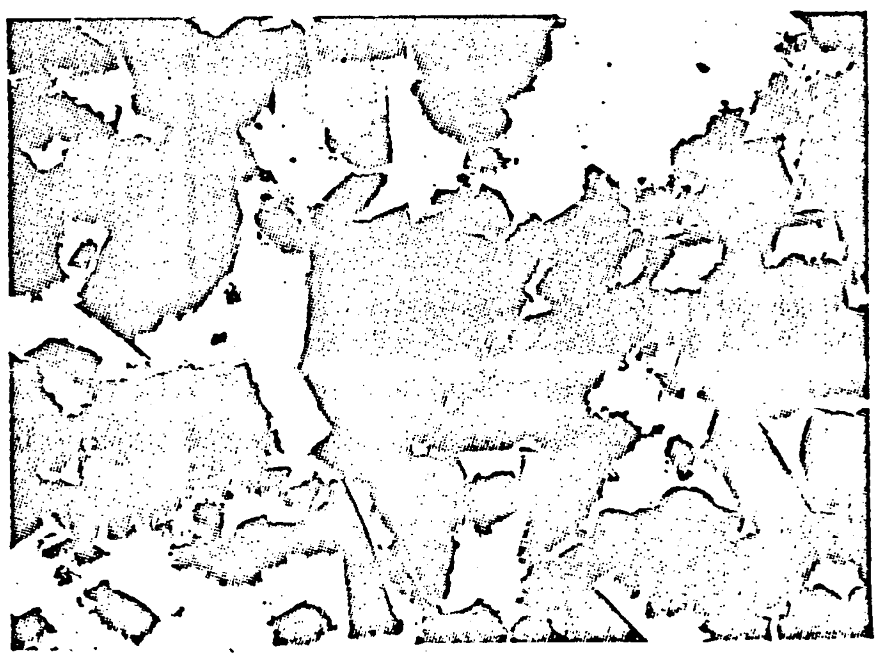


Fig. 16. Specimen I44. Face 1. Pure talc sample, x3000. Plate-like particles with some lath-like forms.

Fig. 17. Specimen I45. Face 1. Good talc specimen, x 3000. A mixture of plate-like particles and fibrous forms, including rolled tubes and textile type fibres.

Fig. 18. Specimen I46. Face 3. Coloured specimen x 3000. Plate-like particles with shards and lath like forms, together with a typical textile form, which can be seen to have a

Electron Micrographs of particles produced from those specimens containing amphibole mineral and also from the amphibole mineral itself.

Fig. 1. Specimen I19. Tremolite/carbonate talc sample x 3000. Compact particles,a few lath forms present.

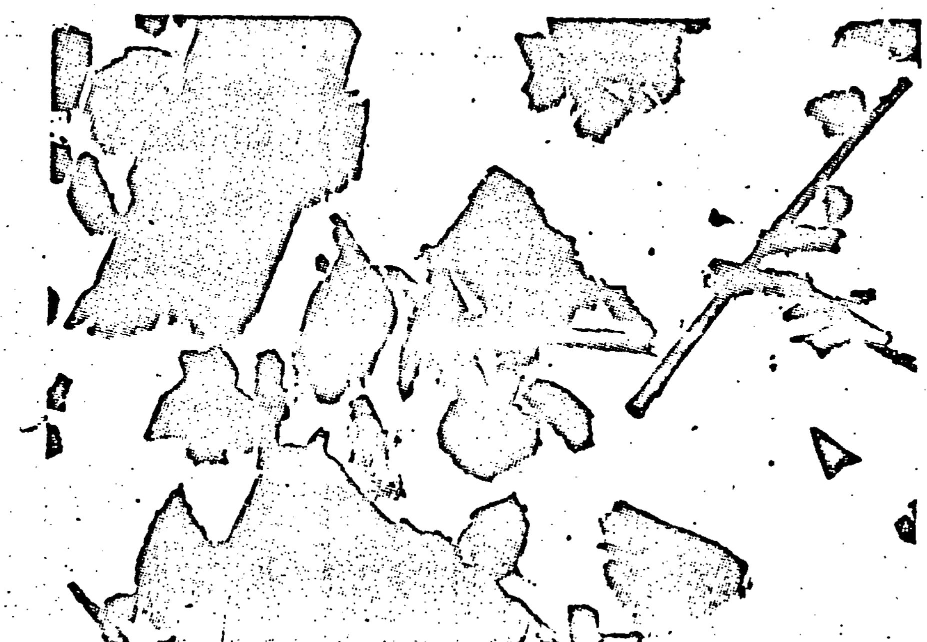
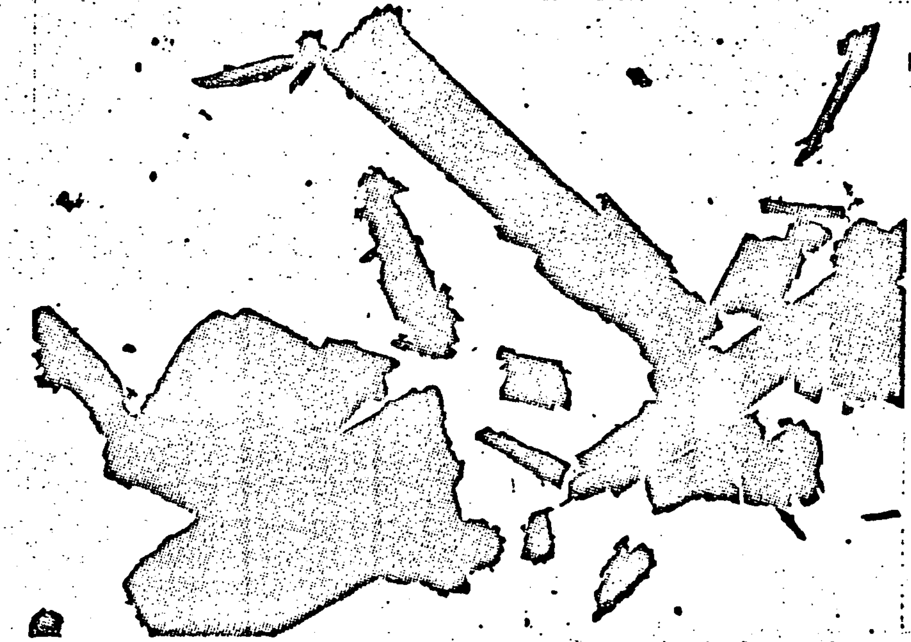
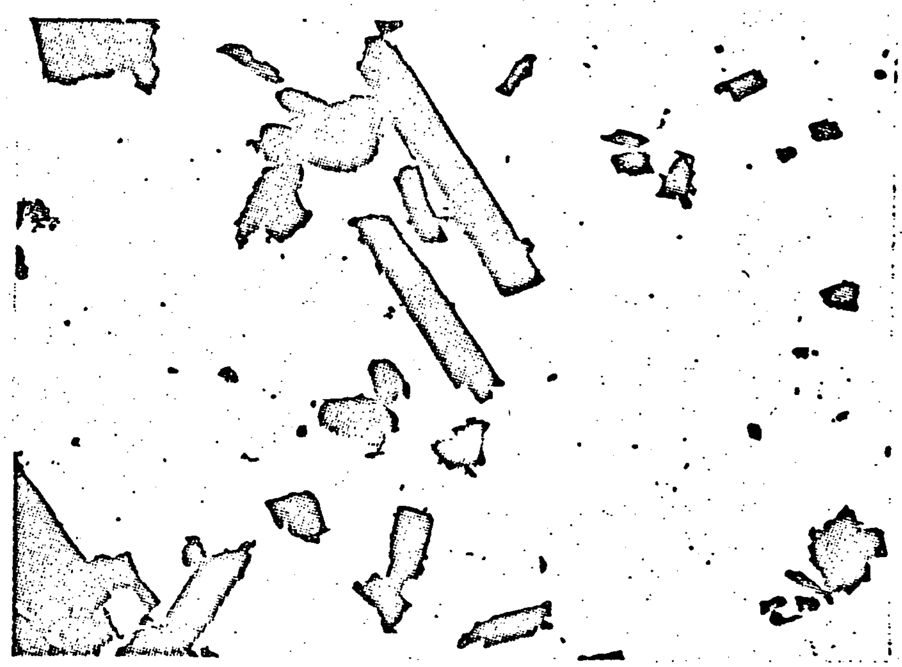


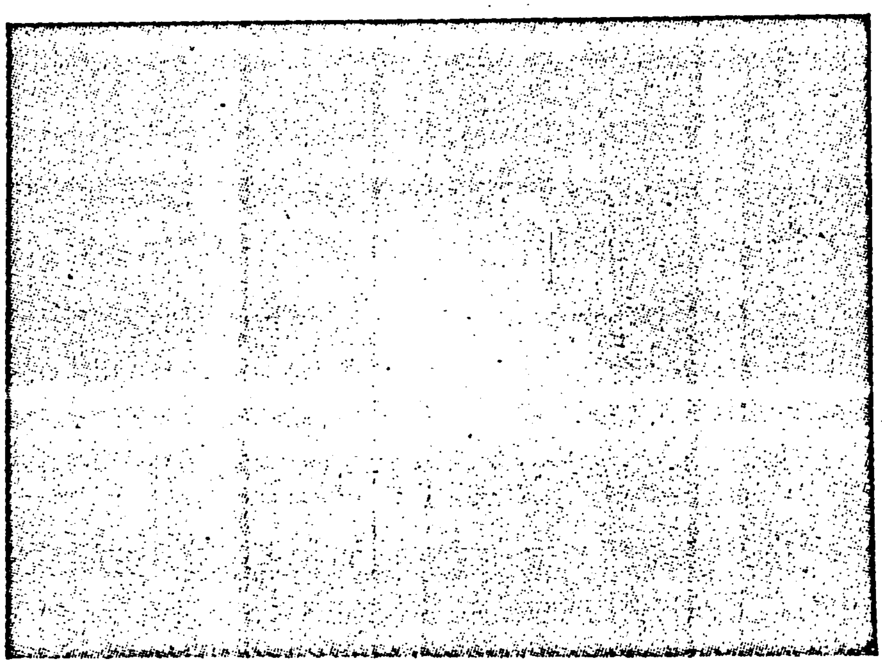
Fig. 2. Specimeh I20. Amphibole sample from Guiana level 1212. x 3000. Compact particles with numerous lath forms.





<u>Figs. 3 and 4</u>

Particles produced from single crystals of tremolite extracted from specimens I19 and I20. x 3000. Very few fibrous particles were produced when this specimen was crushed. Those that were fibrous in nature were thick and stubby in character, less than 50% of the particles were elongated in shape.



Figs. 5 and 6

Selected area electron diffraction patterns obtained from amphibole particles found in specimens I_{19} and I_{20}.

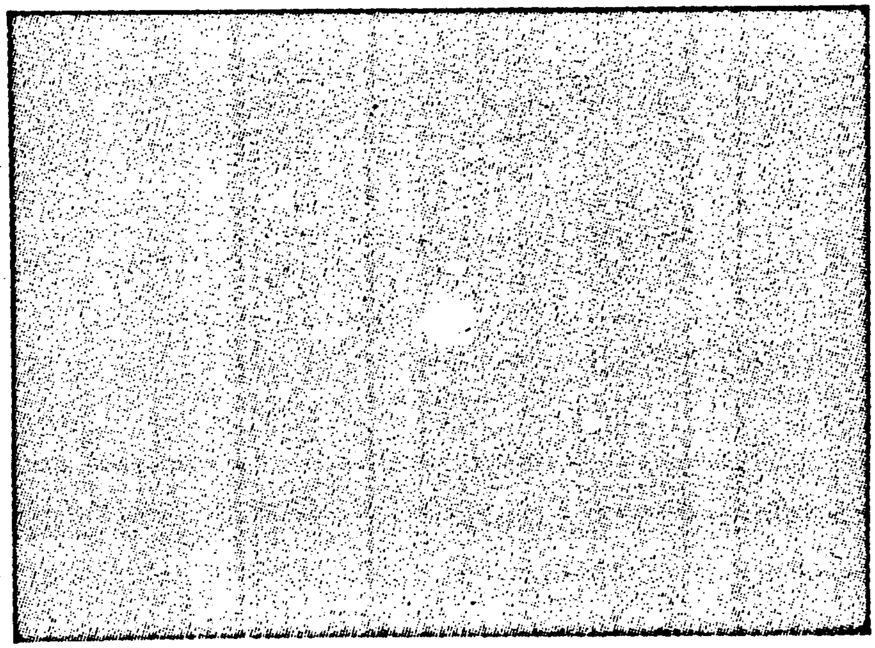


Fig. 7. Typical selected area diffraction pattern obtained from talc plates.

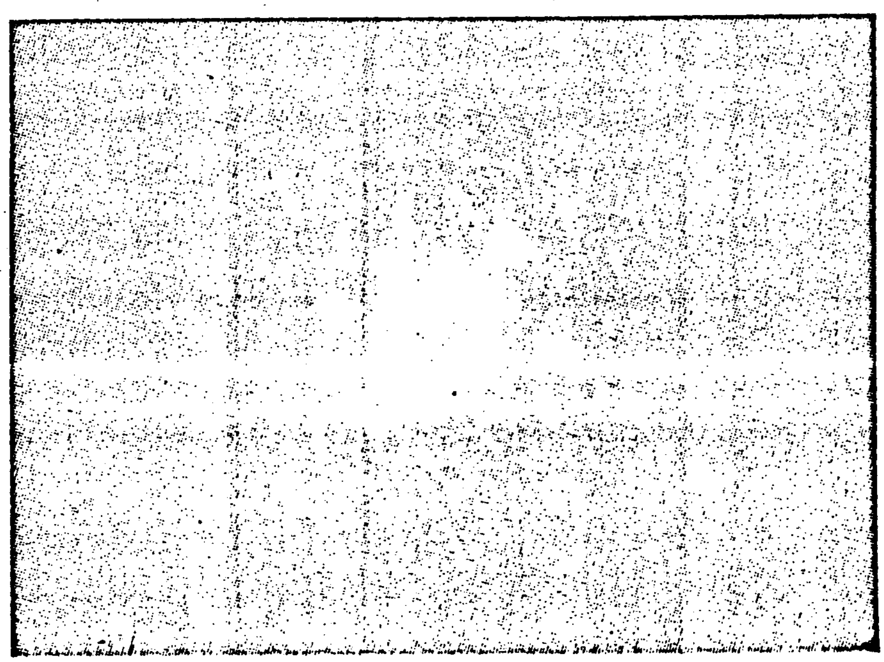


Fig. 8. Selected area diffraction pattern obtained from a typical textile type fibre showing features of a rotated or coiled structure.

X-RAY ANALYSIS OF ITALIAN MINE SAMPLES

Introduction

This report concerns the X-ray powder analysis of the Italian mine samples. The samples were classified into three categories according to their chemical and physical properties:

(i) 'Rock' Type
(ii) 'Talc' Type
(iii) 'Carbonate' Type

All the samples were prepared by similar means and the procedure for obtaining the X-ray powder patterns was standardised.

From these powder photographs, several were chosen which clearly showed distinct mineral phases. These were used as standards for this group of samples. These standard patterns were compared against the ASTM index and this comparison illustrates the need to prepare standards for a particular locality from specimens at that locality.

The samples were compared with these standards by computer methods and visually and the results and discrepancies between the methods of comparison noted.

LIST OF SAMPLES

See Table 1

SAMPLE PREPARATION

The samples were received mainly as large rocks and were labelled according to their appearance and location in the mire.

With the larger samples a section was cut from the middle to be a representative sample, for the smaller samples as many pieces as possible were crushed to form the representative sample.

These samples were then roughly broken up and placed in a 'Tema' disc mill and ground for 5 mins. until all the sample was below approx. 100 mesh. These powders were stored in clean plastic bags. The samples, when required for X-ray analysis, were further ground (to less than 300 mesh) in a small agate ball mill and then sieved through a 350 mesh screen and stored in plastic bags.

The grinding mills and other apparatus used were thoroughly cleaned between samples and during the grinding care was taken to obtain a good representative sample.

X-RAY ANALYSIS

All the samples were analysed using a Debye-Scherrer camera mounted on a Raymax RX 3-D X-ray generator. A copper X-ray tube was used with nickel filters (0.02 mm thick) and the power rating of the tube set at 36 kV and 22mA.

The apparatus was carefully aligned and checked before mounting a sample. All the samples had the same exposure time of 8 hrs.

The samples were loaded into 0.5 mm diameter Lindemann glass tubes to be mounted in the Debye-Scherrer cameras. In the cameras Ilford Industrial 'G' X-ray film was used. The film was processed using Kodak DX-80 developer and Ilford Hypain fixer. The films were developed for 5 minutes using a 1:4 dilution for the developer and fixed for 2 minutes. The films were then washed in running water for 30 minutes and allowed to dry naturally. The X-ray films were then measured.

Using an illuminated screen and the line-spacings calculated, taking into account film shrinkage, from these line spacings the bragg angle and 'd' spacings can be calculated.

STANDARD PATTERNS

When all the samples X-ray photographs had been measured and the 'd' spacings calculated, they were visually inspected to find the film showing samples with pure mineral phases. These patterns were then taken as standards.

The samples were then broken up and the different mineral phases were sorted by hand to attempt to find a purer standard. These samples were then crushed in a similar way to the samples crushed beforehand. For X-ray analysis they were placed in 0.2 mm diameter tubes and given a 12 hr exposure. This method was used to give finer lines on the X-ray photograph and the larger exposure was to try and detect as many impurities as possible.

The 'd' spacings of the standards were compared with the A.S.T.M. index and also with themselves. They were compared with themselves to check that all the Talc and Chlorite standards matched each other and were similar in intensity.

Several standards were prepared containing the same mineral. This was because the 'd' spacings of the mineral varied slightly from sample to sample and especially with chlorite, depending on its composition the major reflections varied between 13.5% and 15.0%. This was mainly due to varying iron content and this can easily be seen on the X-ray films as it causes fluorescence with copper radiation and blackens the X-ray film generally.

RESULTS

For the analysis of the results the samples have been divided into five sections:

(i) standard patterns
(ii) sample patterns (rock type)
(iii) sample patterns (carbonate type)
(iv) sample patterns (talc type)
(v) batch sample patterns (includes old powders and shipments).

Two methods were used to find the mineral present in the sample. One method uses a computer program to detect the mineral.

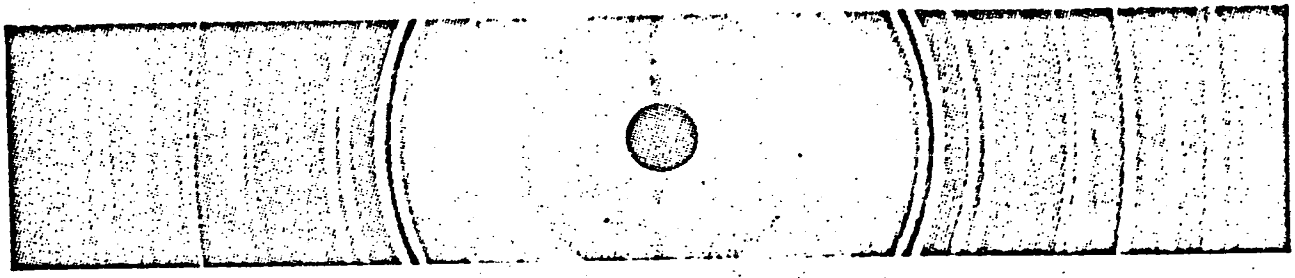
In this method the bragg angles of samples were compared with the bragg angles of the standard and the number of lines fitted printed out. A print out was also obtained of all the standards which fitted a particular line to find all the possible minerals present and to see which lines were common to several standards.

As this procedure is quite long, the lines in the sample were first sorted into order of decreasing intensity and then the three most intense lines of the sample compared with the standards. If all three lines failed to match it was considered that that standard was not present and so the program deleted that standard from the comparison. At the end of the program the list of the standards was printed with the percentage of lines fitted to the sample noted.

The obvious disadvantage of this comparison was that the program could take no account of the relative intensities of the lines and so a visual method was used to find which was the major mineral phase. The computer program usually found the mineral phases present in the samples but could not place them in the correct order.

Patterns used as standards from the Italian mine samples and their comparison with A.S.T.M. data and against themselves.

SAMPLE SIP 1 : TALC



Comparison against A.S.T.M. index: 1 line unmatched, 1.1145 Å

Patterns not included: 6-263 Muscovite -2M1, 7-25 Muscovite (1M), 7-32 Muscovite (2M1), 7-76 Ripidolite (Chlorite), 7-78 Thuringite (Chlorite), 7-166 Bavalite (Chlorite), 10-183 Peninnite Chlorite , 11-78 Dolomite, B and T Quartz.

Most probable minerals present: Talc Muscovite Calcite

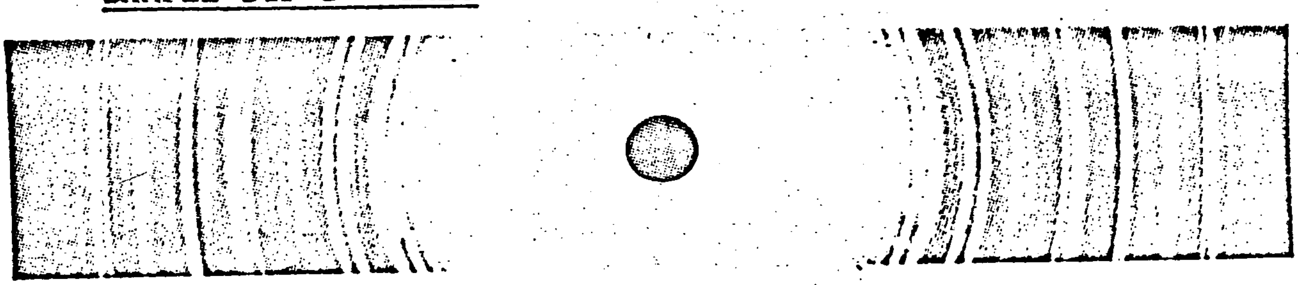
Comparison against Italian Standards

Patterns not included: Chlorite (I42), Chlorite (I4), Muscovite (I35), Magnesite (I6), Tremolite (I19/I20), Dolomite

Most probable minerals present: Talc

Visual comparison	Minerals detected
Talc, Calcite	Talc, Calcite

SAMPLE SIP 2 TALC



Comparison against A.S.T.M. index: 2 lines unmatched, 1.1159Å 1.1353Å

Patterns not included: 7-76 Ripodolite (Chlorite), 7-78 Thuringite (Chlorite), 7-166 Bavalite (Chlorite).

Most probable minerals present: Talc, Muscovite, Calcite

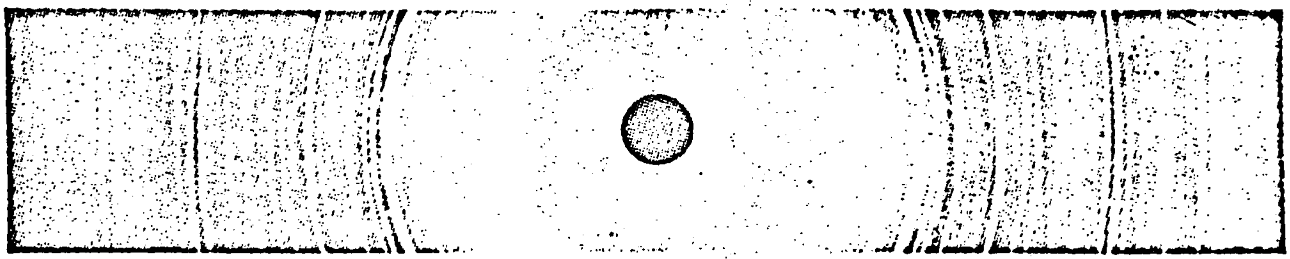
Comparison against Italian Standards

Patterns not included: Chlorite (I42), Chlorite (I4), Tremolite (I19/I20).

Most probable minerals present: Talc, Muscovite, Magnesite.

Visual Comparison	Minerals Detected
Talc, Chlorite, Magnesite	Talc, Chlorite, Magnestie

SAMPLE SIP 3   CHLORITE



Comparison against A.S.T.M. index: 2 lines unmatched, 1.1739Å, 1.29Å

Patterns not included: 6-263 Muscovite -2M1, 7-25 Muscovite (IM) 7-32 Muscovite (2M1), 7-79 Forsterite (Olivine), 8-479 Magnesite

Most probable minerals present: Chlorite, Talc

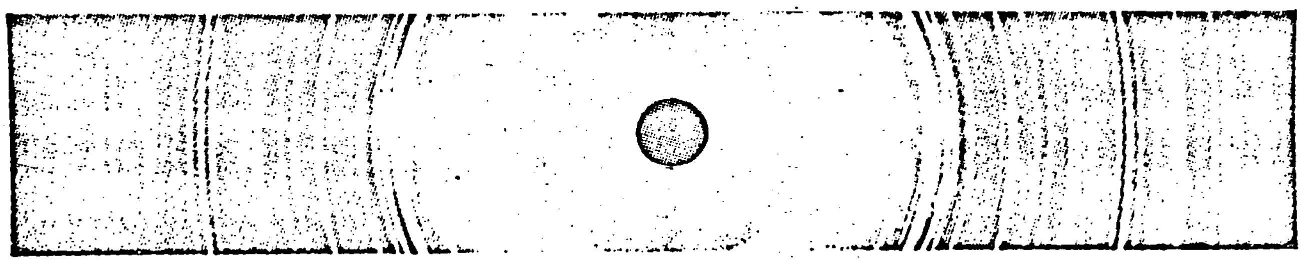
Comparison against Italian Standards

Patterns not included: Muscovite (I35), Tremolite (I19 and I20)

Most probable minerals present: Chlorite, Talc.

Visual Comparison	Minerals Present
Chlorite, Talc	Chlorite, Talc

SAMPLE SIP 4   CHLORITE



Comparison against A.S.T.M. index: 3 lines unmatched 1.1741Å, 1.1318Å, 1.0984Å.

Patterns not included: 6-263 Muscovite -2M1, 7-32 Muscovite (2M1), 8-479 Magnesite, 11-78 Dolomite, 13-437 Boric Acid.

Most probable minerals present: Chlorite, Talc

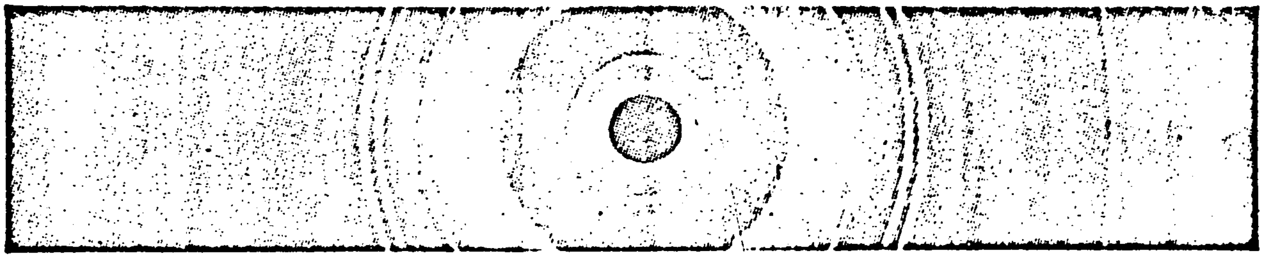
Comparison against Italian Standards

Patterns not included: Calcite (I34), Magnesite (I37), Muscovite (I35), Tremolite (I19/I20), Dolomite.

Most probable mineral present: Chlorite, Talc

Visual Comparison	Minerals Present
Chlorite, Talc	Chlorite, Talc

SAMPLE SIP 5 TALC



Comparison against A.S.T.M. index:

Patterns not included: 5-586 Calcite, 7-25 Muscovite (IM), 7-77 Sheridanite (Chlorite), 7-79 Forsterite (Olivine), 7-166 Bavalite (Chlorite).

Most probable minerals present: Talc, Muscovite, Chlorite

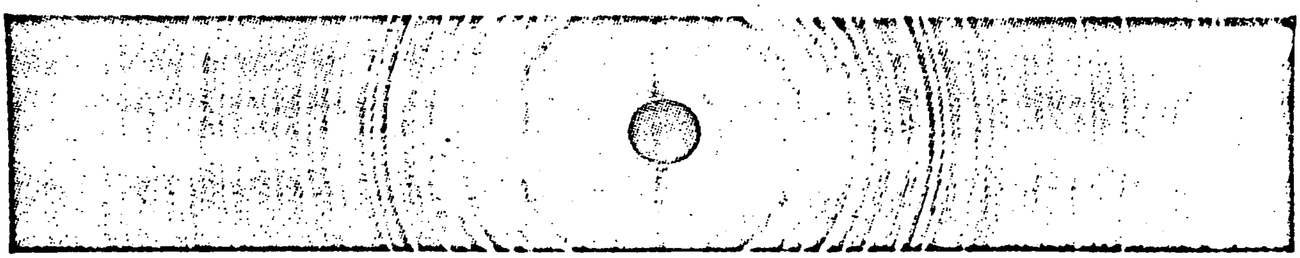
Comparison against Italian Standards

Patterns not included: Chlorite (I42), Chlorite (I4), Magnesite(I6), Tremolite (I19/I20).

Most probable minerals present: Talc

Visual comparison	Minerals Present
Talc, Chlorite	Talc, Chlorite

SAMPLE SIP 6 MUSCOVITE



Comparison against A.S.T.M. index: 3 lines unmatched, 1.7999Å, 1.3721Å, 1.2741Å.

Patterns not included: 3-881 Talc, 7-79 Forsterite (Olivine), 7-166 Bavalite (Chlorite), 7-183 Penninite (CHlorite), 8-479 Magnesite, 11-78 Dolomite, 19-770 Talc.

Most probable minerals present: Muscovite, Chlorite

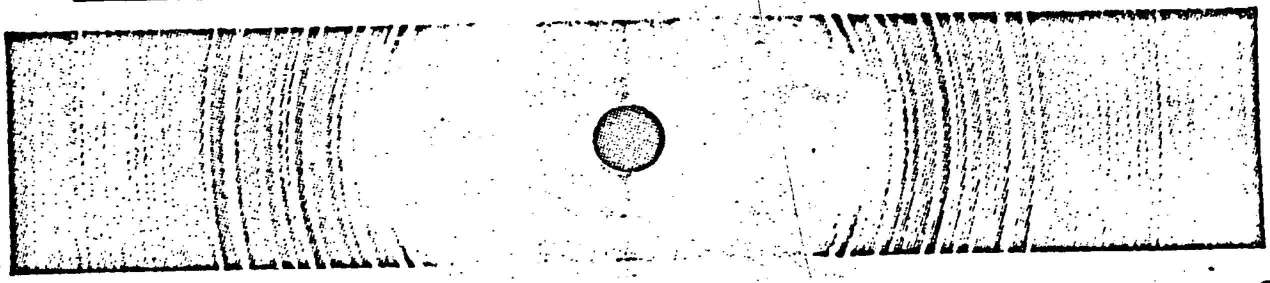
Comparison against Italian Standards

Patterns not included: Magnesite (I37), Tremolite (I19 and I20), Dolomite

Most probable minerals present: Muscovite, Talc

Visual Comparison	Mineral Present
Muscovite, Calcite	Muscovite, Calcite

SAMPLE SIP 7 MAGNESITE



Comparison against A.S.T.M. Index: 1 line unmatched 1.1092Å

Patterns not included: 5-586 Calcite, 6-263 Muscovite -2M1, 7-25 Muscovite (IM), 7-32 Muscovite (2M1), 7-160 Chlorite (Kotshubeite), 7-76 Ripodolite (Chlorite), 7-78 Thuringite (Chlorite), 7-166 Bavalite (Chlorite), 10-183 Penninite Chlorite, 13-437 Tremolite.

Most probable minerals present: Magnesite, Dolomite, Talc

Comparison against Italian Standards

Patterns not included: Calcite (I34), Chlorite (I4) Muscovite (I35), Tremolite (I19/I20).

Most probable minerals present: Magnesite, Dolomite, Talc

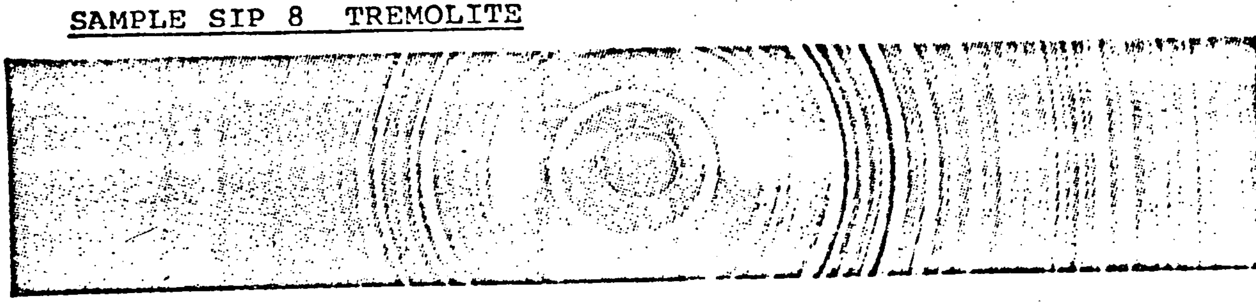
Visual Comparison

Magnesite, Talc

Minerals Present

Talc, Magnesite.

SAMPLE SIP 8 TREMOLITE



Comparison against A.S.T.M. Index: 1 line unmatched 1.1118Å

Patterns not included: 6-263 Muscovite -2M1, 7-25 Muscovite (IM), 7-32 Muscovite (2M1), 7-42 Muscovite (3T), 7-79 Forsterite (Olivine).

Most probable minerals present: Tremolite, Talc, Calcite

Comparison against Italian Standards

Patterns not included: Magnesite (I37), Chlorite (I4), Muscovite (I35).

Most probable minerals present: Tremolite, Talc, Calcite

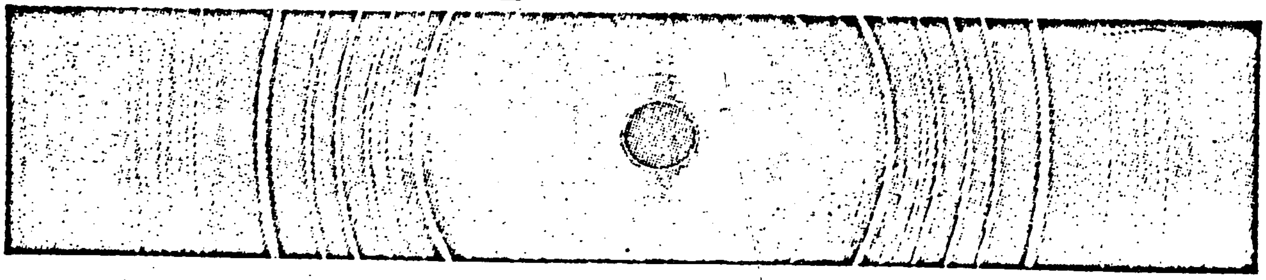
Visual Comparison

Tremolite, Talc

Minerals Present

Tremolite, Talc

SAMPLE SIP 9 DOLOMITE



Comparison against A.S.T.M. Index: 1 line unmatched 1.1094Å

Patterns not included: 3-881 Talc, 6-263 Muscovite -2M1, 7-25 Muscovite (IM), 7-32 Muscovite (2M1), 19-814 Muscovite 2M1 (Vanadian), 7-160 Chlorite (Kotschubeite), 7-79 Forsterite (Olivine), 13-437 Tremolite, 19-770 Talc.

Most probable minerals present: Dolomite, Muscovite

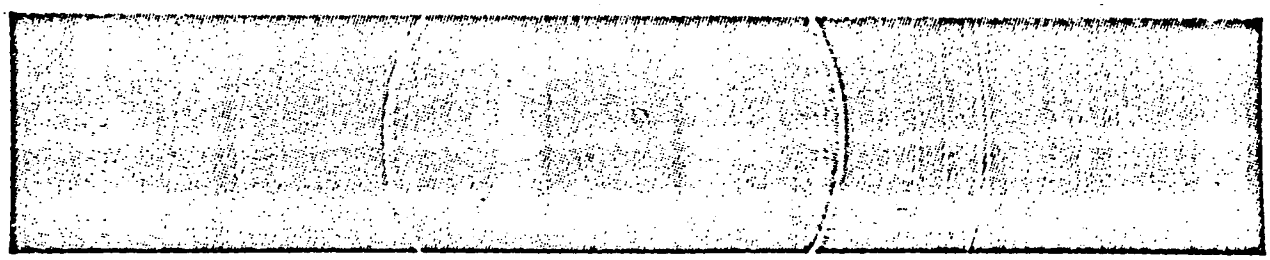
Comparison against Italian Standards

Patterns not included: Magnesite (I37), Chlorite (I4) Tremolite (I19/I20).

Most probable minerals present: Dolomite, Talc

Visual Comparison	Minerals Present
Dolomite, Muscovite, Calcite	Dolomite, Muscovite, Calcite

SAMPLE SIP 10 CALCITE



Comparison against A.S.T.M. Index: 3 unmatched lines 1.2095Å, 1.1098Å, 1.0926Å

Patterns not included: 7-160 Chlorite (Kotschubeite), 7-79 Forsterite (Olivine), 13-437 Tremolite.

Most probable minerls present: Calcite, Muscovite

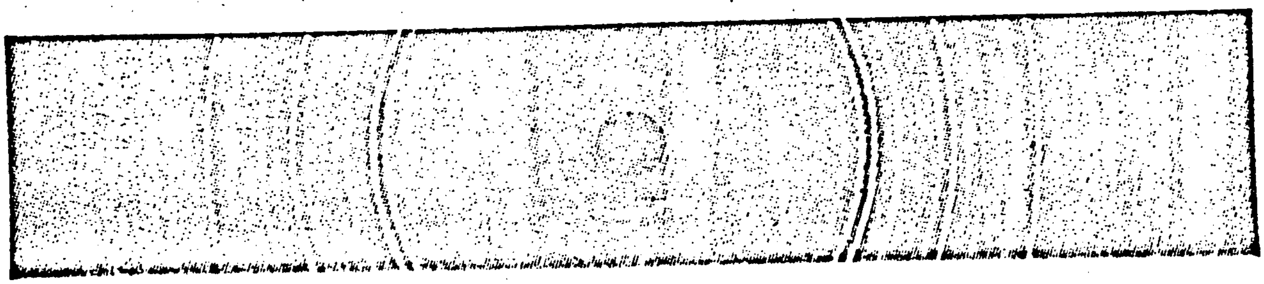
Comparison against Italian Standards

Patterns not included: Magnesite (I6), Tremolite (I19-I20).

Most probable minerals present: Calcite, Muscovite

Visual Comparison	Minerals Present
Calcite	Calcite, Muscovite

SAMPLE SIP 11 MAGNESITE



Comparison against A.S.T.M. Index: 1 unmatched line 1.1085Å

Patterns not included: 5-586 Calcite, 7-25 Muscovite (IM), 7-160 Chlorite (Kotschubeite), 7-76 Ripidolite (Chlorite), 7-78 Thuringite (Chlorite), 7-166 Bavalite (Chlorite), 10-183 Penninite Chlorite, B & T Quartz.

Most probable minerals present: Magnesite, Dolomite, Talc

Comparison against the Italian Standards

Patterns not included: Calcite (I34), Chlorite (I4), Muscovite (I35).

Most probable minerals present; Magnesite, Dolomite, Talc

Visual Comparison	Minerals Present
Magnesite, Dolomite, Talc	Magnesite, Talc, Dolomite

Examples of Patterns Obtained from Rock Type Specimens and Their Major Mineral Content from X-Ray Comparison.

SAMPLE I1 TALC FROM FOOTWALL CONTACT

Comparison

Patterns not included: Magnesite (I37), Tremolite (I19/I20).

Most probable minerals present: Chlorite, Muscovite, Talc, Dolomite.

Visual Comparison: Talc Chlorite, Calcite

Minerals Present: Talc Chlorite, Calcite.

SAMPLE I7 MICA SCHIST

Comparison

Patterns not included: Magnesite (I37), Talc (I46), Tremolite (I19/I20).

Most probable minerals present: Muscovite, Talc, Quartz

Visual Comparison: Muscovite, Talc,Quartz

Minerals Present:

SAMPLE I12 FOOTWALL SAMPLE? AMPHIBOLITE

Comparison: 3 lines unmatched. 6.4653Å 1.2819Å 1.225Å

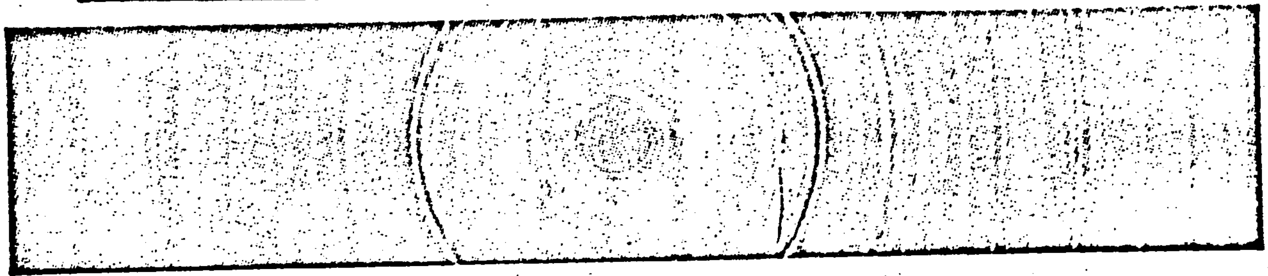
Patterns not included: Calcite (I34), Magnesite (I37), Talc (I46), Talc (I5), Tremolite (I19/I20).

Most probable minerals present: Muscovite, Dolomite, Quartz.

Visual Comparison: Muscovite, Chlorite, Quartz

Minerals Present:

SAMPLE I13 INCLUSION SHOWING PASSAGE INTO TALC BOTTOM TRANSIT



Comparison: 1 unmatched line 1.1541Å

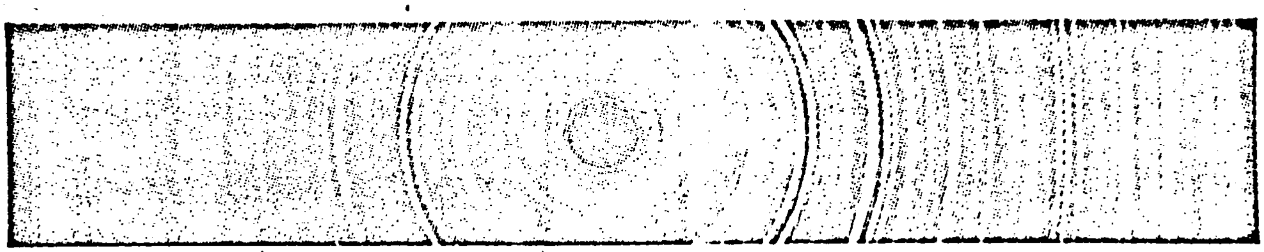
Patterns not included: Magnesite (I37), Muscovite (I35), Tremolite (I19/I20), Dolomite

Most probable minerals present: Chlorite, Talc, Quartz

Visual Comparison: Chlorite, Muscovite, Quartz

Minerals Present: Chlorite, Muscovite, quartz

SAMPLE I15 TALC-FOOTWALL CONTACT



Comparison:

Patterns not included: Magnesite (I37), Tremolite (I19/I20).

Most probable minerals present: Chlorite, Talc, Muscovite, Quartz.

Visual Comparison: Chlorite, Talc, Quartz

Minerals Present: Chlorite, Talc, Quartz

SAMPLE I16 FACE 1 INCLUSION BELOW SEAM

Comparison

Patterns not included: Talc (I45), Tremolite (I19/I20) Dolomite

Most probable minerals present: Muscovite, Chlorite, Calcite, Quartz

Visual Comparison: Chlorite, Muscovite, Calcite, Quartz

Minerals Present: Chlorite, Muscovite, Calcite, Quartz

SAMPLE I17 FOOTWALL ROCK SAMPLE

Comparison: 2 unmatched lines 6.6957Å, 1.6305Å

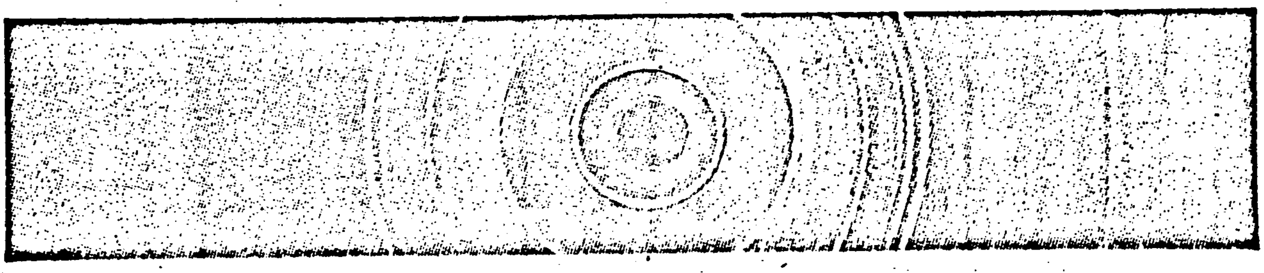
Patterns not included: Talc (I46), Chlorite (I42), Muscovite (I35), Magnesite (I6), Tremolite (I19/I20), Dolomite.

Most probable minerals present: Calcite, Talc, Quartz

Visual Comparison: Calcite, Talc, Quartz

Minerals Present: Calcite, Talc, Quartz

SAMPLE I20 AMPHIBOLE SAMPLE FROM GUIANA LEVEL 1212



Comparison: 1 unmatched line 1.6309Å

Patterns not included: Chlorite (I42), Chlorite (I4), Muscovite (I35), Magnesite (I6), Dolomite.

Most probable minerals present: Talc, Tremolite, Calcite, Magnesite.

Visual Comparison: Talc, Tremolite, Chlorite

Minerals Present: Talc, Chlorite, Tremolite

SAMPLE I23 BLACK GNEISS

Comparison: 5 unmatched lines 6.3586Å, 1.449Å, 1.2278Å, 1.2121Å, 1.1520Å.

Patterns not included: Calcite (I34), Tremolite (I19/I20)

Most probable minerals present: Muscovite, Talc, Magnesite, Quartz

Visual Comparison: Muscovite, Magnesite, Quartz

Minerals Present: Muscovite, Magnesite, Quartz

SAMPLE I25 LIMESTONE FOOTWALL

Comparison

Patterns not included: Calcite (I34), Tremolite (I19/I20).

Most probable minerals present: Talc, Chlorite, Quartz

Visual Comparison: Talc, Magnesite, Quartz

Minerals Present: Talc, Magnesite, Quartz

SAMPLE I27 LITHOLOGICAL INCLUSION

Comparison

Patterns not included: Chlorite (I42), Chlorite (I4), Tremolite (I19/I20), Magnesite (I6), Dolomite

Most probable minerals present: Talc, Calcite, Quartz

Visual Comparison: Talc, Calcite, Quartz

Minerals Present: Talc, Calcite, Quartz

SAMPLE I29 SAMPLE 6 FOOTWALL

Comparison: 2 unmatched lines 1.1526Å, 6.3031Å

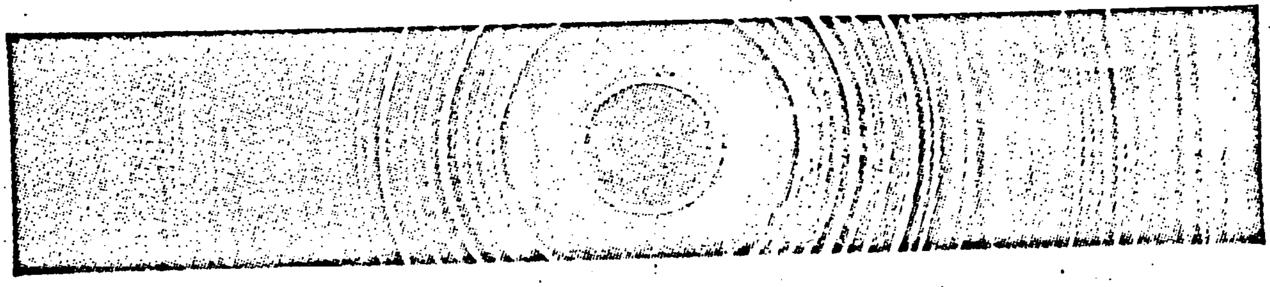
Patterns not included: Calcite (I34), Magnesite (I37), Chlorite (I4), Talc (I5).

Most probable minerals present: Muscovite, Quartz, Dolomite, Talc

Visual Comparison: Muscovite, Quartz

Minerals Present: Muscovite, Quartz

SAMPLE I31 BLACK INCLUSION



Comparison: 1 unmatched line 1.2145Å

Patterns not included: Magnesite (I37), Talc (I5), Dolomite

Most probable minerals present: Muscovite, Calcite, Talc

Visual Comparison: Muscovite, Calcite

Minerals Present: Muscovite, Calcite

SAMPLE I34 TUNNEL WALL - MARBLE

Comparison

Patterns not included: Tremolite (I19/I20), Magnesite (I6)

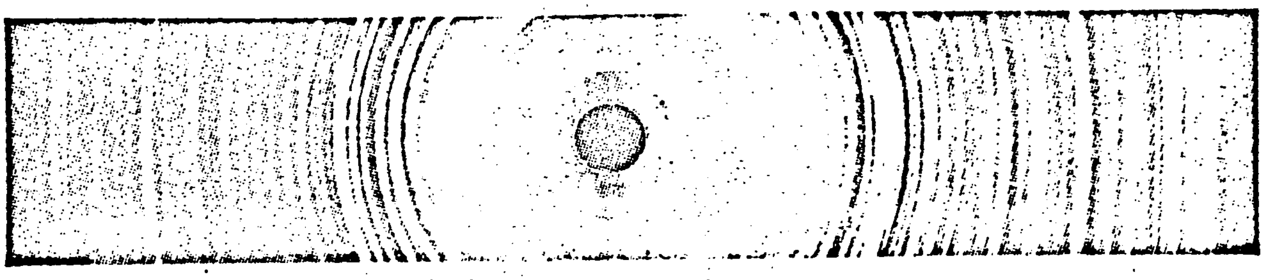
Most probable minerals present: Calcite, Muscovite, Talc

Visual Comparison, Calcite

Minerals Present Calcite

Examples of Patterns Obtained from the Carbonate Specimens and their Major Mineral Composition Obtained from Comparison with Standards.

SAMPLE I4 FACE 10 AMPHIBOLE



Comparison: 3 unmatched lines 1.2586Å, 1.0823Å, 1.074Å

Patterns not included: Chlorite (I42), Chlorite (I4)
Dolomite

Most probable minerals present: Tremolite, Talc, Magnesite

Visual Comparison: Talc, Tremolite, Magnesite

Minerals Present: Talc, Tremolite, Magnesite

SAMPLE I6 QUARTZ

Comparison

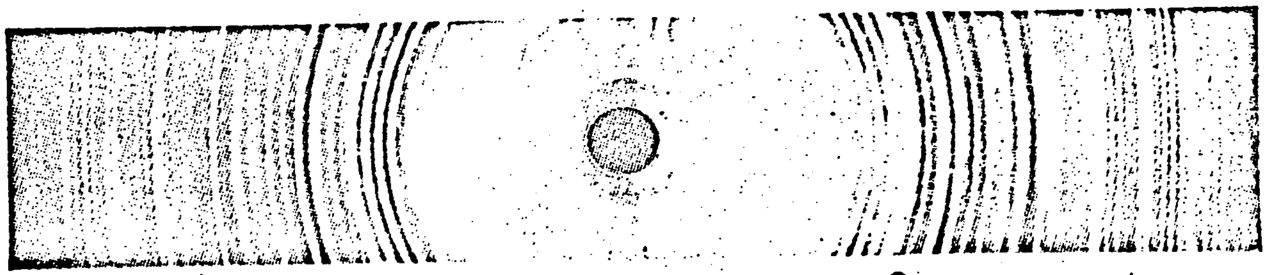
Patterns not included: Calcite (I34), Chlorite (I4)
Tremolite (I19/I20)

Most probable minerals present: Magnesite, Dolomite, Talc

Visual Comparison: MAGNESITE, Talc

Minerals Present: Magnesite, Talc

SAMPLE I11 CARBONATE - TALC INCLUSION



Comparison: 1 unmatched line 1.2143Å

Patterns not included: Chlorite (I42), Chlorite (I4)

Most probable minerals present: Magnesite, Dolomite, Talc

Visual Comparison: Talc, Magnesite, Calcite

Minerals Present: Talc, Magnesite, Calcite

SAMPLE I14 SEAM 4 INCLUSION IN TALC

Comparison

Patterns not included: Magnesite (I37), Chlorite (I4), Muscovite (I35), Tremolite(I19/I20)

Most probable minerals present: Dolomite, Talc

Visual Comparison: Talc, Dolomite

Minerals Present: Talc, Dolomite

SAMPLE I18 FACE 3 MAGNESITE AND TALC

Comparison:

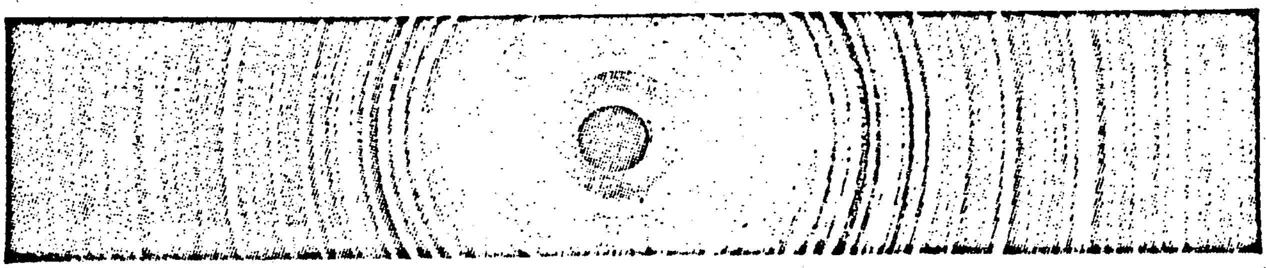
Patterns not included: Talc (I5), Tremolite (I19/I20)

Most probable minerals present: Dolomite, Magnesite, Chlorite

Visual Comparison: Dolomite, Talc Chlorite

Minerals Present: Dolomite, Talc, Chlorite.

SAMPLE I 19 IMPURITY IN TALC AND QUARTZ



Comparison:

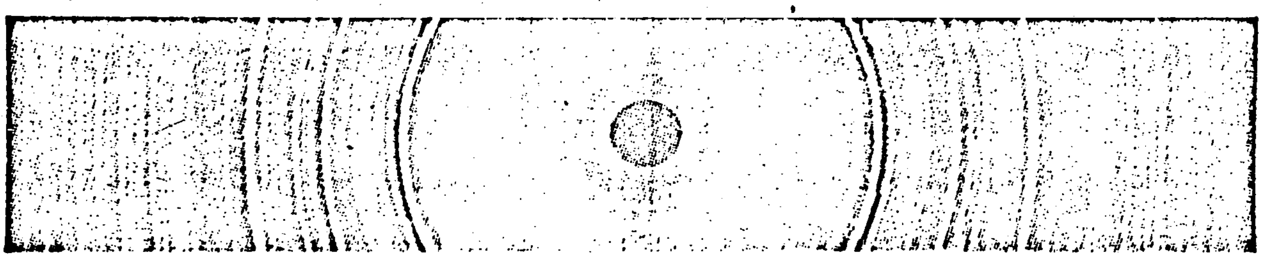
Patterns not included: Magnesite (I37)

Most probable minerals present: Tremolite, Dolomite, Muscovite, Talc

Visual Comparison: Talc, Tremolite, Magnesite.

Minerals Present: Talc, Tremolite, Magnesite

SAMPLE I21 FACE 2 OCCLUSION (MAGNESITE)



Comparison:

Patterns not included: Calcite (I34), Chlorite (I4), Muscovite (I35), Tremlite (I19/I20)

Most probable minerals present: Dolomite, Magnesite, Talc

Visual Comparison: Talc, Magnesite, Dolomite

Minerals Present: Talc, Magnesite, Dolomite

SAMPLE I22 MAGNESITE, DOLOMITE, TALC

Comparison:

Patterns not included: Calcite (I34), Talc (I45), Talc (I46) Muscovite (I35), Tremolite (I19/I20).

Most probable minerals present: Dolomite, Magnesite, Chlorite, Talc.

Visual Comparison: Talc, Dolomite.

Minerals Present: Talc, Dolomite

SAMPLE I30 TALC AND OTHERS

Comparison:

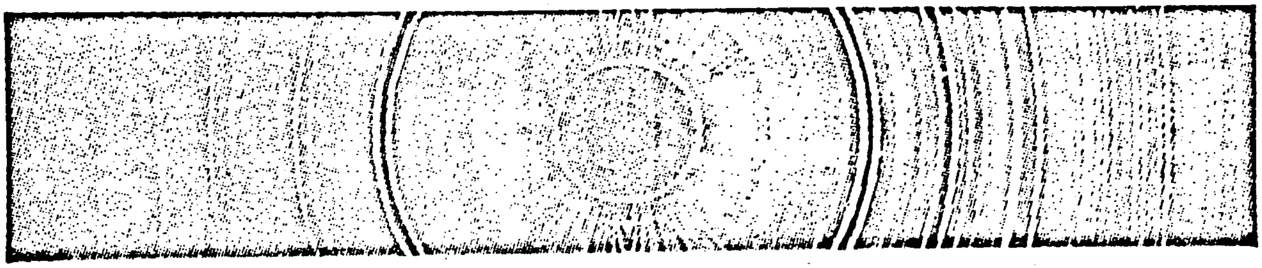
Patterns not included: Magnesite (I37), Talc (I5), Tremolite (I19/I20).

Most probable minerals present: Dolomite, Chlorite, Muscovite, Talc.

Visual Comparison: Talc, Chlorite

Minerals Present: Talc, Chlorite

SAMPLE I35 MASSIVE CARBONATE. END OF WORKING



Comparison:

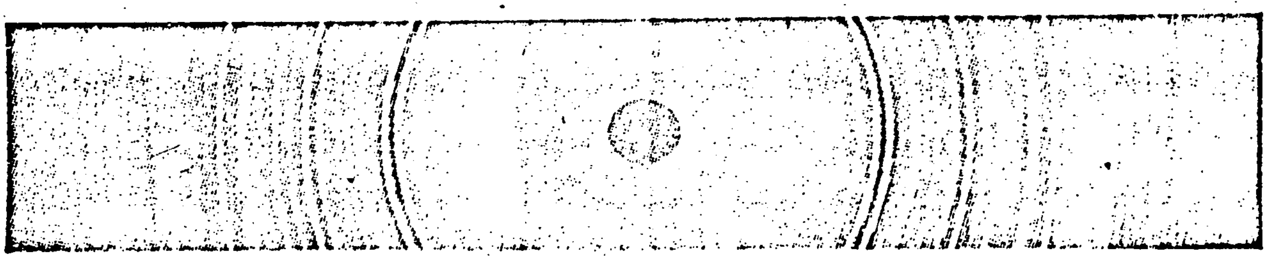
Patterns not included: Tremolite (I19/I20)

Most probable minerals present: Muscovite, Magnesite, Chlorite

Visual Comparison: Magnesite, Talc, Chlorite

Minerals Present: Magnesite, Talc, Chlorite

SAMPLE I37 CARBONATE AND TALC



Comparison

Patterns not included: Calcite (I34), Chlorite (I4), Muscovite (I35).

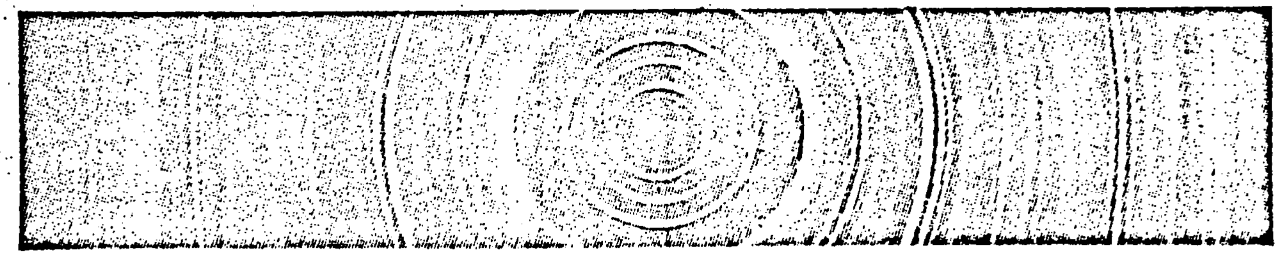
Most probable minerals present: Magnesite, Dolomite, Talc

Visual Comparison: Magnesite, Talc

Minerals Present: Magnesite, Talc

Examples of Patterns and Major Mineral Content of Those Specimens Classified as Talc Types Obtained by Comparison.

SAMPLE I2 SORTING PIECES



Comparison

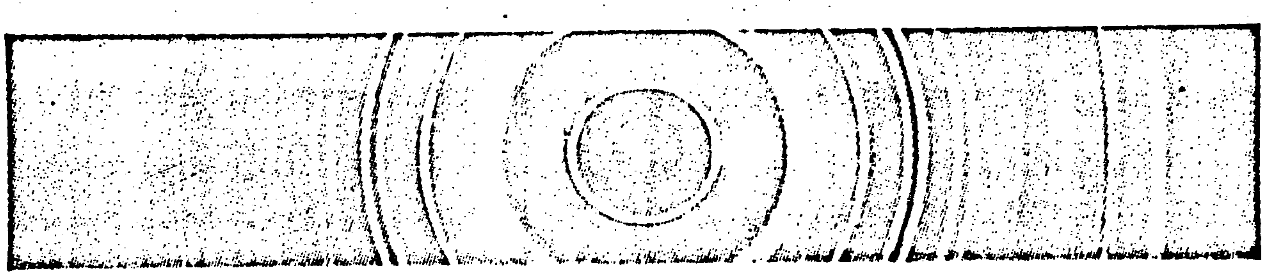
Patterns not included: Tremolite (I19/I20).

Most probable minerals present: Chlorite, Magnesite, Talc

Visual Comparison: Chlorite, Talc

Minerals Present: Chlorite, Talc

SAMPLE I3 COLOURED TALC



Comparison:

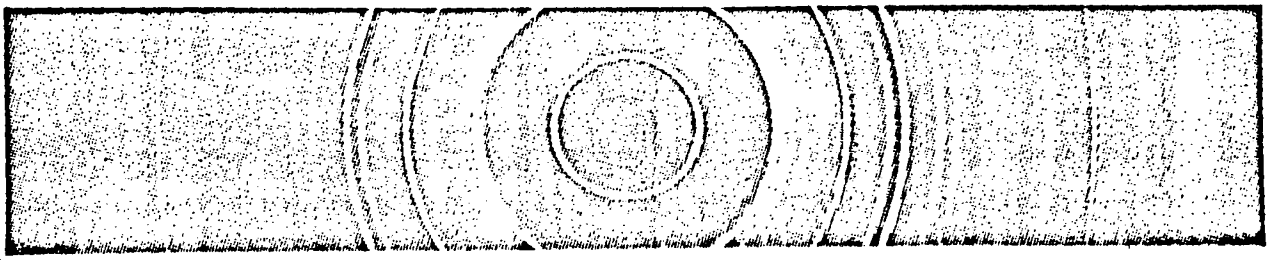
Patterns not included: Chlorite (I42), Chlorite (I4), Muscovite (I35), Magnesite (I6), Tremolite (I19/I20), Dolomite.

Most probable minerals present: Talc

Visual Comparison: Talc

Minerals present: Talc

SAMPLE I5 GENERAL ORE



Comparison: 2 unmatched lines 18.1157Å 7.0073Å

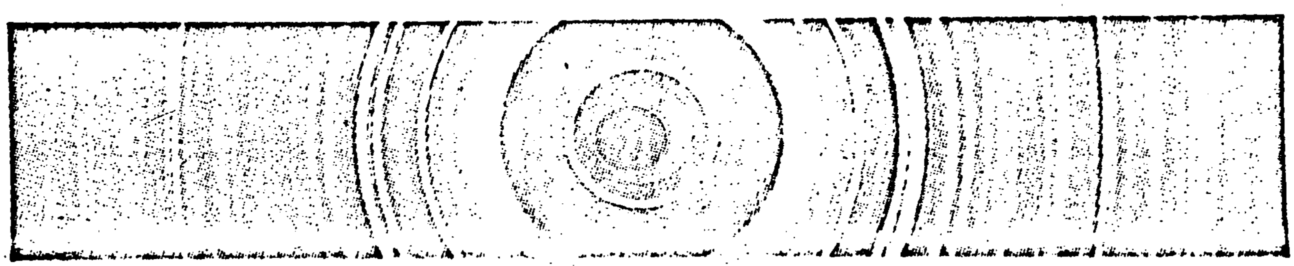
Patterns not included: Chlorite (I42), Chlorite (I4), Muscovite (I35), Dolomite.

Most probable minerals present: Talc, Magnesite

Visual Comparison: Talc

Minerals present: Talc

SAMPLE I8 MASSIVE TALC



Comparison

Patterns not included: Magnesite (I6), Tremolite (I19/I20).

Most probable minerals present: Talc, Chlorite

Visual Comparison: Talc, Chlorite

Minerals Present: Talc, Chlorite

SAMPLE I9 FACE 1 GREY TALC

Comparison

Patterns not included: Calcite (I34), Magnesite (I37), Muscovite (I35), Magnesite (I6), Tremolite (I19/I20).

Most probable minerals present: Talc, Chlorite

Visible Comparison: Talc, Chlorite

Minerals Present: Talc, Chlorite

SAMPLE I10 GRANULAR TALC

Comparison

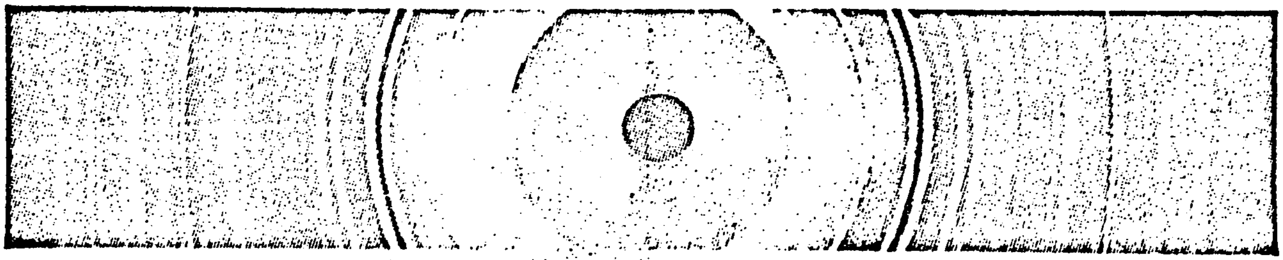
Patterns not included: Calcite (I34), Magnesite (I37), Chlorite (I42) Chlorite (I4), Muscovite (I35), Magnesite (I6) Tremolite (I19/I20)

Most probable minerals present: Talc, Dolomite

Visible Comparison: Talc, Dolomite

Minerals Present: Talc, Dolomite

SAMPLE I24 TALC FACE 2



Comparison:

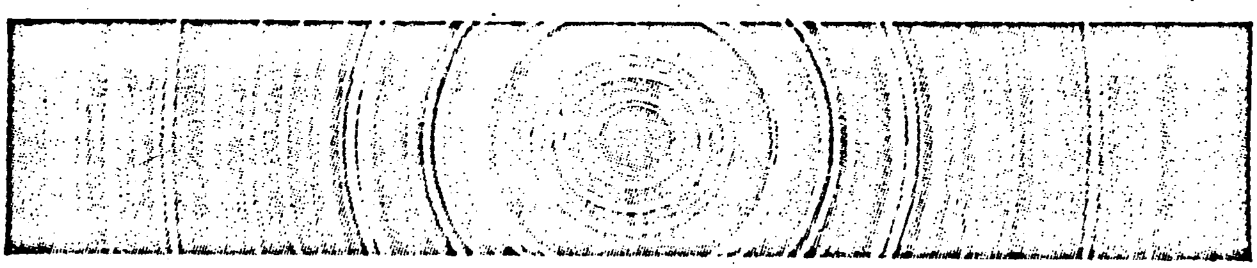
Patterns not included: Muscovite (I35), Tremolite (I19/I20) Magnesite (I6).

Most probable minerals present: Talc, Chlorite, Dolomite, Magnesite

Visual Comparison: Dolomite, Magnesite, Talc

Minerals Present: Dolomite, Magnesite, Talc

SAMPLE I26 TALC INCLUSIONS



Comparison

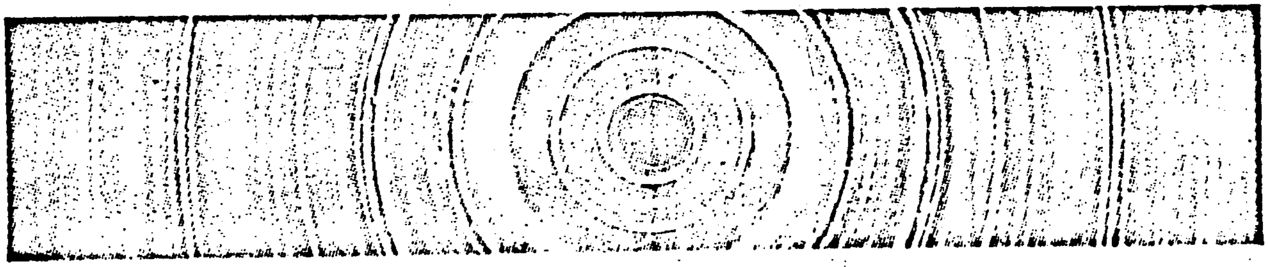
Patterns not included: Calcite (I34), Tremolite (I19/I20)

Most probable minerals present: Talc, Chlorite, Dolomite

Visual Comparison: Talc, Chlorite

Minerals Present: Talc, Chlorite

SAMPLE I28 QUARTZ TALC



Comparison

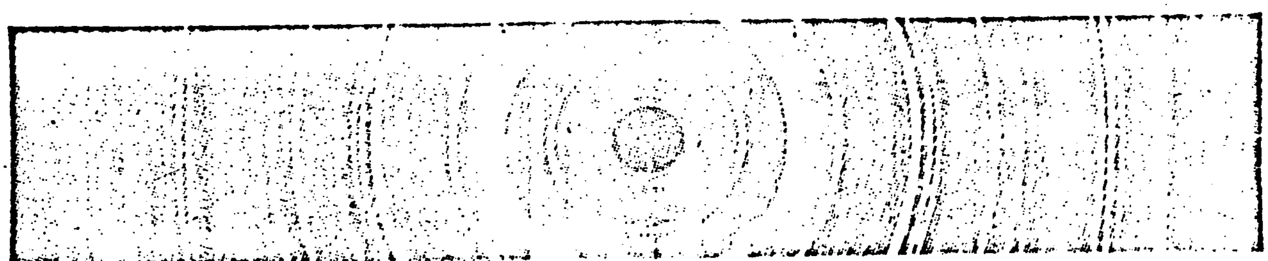
Patterns not included: Muscovite (I35), Tremolite (I19/I20)
Magnesite (I6), Dolomite

Most probable minerals present: Chlorite, Talc, Quartz

Visual Comparison: Chlorite, Talc,Quartz

Minerals Present: Chlorite, Talc, Quartz

SAMPLE I32 OCCLUSION FACE 2



Comparison

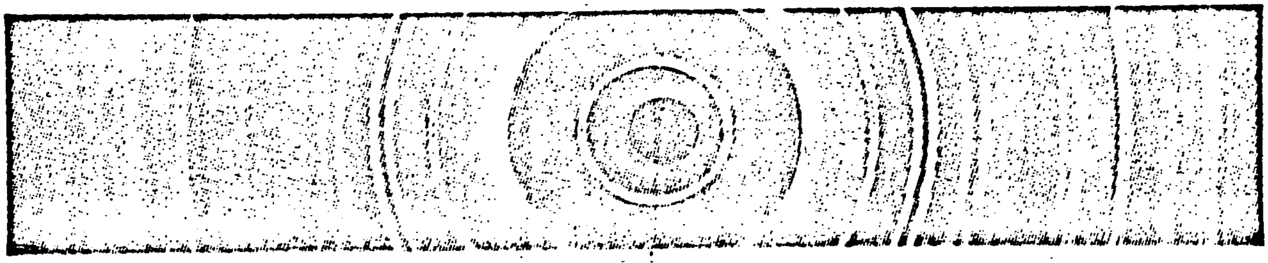
Patterns not included: Muscovite (I35), Tremolite (I19/I20)
Dolomite

Most probable minerals present: Chlorite, Talc, Magnesite

Visual Comparison: Chlorite, Talc

Minerals Present: Chlorite, Talc

SAMPLE I33 TALC END OF WORKING



Comparison:

Patterns not included: Muscovite (I35), Tremolite (I19/I20)

Most probable minerals present: Talc, Chlorite, Magnesite
Dolomite

Visual Comparison: Talc, Chlorite, Magnesite

Minerals Present: Talc, Chlorite, Magnesite

SAMPLE I36 GREY TALC

Comparison: 2 unmatched lines 1.2204Å; 1.1517Å

Patterns not included: Calcite (I34), Talc (I46)
Tremolite (I19/I20).

Most probable minerals present: Chlorite, Muscovite, Talc

Visual Comparison: Chlorite, Talc

Minerals Present: Chlorite, Talc

SAMPLE I38 TALC AND PYRITE

Comparison: 1 unmatched line 1.041Å

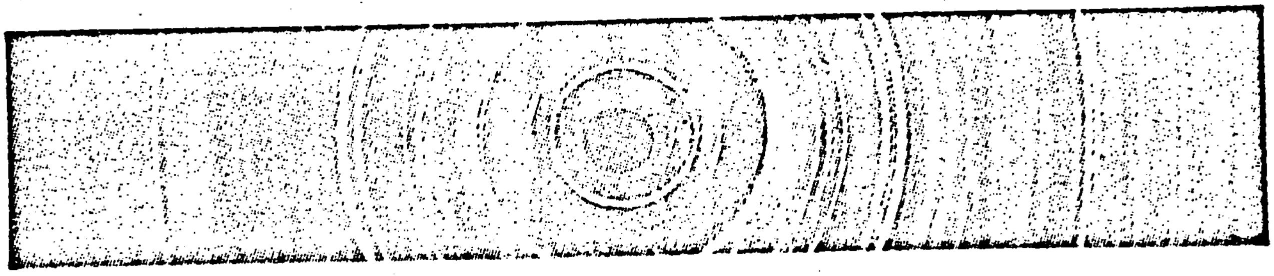
Patterns not included: Chlorite (I42), Chlorite (I4),
Muscovite (I35), Tremolite (I19/I20)

Most probable minerals present: Talc, Calcite

Visual Comparison: Talc, Calcite

Minerals Present: Talc, Calcite

SAMPLE I39 S-'Q' FROM CRUSHER



Comparison

Patterns not included: Muscovite, (I35), Tremolite (I19/I20) Magnesite (I6).

Most probable minerals present: Talc Chlorite

Visual Comparison: Talc, Chlorite, Calcite

Minerals Present: Talc, Chlorite, Calcite

SAMPLE I40 PLATEY TALC

Comparison:

Patterns not included: Tremolite (I19/I20)

Most probable minerals present: Talc, Magnesite, Chlorite

Visual Comparison: Talc, Chlorite, Magnesite

Minerals Present: Talc, Chlorite, Magnesite

SAMPLE I41 GOOD SPECIMEN No.2.

Comparison:

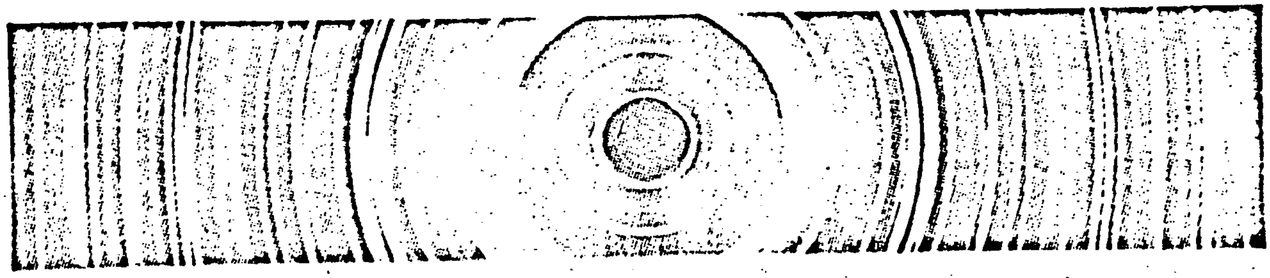
Patterns not included: Calcite (I34), Muscovite (I35), Tremolite (I19/I20), Magnesite (I6), Dolomite

Most probable minerals present: Talc, Chlorite

Visual Comparison: Talc, Chlorite

Minerals Present: Talc, Chlorite

SAMPLE I42 COLOURED TALC No.1.



Comparison

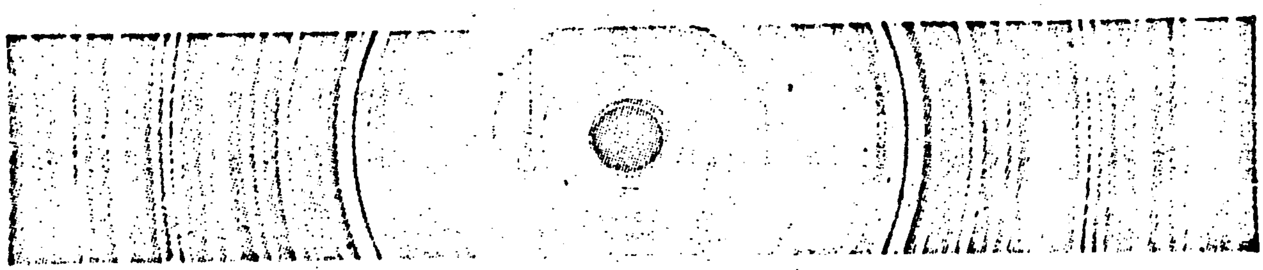
Patterns not included: Magnesite (I37), Talc (I46), Muscovite (I35), Dolomite.

Most probable minerals present: Chlorite, Talc

Visual Comparison: Chlorite, Talc

Minerals Present: Chlorite, Talc

SAMPLE I43 FIBROUS TALC FACE 10



Comparison: 2 unmatched lines 4.8928Å, 4.4431Å

Patterns not included: Calcite (I34), Magnesite (I37), Muscovite (I35), Tremolite (I19/I20)

Most probable minerals Present: Chlorite, Talc

Visual Comparison: Chlorite, Talc

Minerals Present: Chlorite, Talc

SAMPLE I44 PURE TALC FACE 1

Comparison: 1 unmatched line 1.0798

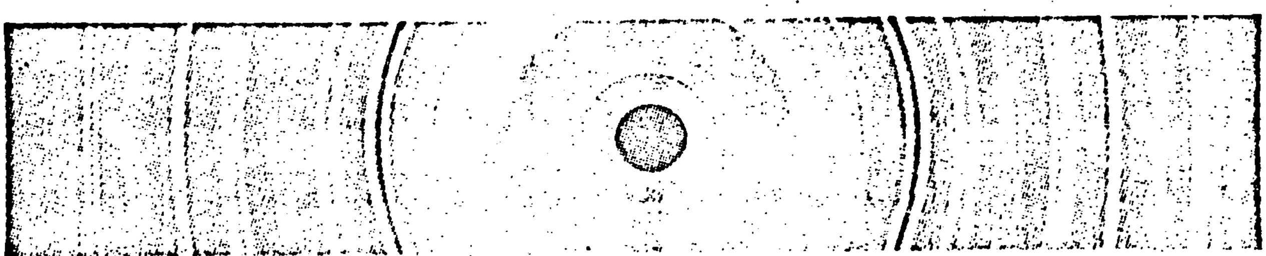
Patterns not included: Magnesite (I37), Talc (I42), Muscovite (I35), Tremlite (I19/I20)

Most probable minerals present: Chlorite, Talc, Dolomite

Visual Comparison: Talc, Magnesite, Chlorite

Minerals Present: Talc, Magnesite, Chlorite

SAMPLE I45 GOOD SPECIMEN FACE 1



Comparison: 2 unmatched lines 1.0882Å, 1.0505Å

Patterns not included: Calcite (I34), Chlorite (I42), Chlorite (I4) Muscovite (I35), Magnesite (I6), Tremolite (I19/I20), Dolomite.

Most probable minerals present: Talc, Magnesite

Visual Comparison: Talc

Minerals Present: Talc

SAMPLE I46 COLOURED TALC FACE 3

Comparison:

Patterns not included: Chlorite (I42), Chlorite (I4), Muscovite (I35), Tremolite (I19/I20).

Most probable minerals present: Talc, Magnesite

Visual Comparison: Talc, Magnesite

Minerals Present: Talc, Magnesite

Specimen Patterns and Comparison Data for
Samples of Old Powders and ØØØØØ Shipments

SAMPLE BATCH 6 POWDER F1 PW.J. 035

Comparison: 1 unmatched line 8.1972Å

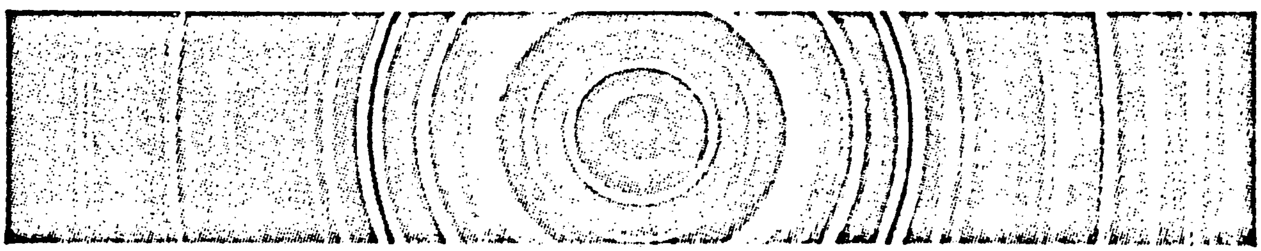
Patterns not included: Muscovite (I35), Tremolite (I19/I20)

Most probable minerals present: Talc, Magnesite, Chlorite

Visual Comparison: Talc, Chlorite, Magnesite

Minerals Present: Talc, Chlorite, Magnesite

SAMPLE BATCH 8 POWDER (S and G) PW.J. 035



Comparison

Patterns not included: Magnesite (I6), Tremolite (I19/I20)

Most probable minerals present: Talc, Magnesite, Boric Acid

Visual Comparison: Talc, Chlorite, Boric Acid

Minerals Present: Talc, Chlorite, Boric Acid

SAMPLE BATCH 9 POWDER T4 P.W.J. 035

Comparison: 1 unmatched line 1. 2587Å

Patterns not included: Tremolite (I19/I20)

Most probable minerals present: Talc, Chlorite, muscovite, Magnesite, Boric Acid

Visual Comparison: Talc, Chlorite, Boric Acid

Minerals Present: Talc, Chlorite, Boric Acid

SAMPLE BATCH 10 POWDER SK1BP PW.J. 035

Comparison

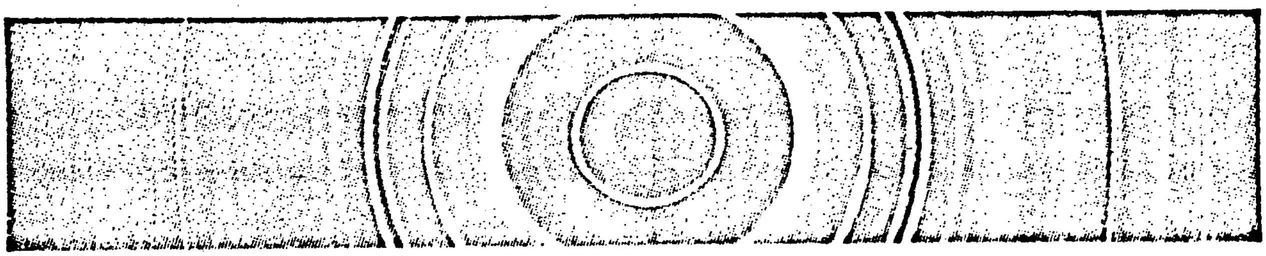
Patterns not included: Calcite (I34), Muscovite (I35), Tremolite (I19/I20), Dolomite

Most probable minerals present: Talc, Chlorite, Magnesite, Boric Acid.

Visual Comparison: Talc, Chlorite, Boric Acid

Minerals Present: Talc, Chlorite, Boric Acid

SAMPLE BATCH 11 POWDER LD18P PW.J. 035



Comparison: 1 unmatched line 8.1363Å

Patterns not included: Magnesite (I6), Tremolite (I19/I20) Dolomite

Most probable minerals present: Talc, Chlorite, Boric Acid

Visual Comparison: Talc, Chlorite, Boric Acid, Magnesite

Minerals Present: Talc, Chlorite, Boric Acid, Magnesite

SAMPLE BATCH 12 TALC 1960 PW.J. 025

Comparison: 1 unmatched line 8.12 Å

Patterns not included: Tremolite (I19/I20)

Most probable minerals present: Talc, muscovite, chlorite, Boric Acid.

Visual Comparison: Talc, Chlorite, Boric Acid, Magnesite

Minerals Present: Talc, Chlorite, Boric Acid, Magnesite

SAMPLE BATCH 13 TALC 1961 PW.J. 026

Comparison

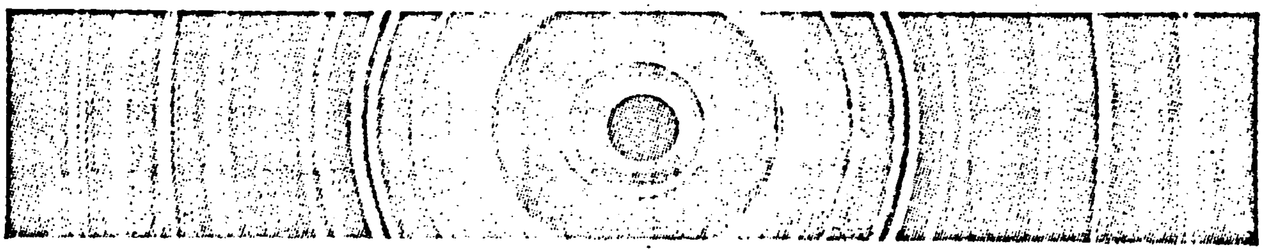
Patterns not included: Calcite (I34), Muscovite (I35)
Tremolite (I19/I20)

Most probable minerals present: Talc, Chlorite, Magnesite
Boric Acid

Visual Comparison: Talc, Chlorite, Magnesite, Boric Acid

Minerals Present: Talc, Chlorite, Magnesite, Boric Acid

SAMPLE BATCH 19 S.S. CATHERINA W. 02/05/72



Comparison

Patterns not included: Tremolite (I19/I20)

Most probable minerals present: Talc, Chlorite, Magnesite

Visual Comparison: Talc, Chlorite, Magnesite

Minerals Present: Talc, Chlorite, Magnesite

SAMPLE BATCH 2 TALC S.S. EDNA 'B' 14/02/72

Comparison

Patterns not included: Talc (I45), Tremolite (I19/I20)

Most probable minerals present: Talc, Chlorite

Visual Comparison: Talc, Chlorite

Minerals Present: Talc, Chlorite

CONCLUSIONS

The optical examination has shown that there are a large number of minerals associated with the rock types found both in the talc seam and in the associated rocks. The footwall rocks in contact with the talc are mainly composed of the minerals quartz, muscovite, chlorite, garnet, and some carbonate material both calcite and magnesite. Minor minerals in the footwall contact rocks include epidote, microcline, tremolite and actinolite, sphene, rutile, hornblende, rare talc, biotite, pyrite, pyrrhotite and chalcopyrite. Rock type inclusions into the talc have similar compositions to the footwall rocks but with higher muscovite and chlorite contents. The muscovite was generally an iron rich variety (phengite), while two forms of chlorite were observed namely sheridanite and penninite. Other talc inclusions consist mainly of carbonate minerals, calcite and magnesite in varying quantities. It is with these nodules that some tremolite is found. The rocks further away from the talc seams, namely the gneiss, become richer in quartz and microcline and below these marble occurs.

The carbonate specimens examined by optical means showed that the carbonate minerals, calcite and magnesite, were accompanied by talc, chlorite, tremolite, muscovite, rutile and pyrite, all in minor amounts. In general the carbonate inclusions were large and very discrete in the talc seam itself.

The specimens examined, which can be classified as talc samples, were found to be in the main composed of talc with chlorite as the major contaminant. Some specimens, however, were predominantly composed of chlorite with minor talc inclusions. Other minerals found in association with the talc specimens included garnet, rutile and magnesite with rare tremolite and a quartz or serpentine inclusion. Some differences were observed in the talc itself, some of the talc appearing to be a little murky in texture. X-ray pictures of the clear and murky material showed no differences however.

The powder X-ray examination confirmed the major minerals occurring in the hand specimens and a classification was possible into the three groups already mentioned, i.e. rock types, carbonate samples and talc specimens. The only asbestos type mineral to be detected in the hand samples was tremolite, which was found in three of the specimens. The tremolite was associated with carbonate minerals, namely magnesite and calcite, no tremolite was detected in the talc type specimens. Chlorite was, however, very common in the talc types, some of the specimens being very nearly pure chlorite in composition. There appeared to be some association of the chlorite with coloured talc specimens, especially those with a greyish colour. Other colour variations due to rutile were not detected by X-ray examination.

The examination of consecutive samples at face 1 in the mine showed that the chlorite content can vary very drastically over a 6ft thick section of the talc seam. Patterns obtained from several shipments of ØØØØØ talc showed that chlorite, together with carbonate material, were the major contaminant minerals. This was also true of powder samples ranging back to 1949 in which the only observable difference was the presence of boric acid.

The electron microscope examination of the powdered samples showed that a difference could be drawn between particles produced from the various samples. The carbonates and rock types on the whole produced compact fibre free particles. The talc specimens were, however, plate-like in appearance with varying quantities of lath like particles coupled with fibres which were textile in appearance. Both lath and textile types of particles were not composed of minerals associated with the commercial asbestos industry. Particles formed from the amphibole mineral found at the mine were hardly fibrous in character, the majority of the tremolite breaking to give compact particles. Those fibres formed were short and had a very large diameter when compared with the commercial varieties of asbestos. No amphibole or chrysotile mineral was detected in any of the numerous powders examined.

The Italian talc ØØØØØ contains observable quantities of chlorite and carbonate minerals and could contain any one of the following minerals in very minor amounts: muscovite, quartz, tremolite, garnet and rutile. If small pieces of footwall rock were to contaminate the ore during production, several of the other listed minerals found in the rock type specimens could appear in the shipped product. It is unlikely that they would be present in detectable amounts.

F.D. POOLEY

Project Supervisor

OCCUPATIONAL EXPOSURES TO NON-ASBESTIFORM TALC IN VERMONT

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INTRODUCTION

An environmental study of the Vermont talc mines and mills was undertaken in support of a concurrent epidemiological study of talc workers. Since geological studies dating from the early 1900's have shown that the Vermont talc deposits contain no asbestos and little quartz this population represents a group of talc workers employed in mining and milling operations who have no association with these two fibrosis producing minerals (Jacobs, 1914, 1918; Weiss and Boettner, 1967). Therefore, the intent of this study was to verify these geological reports by quantitating the personal dust exposures of these talc workers, and by identifying the mineral content of this "clean" talc ore.

MINERALOGY

Pure talc mineral is a hydrous magnesium silicate (Table 1) and consists of a brucite sheet containing magnesium ions sandwiched between two weakly held silica sheets (Hildick-Smith, 1976). This mineral is extremely soft and slippery, and has a hardness of 1 on the Mohs scale. However, as used industrially, the term "talc" refers to a mixture of minerals that meet certain physical requirements rather than one which has a fixed chemical composition (Brown, 1973). Industrial grades of talc (Table 2) usually contain chlorites which are sheet silicate minerals containing magnesium, iron, and aluminum, and carbonates which include magnesite, dolomite, and calcite. Quartz, iron oxides, serpentine (one of the minerals from which talc evolved) and tremolite may also be present. Since the constituents of industrial talc

TABLE 1. Some Chemical and Physical Properties of Talc

Talc: $3MgO \cdot 4SiO_2 \cdot H_2O$
Refractive indices: 1.54 - 1.6
Specific gravity: 2.6 - 2.8
Hardness (Mohs Scale): 1
Color: White or gray to apple green
Morphological varieties: Laminated and Fibrous

2

vary in their mineral and fiber content, the ensuing product has a considerable range in hardness and particle shape which contributes to its versatility.

TABLE 2. Some Minerals Found in Industrial Talc

Chlorite	$(MgFe)_5Al(AlSi_3)O_{10}(OH)_8$
Magnesite	$MgCO_3$
Dolomite	$CaMg(CO_3)_2$
Calcite	$CaCO_3$
Serpentine	$Mg_6(Si_4O_{10})(OH)_8$
Quartz	SiO_2
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$

FIELD STUDY

The three major Vermont talc companies were surveyed in the summer of 1975 and the winter of 1976. Bulk samples from representative milling and mining operations were collected and were analyzed qualitatively for their mineral constituents A total of 312 personal respirable mass samples (118 in mines and 194 in mills) were taken using nylon, 10 mm cyclones at a flow rate of 1.7 lpm. Seventy percent of these samples were analyzed for free silica content by infrared spectrophotometry or x-ray diffraction (Cares *et al.*, 1973). Fifty-seven parallel filter samples were taken for fiber determinations on 0.8 μm Millipore filters using phase contrast microscopy at X437 magnification and on 0.4 μm Nuclepore filters using scanning electron microscopy at X5000 magnification.

BULK SAMPLES

Bulk samples from the mines and mineral mixtures or products from the mills were obtained from each company. Each sample was ground, dried, and scanned qualitatively by x-ray diffraction (Table 3). For all the samples, talc and magnesite are found in major amounts, chlorite and/or dolomite are minor constituents, and dolomite, calcite, quartz, biotite, ankerite, chromite, oligoclase, or phlogopite may be found in trace quantities.

Quartz was present in trace amounts in 15% of these samples. Further analysis by NIOSH, which included petrographic microscope analysis, transmission electron microscopy, and x-ray diffraction with step-scanning, revealed no asbestos in these samples.

TABLE 3. Qualitative Analysis of Bulk Samples by X-Ray Diffraction

Source	Major (20-100%)	Minor (5-20%)	Trace (<5%)
Mine (37)	Talc Magnesite	Chlorite (Dolomite)	Dolomite Calcite Quartz Biotite Ankerite Chromite Phlogopite Oligoclase
Mill (20)	Talc Magnesite	Chlorite (Dolomite)	Calcite Quartz Phlogopite Biotite Dolomite

RESPIRABLE MASS SAMPLES

The personal respirable mass concentrations of the miners for the two sampling surveys are presented in Table 4. Companies A and B were working one mine, while Company C had three mines in operation in the summer and two mines during the

TABLE 4. Respirable Mass Concentrations of Vermont Miners

Company		Summer 1975 (N)	GM	GSD	Winter 1976 (N)	GM	GSD
			(mg/m³)			(mg/mg³)	
A	Underground Mine	(18)	0.6	2.1	(16)	0.5	2.1
B	Underground Mine	(15)	1.5	1.6	(23)	0.9	1.9
C	Underground Mine	(12)	0.5	1.9	(19)	0.7	1.8
	Walk-in Mine	(7)	1.2	2.2			
	Walk-in Mine				(6)	1.7	3.3
	Open Pit Mine	(2)	5.1	1.4			

GM - Geometric mean
GSD - Geometric standard deviation
N - Number of samples

winter survey. Table 4 shows that the highest dust concentrations in the underground mines occur at Company B. The ore in this mine is relatively hard, and the extensive drilling operations required to break apart the large boulders may account for the higher dust levels. There is no statistical difference between the dust exposures of the summer and winter surveys for the mines.

The respirable mass data of the millers for the summer and winter surveys are presented in Table 5. With the exception of Mill #1 at Company C, all the Vermont talc mills are large, barn-like, drafty structures heated by space-heaters. Despite the

TABLE 5. Respirable Mass Concentrations of Vermont Millers

Company	Shift	Summer 1975 (N)	GM	GSD	Winter 1976 (N)	GM	GSD
			(mg/m³)				
Company A	1st	(4)	1.7	1.6	(13)	1.7	1.9
	2nd	(6)	0.5	2.0	(3)	1.5	2.2
Company B	1st	(22)	1.8	1.8	(42)	1.8	1.6
	2nd	(12)	2.9	1.7	(16)	1.9	1.6[1]
Company C							
Mill #1	1st	(12)	0.9	2.4	(20)	1.1	2.8
	3rd	(3)	0.8	2.0	(4)	1.4	1.9
Mill #2	1st	(11)	1.0	1.4	(8)	0.5	1.7[2]
	2nd	(13)	0.8	1.5	(3)	1.1	1.5

[1]$p<0.5$
[2]$p<0.2$
GM - Geometric mean
GSD - Geometric standard deviation
N - Number of samples.

winter closed-door policy, Table 5 shows that the dust concentrations were statistically different for only two shifts during the winter study. At Company B, the lower winter respirable dust exposures for the second shift may be caused by the severe weather conditions which forced the milling area employees to stay inside their acoustical booths whenever possible.

Of the three companies, the millers at Company C have the lowest respirable dust exposures. The bagging area at Mill #1 was not operational in the summer, since most of the product is shipped in bulk. However, this area was sampled during the winter survey and may partially account for the slight increase in the mean dust exposures. Since only the bagging area at Mill #2 was operational during the winter survey, the mean exposures are lower than the summer data.

FIBER COUNTS

The carcinogenic potential and the hazards of asbestos exposures have been well documented. Also, several types of asbestos are known to be geological contaminants in talc ore. Since the accepted best index of exposure to asbestos requires counting the respirable fibers in the worker's breathing zone, a problem arises in the methodology of distinguishing asbestos fibers from talc. Charcteristically, talc has a tendency to curl and stand on its edge which may result in many erroneous counts by optical microscopy.

The latest USPHS/NIOSH method for counting asbestos fibers requires phase contrast microscopy at X400-500 magnification, and arbitrarily defines a fiber as a particulate with a length to width ratio of 3:1 or greater, and a maximum width and minimum length of 5 micrometers (Leidel *et al.*, in press). This method is a crude determination of total fiber exposure because of the resolution limitations of optical microscopy. Most airborne asbestos fibers are less than 5 μm in length, and those that are longer may have diameters too small to be resolved by phase contrast microscopy.

To compensate for the many controversies, our sampling protocol involved taking parallel fiber samples on Millipore (0.8 μm) and Nuclepore (0.4 μm) filters and quantitating the fibers by phase contrast microscopy and scanning electron microscopy. The fiber samplers were placed in the immediate vicinity of the worker, and a breathing zone sample was obtained without having the man wear the pumps. The Millipore filters were counted using the latest USPHS/NIOSH method at X437 magnification.

The evaluation of the corresponding Nuclepore filter by scanning electron microscopy at X5000 magnification allows one to morphologically distinguish rolled talc particles and talc shards from actual fibers. Fibers less than five micrometers in length may be counted by the higher magnification of this instrument, and the sample stage may be rotated to view a specific particle at various angles. Figures 1 through 7 represent scanning electron micrographs (SEM) of some Nuclepore filter samples showing rolled talc and elongated talc particles. Phase contrast magnifications cannot resolve the detailed morphology of these particles, and hence they would be erroneously counted as fibers.

Table 6 represents a partial list of fiber samples, and shows that by phase contrast microscopy the counts range from 0 to 60 fibers/cc. The parallel filters counted by SEM are greatly reduced and range from 0 to 0.8 fibers/cc. These concentrations are below the present time-weighted average (TWA) of asbestos which is 2 fibers/cc greater than five micrometers in length based on the phase contrast method. If the minimum length restriction is released, then the total fiber concentration for some of these samples changes slightly and ranges from 0 to 2.0 fibers/cc. Thus this SEM method provides a more realistic approach to fiber counting in the talc industry.

FIGURE 1. Scanning electron micrograph of a Nuclepore filter showing a counting field at X400 which is the magnification recommended for fiber counting by phase contrast microscopy. Notice the number of elongated particles that fit the definition of a fiber.

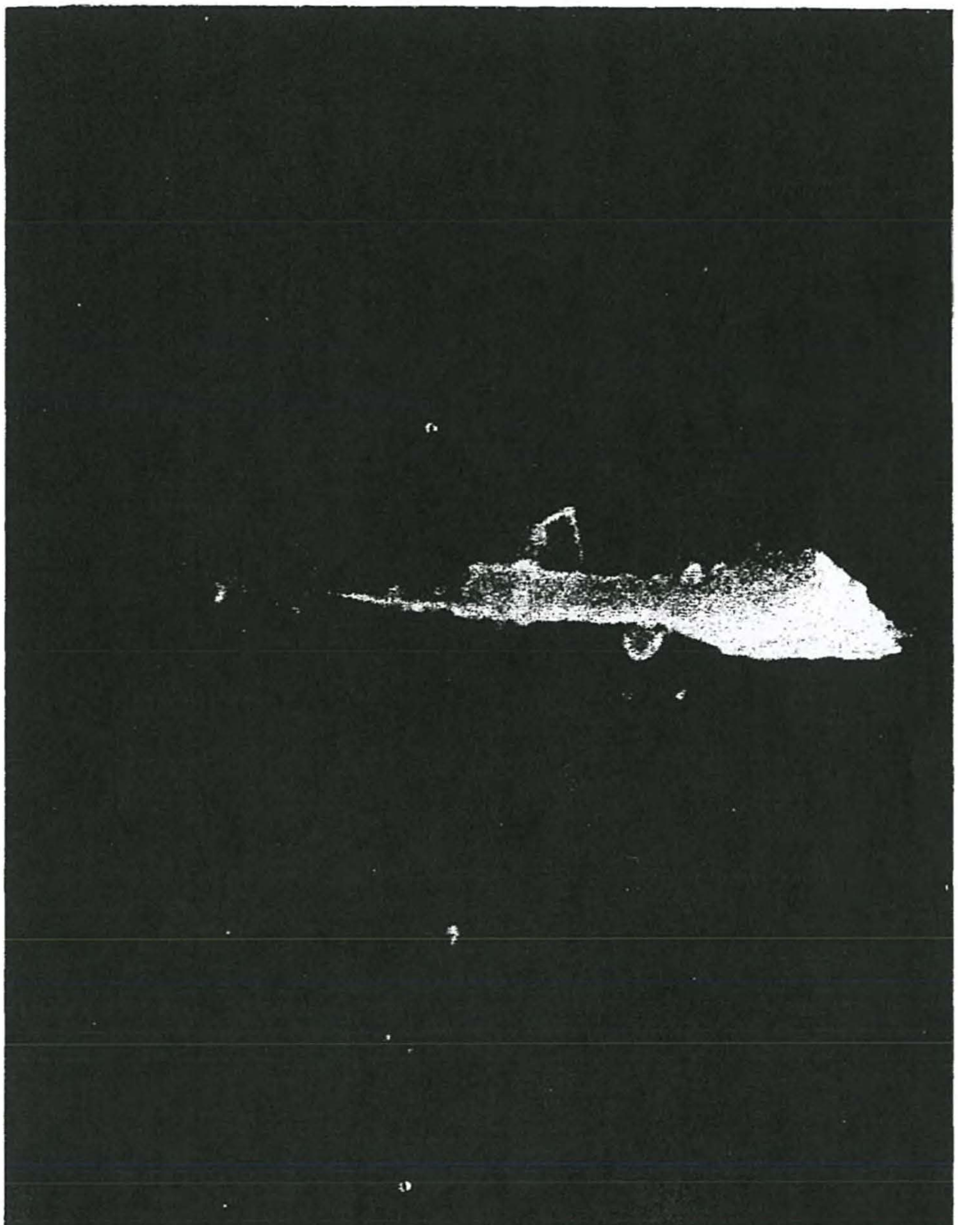

FIGURE 2. Scanning electron micrograph at X7000 magnification showing that the elongated particle located in the center of Figure 1 is morphologically not a fiber.

FIGURE 3. Scanning electron micrograph of one rolled talc particle at X12,000 which has curled on both sides to form a tube. At a lower magnification this particle would be counted as a fiber.

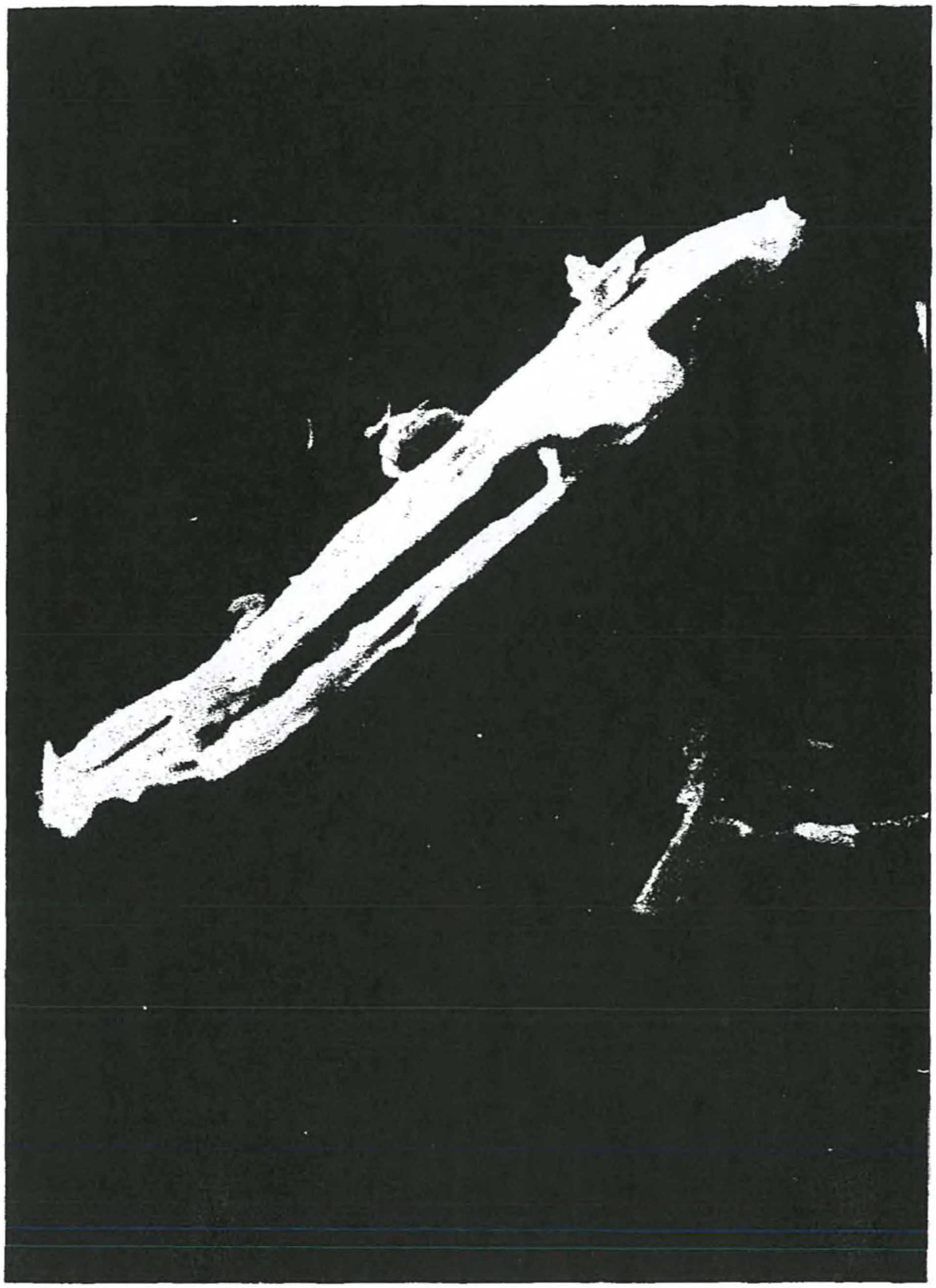

FIGURE 4. Scanning electron micrograph of an elongated particle standing on edge at X3500 magnification which might be considered as a fiber. By rotating the sample stage 60° (Figure 5), the laminated features of this talc particle can be seen.

FIGURE 5. (see Fig. 4 for legend).

FIGURES 6. Scanning electron micrographs showing that even some "fibers" are not immune from closer scrutiny. When the sample stage of the "fiber" in Figure 6 is rotated 50°, this "fiber" has the appearance as shown in Figure 7. These magnifications are X5000 and X15,000 respectively.

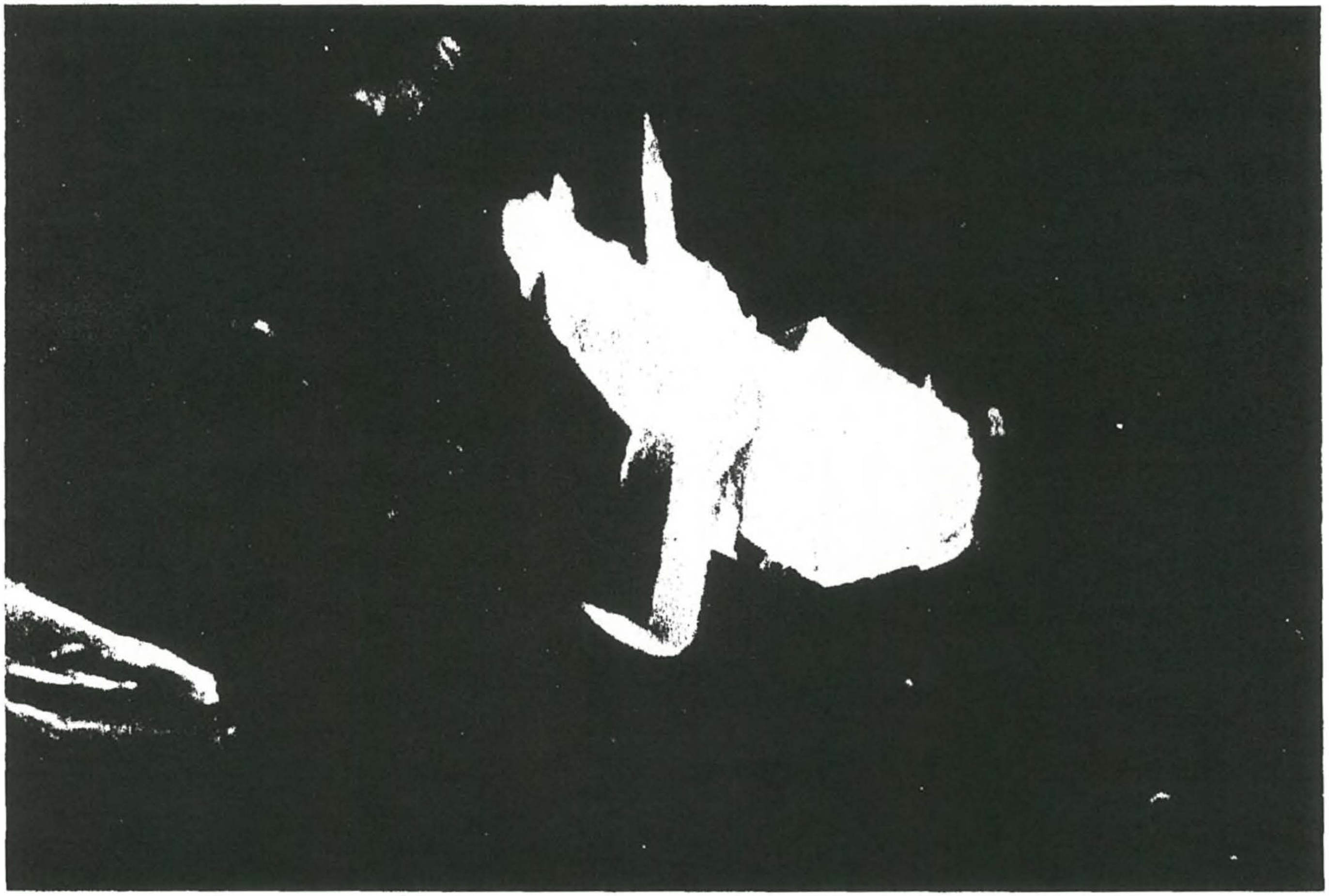

FIGURE 7. (see Fig. 6 for legend).

TABLE 6. Fiber Counts

Company		Location	Phase Contrast (fibers/cm³ > 5 μm length)	SEM (fibers/cm³ > 5 μm length)	SEM fibers/cm³
A	Mine	Bobcat area	3.8	0	0.3
		Drilling area	4.1	0	
	Mill	Crushing area	4.7	0	
		Bagger	63.5	0	
		Palletizer	7.9	0.7	
B	Mine	Driller	0.8	0	
		Scraper	16.1	0.7	2.0
	Mill	Crusher	1.6	0	
		Bagger	6.0	0.8	
		Palletizer	4.6	0.3	
C	Underground mine	Driller	0.6	0.3	
		Mucker	0	0.3	0.6
	Walk-in Mine	Automatic Miner	7.5	0	
	Mill #2	Bagging Area	0.6	0.1	
		Palletizing area	1.7	0	

CONCLUSIONS

The Vermont talc industry was selected by NIOSH for both epidemiological and environmental surveys to establish a TWA dust exposure because this talc was believed to contain minimum amounts of quartz and asbestos. This environmental study characterized bulk samples from the three companies, and quantitated the talc workers' dust exposures. X-ray diffraction studies showed that the bulk samples contained major amounts of talc, and only trace amounts of quartz were found in 15% of these samples. Petrographic microscopy analyses, analytical transmission electron microscopy, and x-ray diffraction with step-scanning revealed no asbestos in the bulk samples.

The study further showed that SEM should be considered as an adjunct to the USPHS/NIOSH method when counting fibers in a dust environment. Phase contrast microscopy may suffice in an asbestos environment, but the resolution limitations of optical microscopy and the inability to distinguish rolled talc particles and talc "shards" from actual asbestos fibers will allow only a crude determination of the total fiber exposure.

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REPORT OF THE EXAMINATION OF ROCK

SAMPLES FROM THE VERMONT MINE

Oct. 1972

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REPORT OF THE EXAMINATION OF ROCK SAMPLES FROM THE VERMONT MINE

The hand specimens examined in this report were collected during a visit to the Windsor Minerals talc mine in Vermont by Dr. F.D. Pooley. They represent samples of the ore footwall and hanging wall rocks and the minerals found in these samples may be regarded as the likely mineral contaminants to be found in any talc produced from this particular mine.

The specimens have been subjected to optical examination by standard mineralogical procedures and also to electron microscope examination and powder X-ray investigations.

The list of samples examined are given in the following table, each specimen having been given a code number which is used to denote the specimen in the following report.

Sample No.	Name and Description
V_1	Core of Orebody
V_2	Talc close to core of orebody
V_3	Centre of Orebody
V_4	Footwall boundary
V_5	Footwall contact
V_6	Hanging Wall rock
V_7	Talc ore with visible chlorite
V_8	Chlorite at contact with footwall
V_9	Amphibole in talc specimen
V_{10}	Magnesite nodule from orebody
V_{11}	Plate-like talc ore
V_{12}	General ore
V_{13}	Ore close to centre of orebody
V_{14}	Grey ore near footwall

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OPTICAL EXAMINATION OF THE VERMONT TALC SAMPLES

Thin and polished sections were prepared of the specimens of wallrock and talc ore except in the case of V_{12} and V_{15}.

The minerals which were present as a major constituent in at least one of the sections were talc, chlorite, biotite, muscovite, quartz, magnesite, dolomite, tremolite, idocrase, and antigorite. Actinolite only occurs as the major phase in Sample V_9 and is non-asbestiform. Phases which were always minor or accessory were garnet, zircon, rutile, ilmenite, and the sulphides pyrrhotite, pentlandite, pyrite, and chalcopyrite.

The identification of the minerals in the sections of these specimens was based on the optical characteristics of the minerals in transmitted and reflected light, both under plane polarised light (PPL) and crossed nicols (XN), combined with the results of the X-ray diffraction study of the crushed hand specimens.

In the following pages the Vermont samples are systematically described as regards their mineral composition and mode of intergrowth. Numerous photomicrographs taken under PPL and XN are provided with the description as part proof of the identifications, but mainly to illustrate the rock textures which, it is hoped, will provide information useful in the comminution of particularly the talc ore sample. The photomicrographs also display the non-occurrence of optically visible asbestiform amphiboles in the talc ore.

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Specimen V1

In thin section V_1 consists of a coarsely crystalline aggregate of dominantly magnesite, talc, and chlorite, with some isotropic 'serpentine' material and accessory scattered grains of ilmenite, pyrrhotite, and pentlandite, associated with very rare chalcopyrite. These accessory opaque constituents were identified in polished section. No identifiable grains of olivine were seen but some fine grained remnants may be present.

The magnesite occurs as medium to coarse granular aggregates in a groundmass mainly composed of orientated coarse lamellar and feathery talc which is intimately intergrown with scattered scaly and platy crystals and aggregates of chlorite (Fig.1). The chlorite shows a weak pleochroism from light green to light brown and displays anomalous blue and brown interference colours. It is probably close to the composition of the variety pennine.

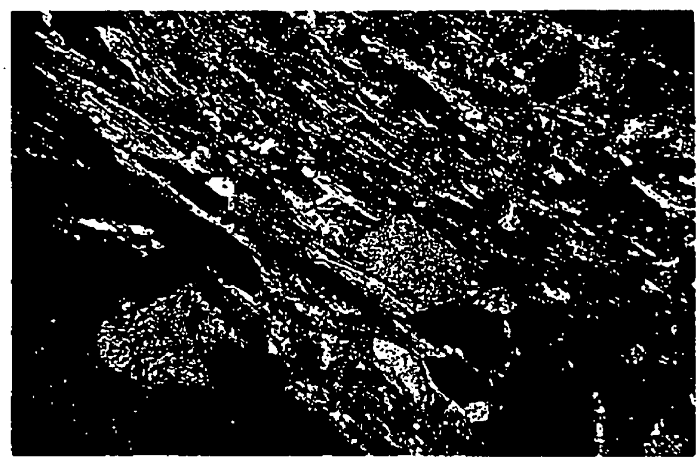

Fig. 1. Photomicrograph, x 24 magnification, of thin section V_1 under XN.

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Specimen V_2

This specimen consists of dominantly talc as coarse lamellar aggregates enclosed by areas of finer grained talc associated with minor chlorite (Figs. 2a, 2b). Some serpentine material appears to be present. Coarse anhedral grains and fine granular aggregates of minor magnesite occur scattered throughout the talc aggregate.

Small scattered anhedral opaque grains in thin section were identified in polished section as dominantly pyrrhotite and pentlandite with rare pyrite and very rare chalcopyrite. Only one small grain of ilmenite was present in the polished section.

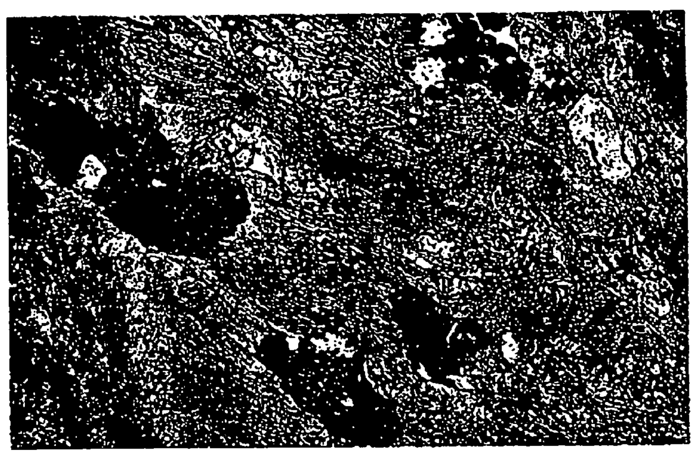

Fig. 2a. Photomicrograph, magnification x 24, of thin section V_2 under PPL showing grains of anhedral magnesite in a compact coarse to fine grained talc matrix.

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Fig. 2b. Photomicrograph, magnification x 24, of thin section V_2 under XN showing areas of coarse lamellar talc intergrown with fine grained talc-serpentine aggregates and enclosing anhedral grains of magnesite.

Specimen V_3

An aggregate of mainly fine grained fibrolammellar crystals of antigorite and colourless chlorite (giving anomalous grey-blue interference colours (Fig. 3b)), associated with other serpentine material which could not be identified optically, and which may be amorphous. This fine grained matrix composes most of the section (Figs. 3a,3b) and encloses medium grained isolated aggregates of anhedral magnesite. Some minor talc occurs scattered throughout the section as small platy aggregates. Very small anhedral magnesite grains also occur scattered randomly throughout the antigorite-chlorite matrix.

Scattered opaque anhedral grains in thin section were identified in polished section as composite grains of pyrrhotite and

DX7046.0007

pentlandite with rare chalcopyrite. No ilmenite was found in the polished section.

Fig. 3a. Photomicrograph, x 24 mag., of thin section V_3 under PPL showing antigorite and other serpentine material enclosing magnesite.

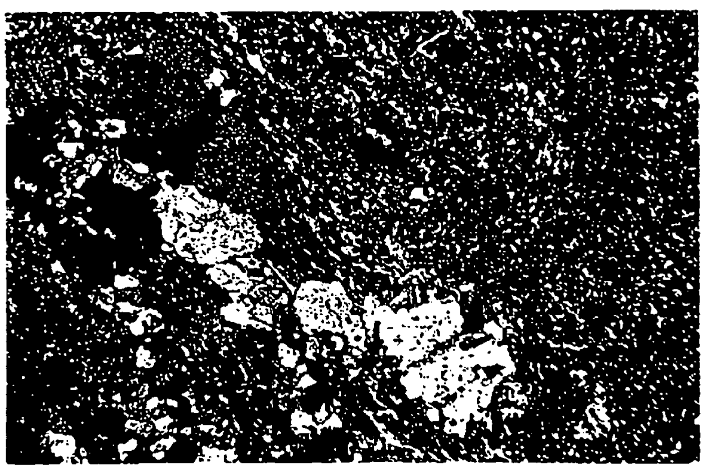

Fig. 3b. Photomicrograph, x 24 mag., of thin section V_3 under XN.

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Specimen V_4

This specimen (Figs. 4a and 4b) is composed of a very coarse to medium grained granular aggregate of quartz, chlorite, biotite, and euhedral polygonal grains of greenish yellow mineral showing zoning and exhibiting strong pleochroism (colourless to greenish-yellow) in tabular sections. It is also uniaxial negative. This mineral is probably idocrase. The quartz is a major phase and occurs, in one half of the section, as compact medium grained polygonal grains with major idocrase and minor scattered laths of biotite. In the other part of the section quartz occurs as an aggregate of coarse grains exhibiting a ragged boundary relationship with each other and poikilitically enclosing polygonal grains of idocrase, small prismatic crystals of muscovite, and larger laths and lathlike aggregates of biotite.

The chlorite, which is also a major constituent of this rock, occurs mainly as scattered pockets of very coarse lathlike or columnar aggregates bounded by the coarse grained quartz in one half of the section and by the finer granular quartz-idocrase aggregate in the other half. Poikilitic inclusions of idocrase also occur within the chlorite laths. The chlorite has identical properties to sheridanite which commonly occurred in the I samples.

The biotite occurs in a similar way to the chlorite but is less abundant. Accessory very dark brown rutile occurs as scattered subhedral grains and aggregates, and in polished section typical knee-shaped twins could be seen. No sulphides were seen in the polished section examination.

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Fig. 4a. Photomicrograph, x 24 mag., of thin section V_4 under PPL showing a coarse aggregate of quartz (white), chlorite (light brown), idocrase (brown polygonal grains), and biotite (dark brown).

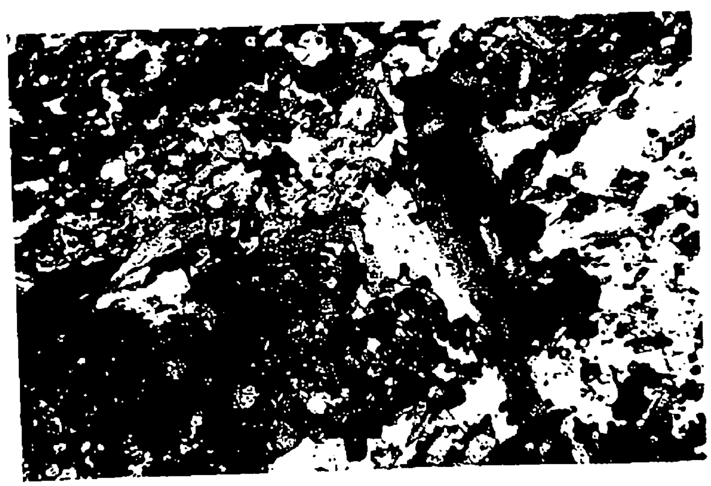

Fig. 4b. Photomicrograph, x 24 mag., of thin section V_4 under XN.

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Specimen V_5

This specimen is dominantly a coarse aggregate of granular quartz and lathlike biotite with minor pockets of chlorite and accessory fine grained euhedral idocrase, garnet and zircon. Some talc is also present.

The zircon occurs as inclusions in the biotite. Dark pleochroic halos are seen in the biotite around the zircon inclusions (Fig. 5a).

The idocrase (identical in properties to V_4) and garnet are found dominantly as scattered poikilitic inclusions in the quartz, but small euhedra also occur within some of the biotite laths and aggregates.

The quantity of chlorite and biotite present increases across the section (at right angles to the schistosity) until chlorite, intimately intermixed with some fine grained talc, occurs in equal abundance to the biotite as long foliated lenses.

The rare small scattered opaque grains seen in transmitted light were identified in polished section as pyrite. Some rutile also occurs.

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Fig. 5a. Photomicrograph, x 24 mag., of thin section V5 under PPL consisting dominantly of quartz and biotite. Note the dark halos around zircon inclusions in the biotite.

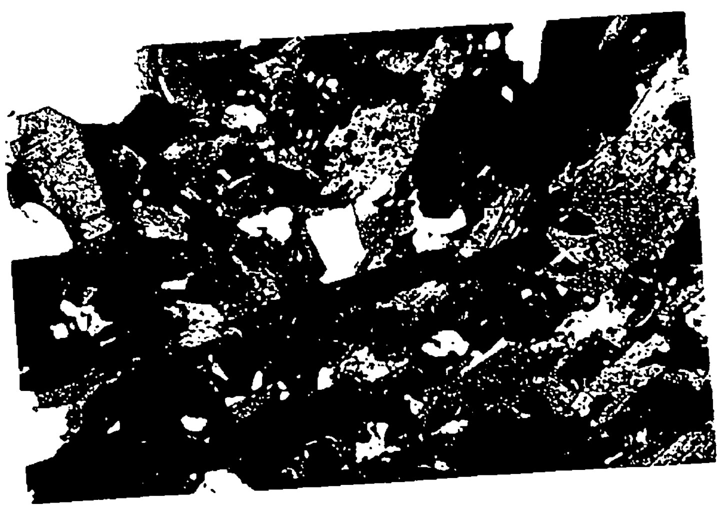

Fig. 5b. Photomicrograph, x 24 mag., of thin section V5 under XN.

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Specimen V_6

This rock specimen is a quartz-biotite-muscovite-chlorite schist (Figs. 6a and 6b) consisting dominantly of layered segregations of foliated muscovite and of granular quartz (quartz > muscovite).

Occasional rounded 'knots' or augen-like aggregates of chlorite associated with platy muscovite occur around which the long lenticular muscovite segregations and smaller lath-like chlorite aggregates are bent. Some of the augen contain remnants of garnet and it appears that these chlorite-muscovite 'knots' mass have resulted from the break down of the garnet.

Biotite, which is less abundant than the muscovite, occurs as scattered laths and small columnar aggregates generally aligned with the overall schistosity of the rock.

In places muscovite is intergrown with and replaced along the cleavages by an opaque material which under the reflected-light microscope was difficult to resolve and may be, from its colour and reflectance, an iron oxide which in part is hydrated.

Coarse scattered anhedral masses occur throughout the section which, in polished section, were identified as dominantly pyrrhotite exhibiting some inversion to marcasite along fractures. Some chalcopyrite and rutile was also present.

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Fig. 6a. Photomicrograph, x 24 mag., of thin section V6 under PPL; a quartz-biotite-muscovite-chlorite schist.

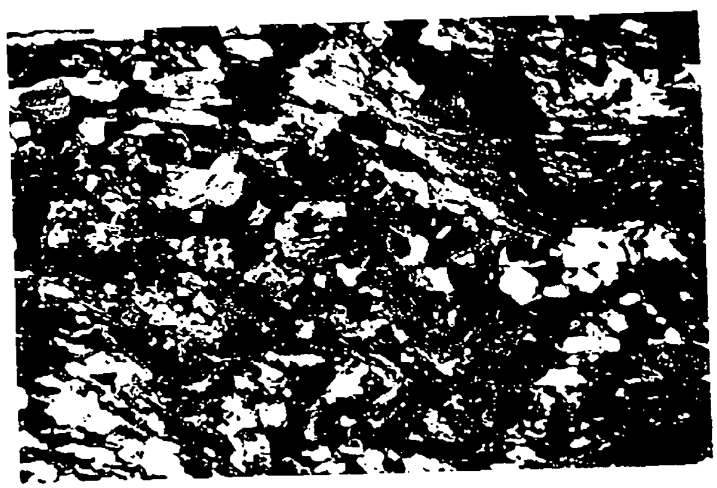

Fig. 6b. Photomicrograph, x 24 mag., of thin section V_6 under XN. Note the chlorite lath showing dark grey interference colours, top right.

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Specimen V_7

This specimen is a biotite-muscovite rock consisting dominantly of a very coarse columnar and lathlike aggregate of biotite with minor intergranular pockets of muscovite (Figs 7a, 7b). Much of the biotite contains small inclusions of zircon around which are characteristic dark pleochroic halos. Small subhedral scattered grains of garnet, occur as poikilitic inclusions in the biotite, and also some rutile.

Fig. 7a. Photomicrograph, x 24 mag., of thin section V_7 under PPL

Fig. 7b. Photomicrograph, x24 mag., of thin section V_7 under XN.

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Specimen V_8

Thin section V_8 is dominantly composed of fine grained laminated aggregate of thin foliated and prismatic crystals of chlorite (var. pennine). Minor magnesite also occurs as occasional large (up to 2mm across) subhedral porphyroblasts (Fig. 8a).

Opaque material is fairly abundant in the section (in greater amounts than magnesite) as scattered small and large subhedral grains in the chlorite groundmass and poikilitically enclosed in the magnesite. In polished section the opaque constituents were identified as pyrrhotite containing small flame-like exsolution masses of the nickel mineral pentlandite. Some opaque grains were of ilmenite showing replacement by 'leucoxene'; a mixture of pseudobrookite, brookite, and rutile. Traces of chalcopyrite also occurred.

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Fig. 8a. Photomicrograph, x 24 mag., of thin section V_8 under PPL showing finely crystalline laminated chlorite enclosing a large euhedral grain of magnesite. Scattered opaque constituents are dominantly pyrrhotite.

Fig. 8b. Photomicrograph, x24 mag., of thin section V_8 under XN.

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Specimen V_9

A coarse aggregate of colourless Actinolite crystals displaying the characteristic amphibole cleavage in rhombic sections. Talc also occurs, in slightly less abundance, as coarse radiating feathery aggregates forming pockets interstitial to the euhedral actinolite crystals. The actinolite is non-asbestiform (Figs. 9a and 9b).

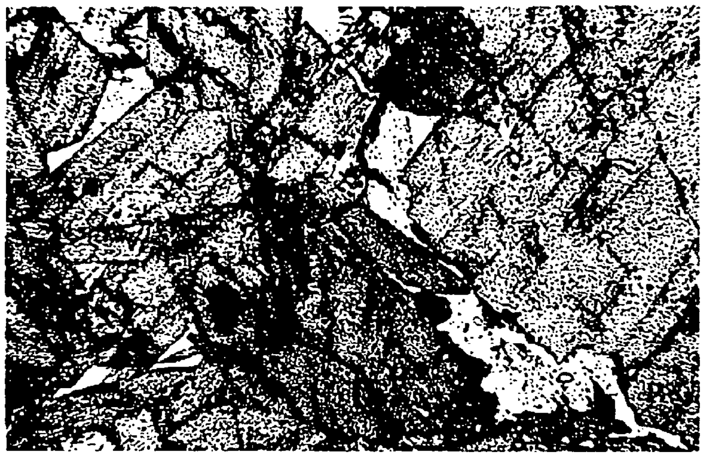

Fig. 9a. Photomicrograph, x 24 mag., of thin section V_9 under PPL displaying coarse actinolite with minor interstitial talc.

Fig. 9b. Photomicrograph, x24 mag., of thin section V_9 under XN. The non-asbestiform nature of actinolite is clearly seen.

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Specimen V_{10}

This specimen is dominantly composed of a medium to coarse grained compact granular aggregate of a carbonate free of any other phases as inclusions or interstitially (Figs. 10a and 10b).

One edge of the section shows a fairly sharp contact between the compact granular magnesite and an aggregate of dominantly medium grained feathery talc and minor chlorite (colourless under PPL and grey interference colours under XN) enclosing and interstitial to grains of magnesite.

Fig. 10a. Photomicrograph, x 24 mag., of thin section V_{10} under PPL.

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Fig. 10b. Photomicrograph, x 24 mag., of thin section V_{10} under XN.

Specimen V_{11}

Thin section V_{11A} is composed dominantly of coarse deformed foliated and wavy talc intimately intergrown (interlaminated) with thin tabular crystals and crystal aggregates of minor chlorite (colourless, grey interference colours). Accessory bladed grains of pyrrhotite occur scattered throughout the section.

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Fig. 11a. Photomicrograph, x 24 mag., of thin section $V_{11}A$ under PPL.

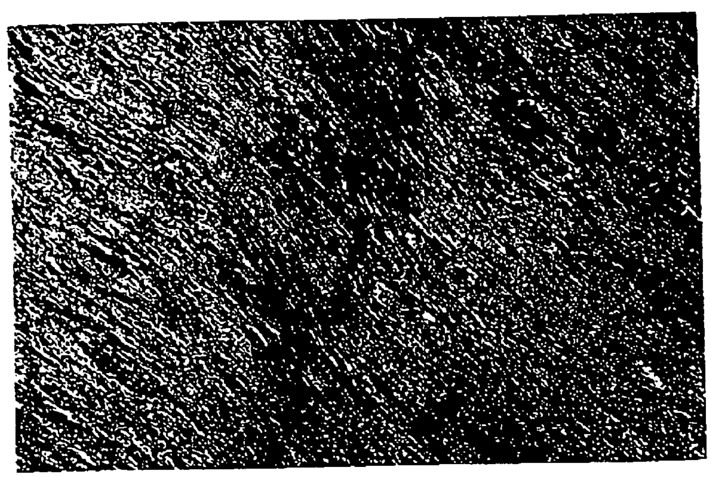

Fig. 11b. Photomicrograph, x 24 mag., of thin section $V_{11}A$ under XN.

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Thin section V_{11B} from another fragment of rock sample V_{11} showed the talc to be less deformed than in thin section V_{11A}. In Figure 11d the chlorite can be clearly seen inter-laminated with the talc. A sharp transgressive boundary is also displayed between talc containing dusty inclusions of a phase so far unidentified and clear inclusion-free talc (Figs. 11c and 11d).

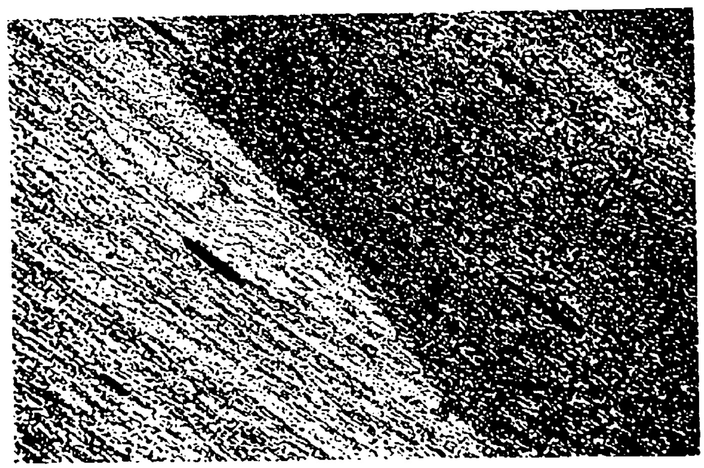

Fig. 11c. Photomicrograph, x 40 mag., of thin section V_{11B} under PPL, showing the appearance of 'dusty' and clear talc.

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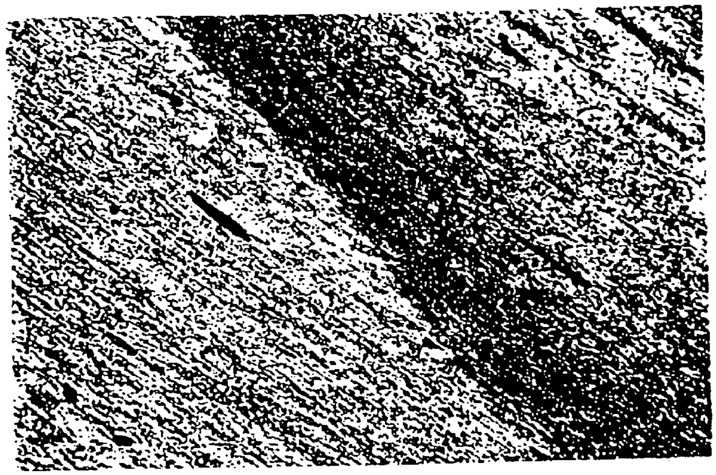

Fig. 11d. Photomicrograph, x 40 mag., of thin section V_{11B} under XN showing the interlaminated chlorite (white) in talc (displaying range of interference colours), and the transgressive nature of the boundary between the 'dusty' and clear talc.

Specimen V_{12} No thin section examination

Specimen V_{13}

Thin section V_{13} is composed of dominantly talc with minor chlorite and magnesite and accessory quartz with some pyrrhotite.

Half of the section is composed of an aggregate of deformed coarse, wavy, foliated talc with thin interlaminated lenses of minor chlorite (similar in properties to sheridanite in the "I" samples), and occasional small anhedra of magnesite. This

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grades (Fig. 12) into a compact medium grained aggregate of polygonal magnesite grains with minor talc occurring interstitially as columnar crystals and aggregates. This again grades into foliated talc enclosing large subhedral porphyroblasts of magnesite.

Some quartz occurs in the talc areas in 'augen-like' pockets associated with a randomly orientated finer talc. The appearance of the talc is in some parts 'dusty' or turbid due to the presence of very fine inclusions of an amorphous and crystalline material (Fig. 12). This is also seen well in section V_{11}, Fig. 11c.

Accessory pyrrhotite is present mainly enclosed by the talc.

Fig. 12. Photomicrograph, x 24 mag., of thin section V_{13} under PPL showing the gradation from dominantly talc into dominantly magnesite.

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Specimen V_{14}

This specimen is dominantly composed of talc and magnesite with very minor chlorite.

The section displays a very inhomogeneous texture. Some parts of the section consist of areas of medium grained granular magnesite, with occasional large anhedral magnesite grains, associated with interstitial columnar talc and lenses of foliated talc (Fig. 13a and 13b). Other parts consist of randomly orientated tabular talc aggregates enclosing small anhedra of magnesite. The chlorite in the section occurs as small tabular crystals and aggregates intimately intergrown with the talc.

Scattered anhedral composite grains of pyrrhotite and pentlandite with rare pyrite were identified in polished section.

Fig. 13a. Photomicrograph, x 24 mag., of thin section V_{14} under PPL.

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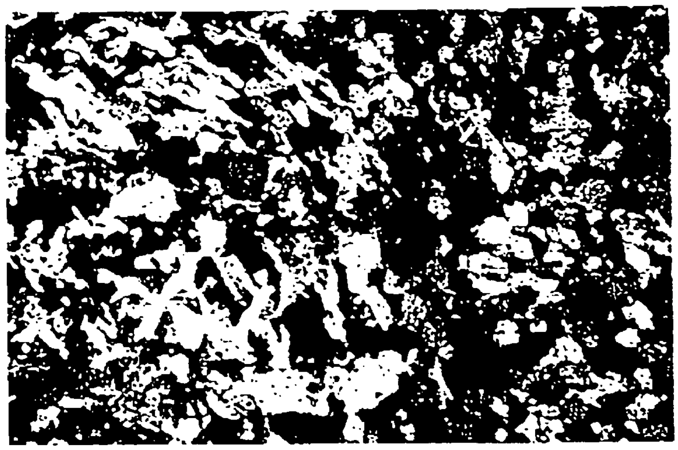

Fig. 13b. Photomicrograph, x 24 mag., of thin section V_{14} under XN.

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ELECTRON MICROSCOPE EXAMINATION OF

VERMONT MINE SAMPLES

The purpose of the examination of the powdered Vermont mine samples has been to establish whether or not any particles corresponding to the commercial forms of asbestos were present.

The Vermont samples were prepared for electron microscopy in the manner described in the report of the Italian mine samples and were examined carefully for fibrous material.

The following figures illustrate the appearance of typical particles formed from the specimens. The results obtained were similar to those of the Italian mine samples. Those specimens representative of the Talc ore produced particles of a flat plate-like appearance, while the rock and carbonate specimens gave compact irregular particles. The only specimen with obvious lath like particles was specimen V.9. which was an Actinolite/Talc sample. The lath-like particles in the powdered V.9. specimen were readily identifiable as being Amphibole mineral by selected area electron diffraction.

The Vermont talc ore specimens in general contained smaller numbers of lath-like particles than the Italian ore specimens. Also the odd textile-like ribbon fibres found in the Italian mine specimens were very scarce in the Vermont material. The talc particles themselves were also more obviously plate-like in appearance and also thinner.

A much closer examination of the powdered specimens obtained close to the centre of the ore body,which is composed of a serpentine phase, revealed no chrysotile fibres at all, thus confirming the material as being mainly Antigorite.

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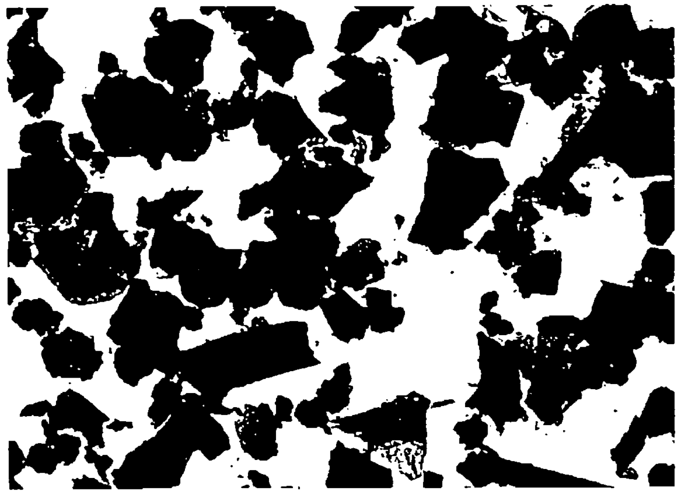

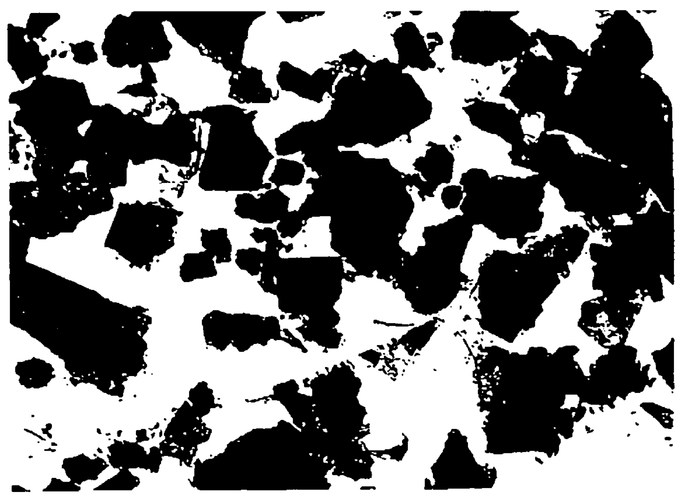

Figs. 1 and 2 Sample V.1. Some compact particles but mainly flakey types. No fibres. x 3000

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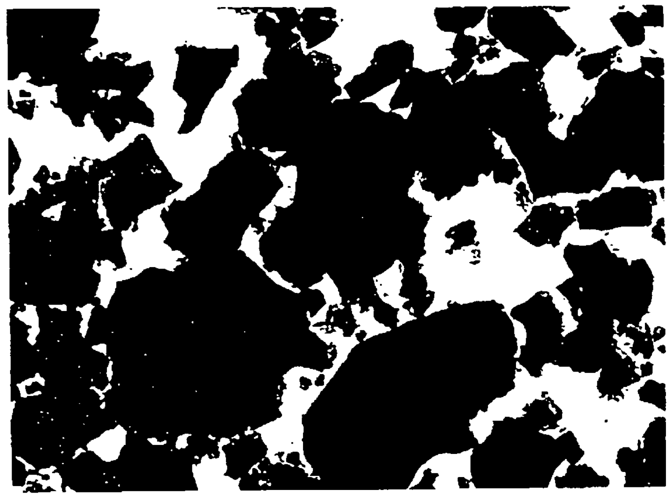

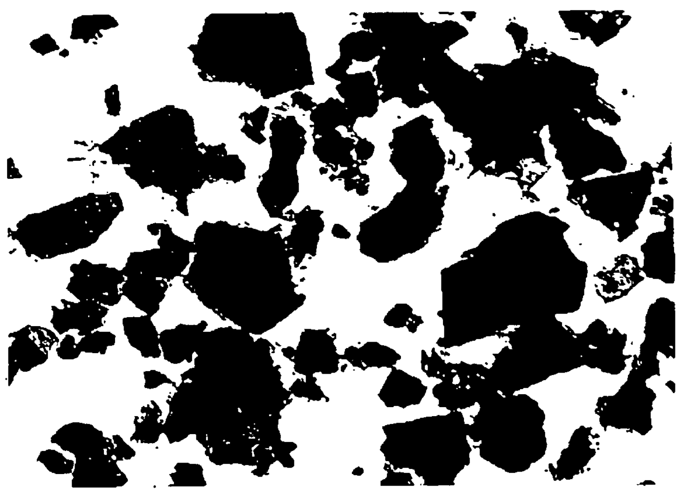

Figs. 3 and 4 Sample V.2. A mixture of plate-like and compact particles. No fibres detected. x 300Q

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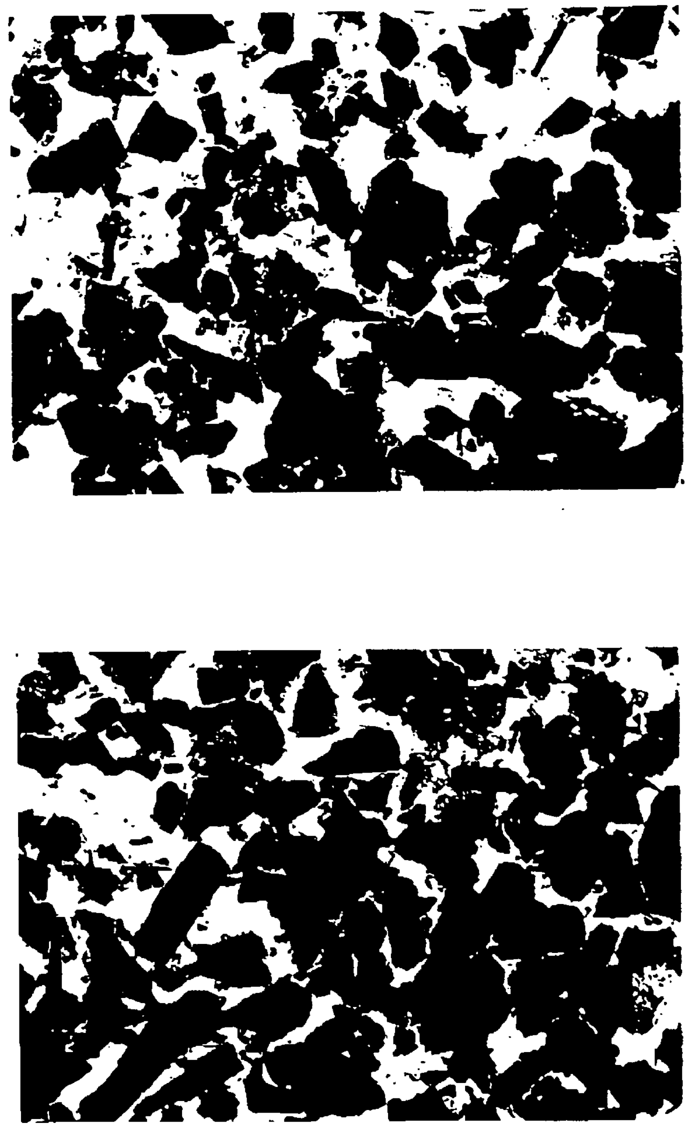

Figs. 5 and 6. Sample V.3. Mainly compact particles,some flakes and a few lath-like forms. x 3000

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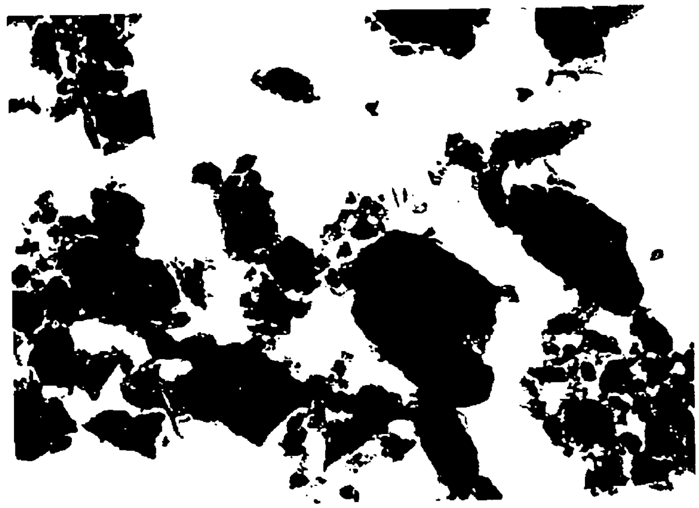

Figs. 7 and 8. Sample V.4. Flakey and compact particles.
No fibres. x 3000

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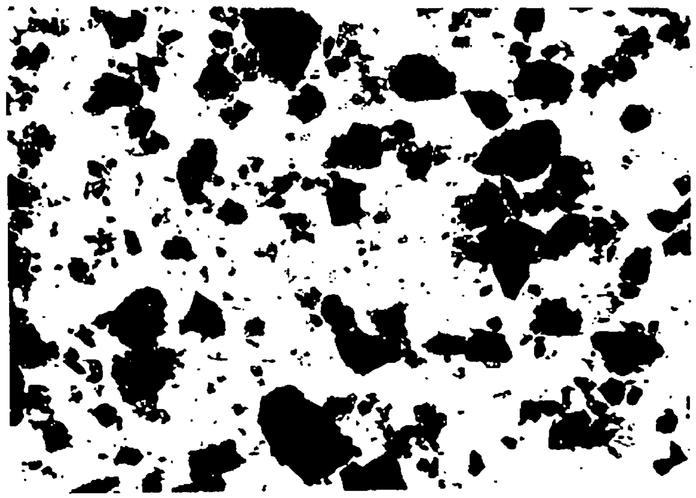

Fig. 9. Sample V.5. Compact particles only. x 3000

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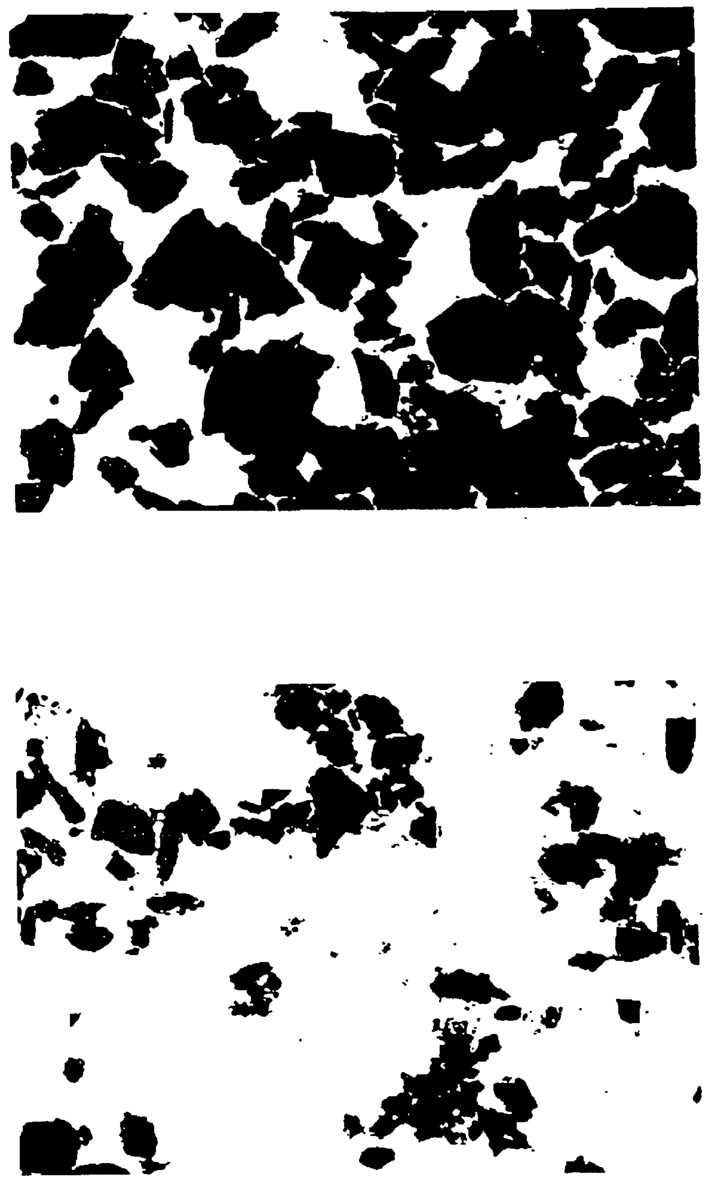

Figs. 10 and 11. Sample V.6. Compact particles only.
No fibres. x3000

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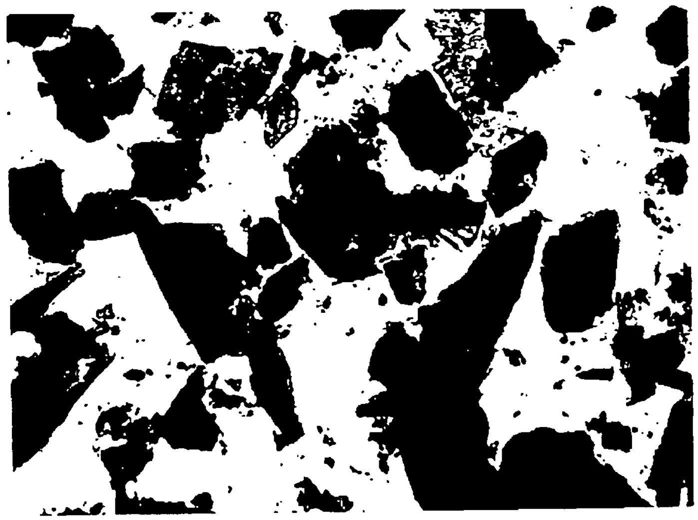

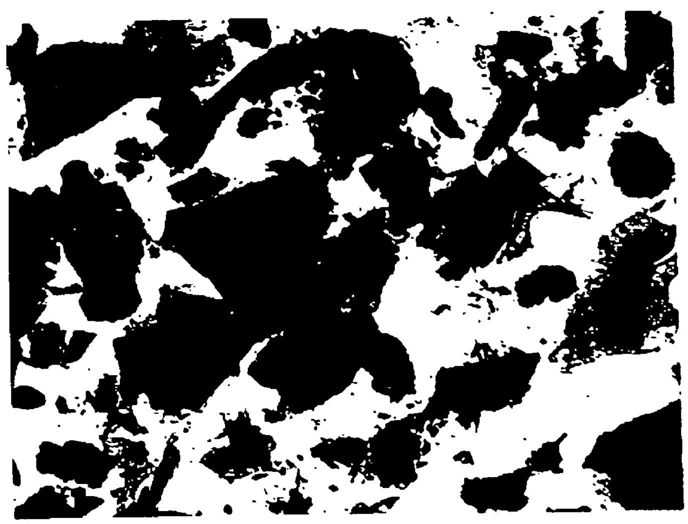

Figs. 12 and 13. Sample V.7. Plate-like particles only.

x 3000

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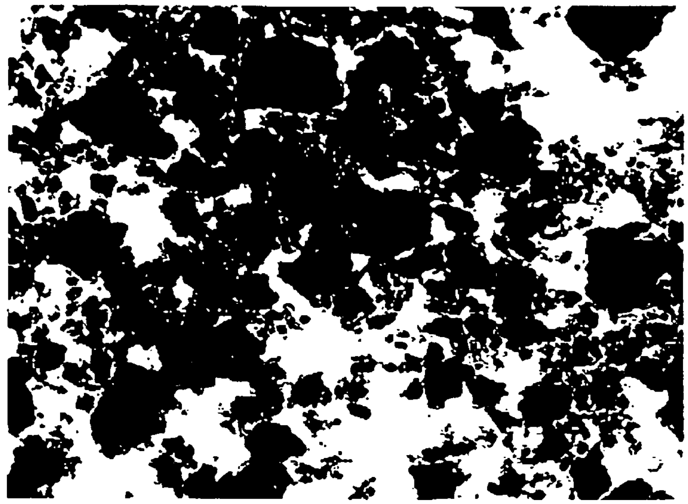

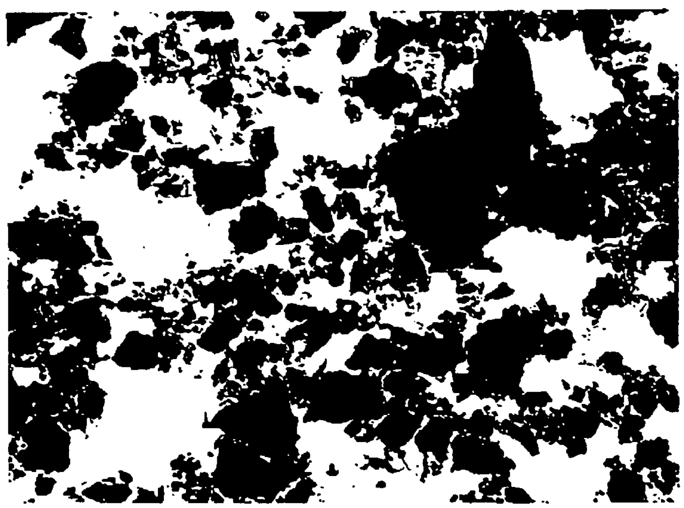

Figs. 14 and 15. Sample V.8. Compact particles with a few flakes. x 3000

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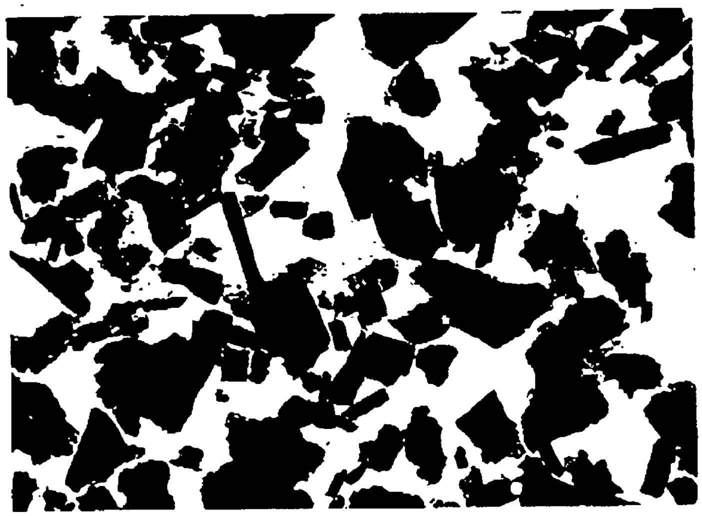

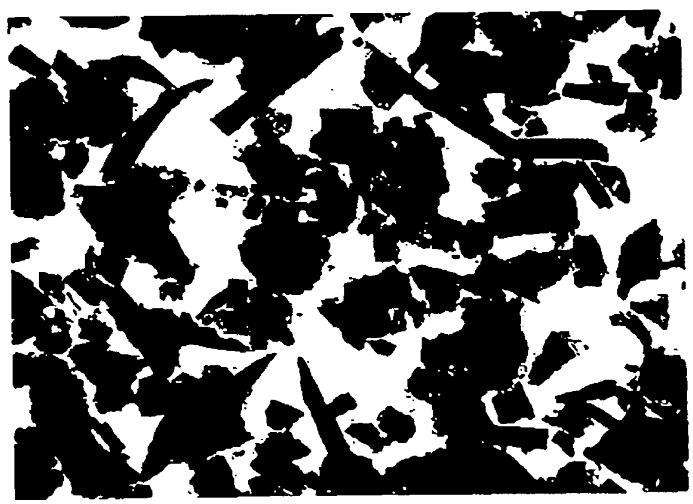

Figs. 16 and 17. Sample V.9. Plate-like particles with lath-like fibres of amphibole mineral. x 3000

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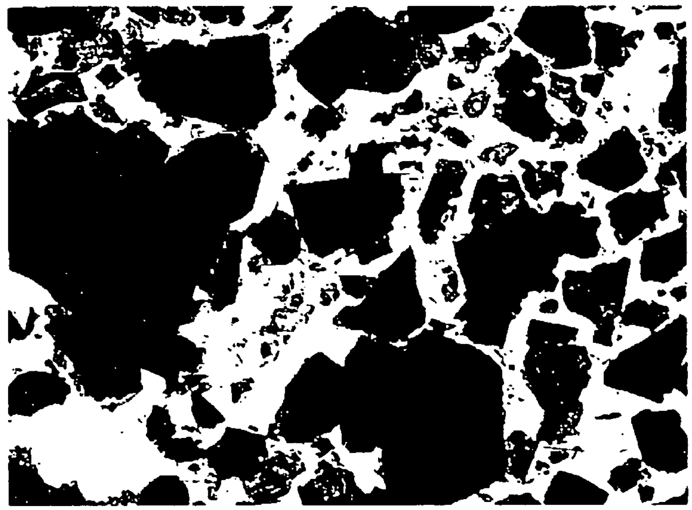
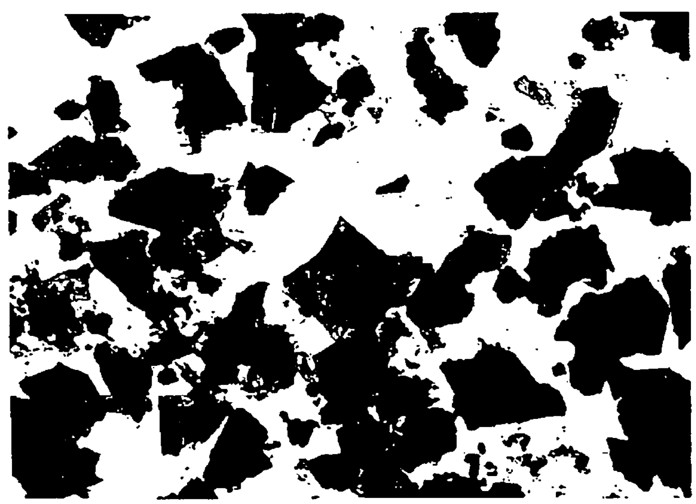
DX7046.0036



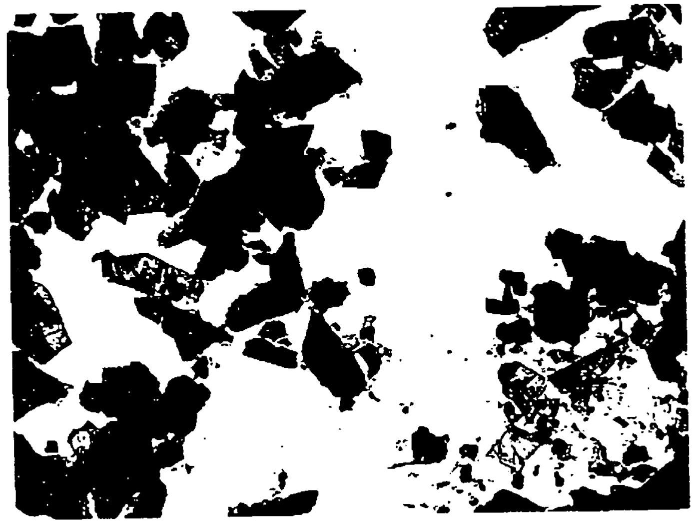


Figs. 18 and 19. Sample V.10. All particles plate-like in form. No fibres present. x 3000

DX7046.0037

Figs. 20 and 21. Sample V.11. All plate-like particles.
No fibres present. x 3000

DX7046.0038



Figs. 22 and 23. Sample V.12. All plate-like particles.

No fibres present.. x 3000

DX7046.0039

Fig. 24. Sample V.13. Plate-like particles with a few compact types. No fibres present. x 3000

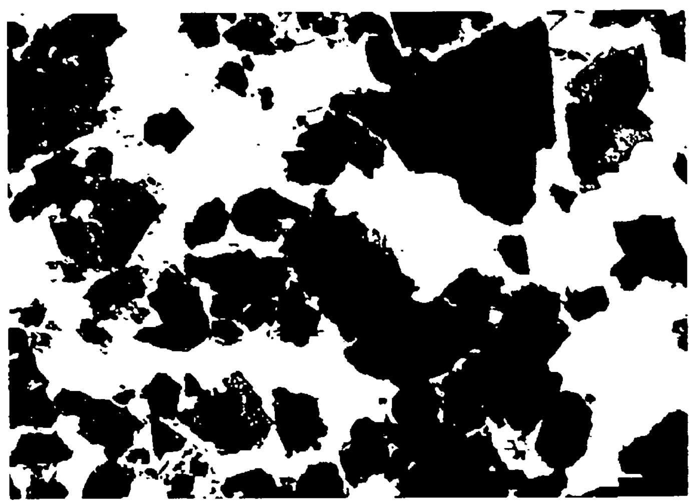


Fig. 25. Sample V.14. Plate-like particles with no visible fibres. x 3000

DX7046.0040

X-Ray Analysis of the Vermont Mine Samples

This report concerns the analysis of samples taken at the Vermont Mine. There are 14 samples and they represent the various mineral phases present in the mine.

The samples were all prepared by the same method and the procedure for obtaining the X-ray powder photographs was standardised. These powder photographs were measured and the results compared against the A.S.T.M. using computing methods. They were also checked visually to find the major phase present.

Sample Preparation

The samples were received mainly as large rocks and they were labelled according to their appearance and location in the mine.

With the larger samples a section was cut from the middle and taken to be a representative sample, for the smaller samples as many pieces as possible were crushed to form the representative sample.

The samples were roughly broken up and placed in a 'Tema' Disc mill and ground for about 5 minutes until all the sample was below approximately 100 mesh. These ground powders were stored for future use in clean plastic bags. The samples, when required for X-ray analysis, were further ground in a small agate ball mill. The resulting powder was sieved through a 350 mesh sieve (British Standard specification) and the undersize fraction stored.

DX7046.0041

The grinding mills and other apparatus used were thoroughly cleaned between sample, and during grinding care was taken to avoid cross contamination of the samples.

X-Ray Analysis

All the samples were analysed using a 11.46 cm diameter Debye-Scherrer camera mounted on a AGI Raymax RX3-D X-ray generator. A copper X-ray tube, with a power rating of 36kV at 22mA, was used with nickel filters (0.02mm thick).

The apparatus was carefully aligned and checked before mounting the cameras. All the samples had the same exposure time (8 hrs).

The samples were loaded into 0.5 mm diameter Lindemann glass tubes to be mounted in the Debye Scherrer cameras. In the cameras Ilford Industrial 'G' X-ray film was used. The film was processed using Kodak DX-80 developer and Ilford Hypam fixer. The films were developed for 5 minutes using a 1:4 dilution for the developer and fixed for 2 minutes. The films were then washed in running water for 30 minutes and allowed to dry naturally. They were labelled and stored in film holders to be measured.

Results

The X-ray powder photographs were measured using an illuminated screen with a mm scale. This scale had a vernier attachment and it was possible to attain a measurement accuracy of ± 0.05 mm. The line spacings were calculated taking into account camera corrections for film shrinkage. From these results the Bragg angle (θ) and the 'd' spacings were calculated.

DX7046.0042

Using computer techniques this sample data was compared against data obtained from the ASTM powder diffraction file to determine the minerals present. The results were also analysed visually to determine the major phase present. These results are tabulated in the appendix.

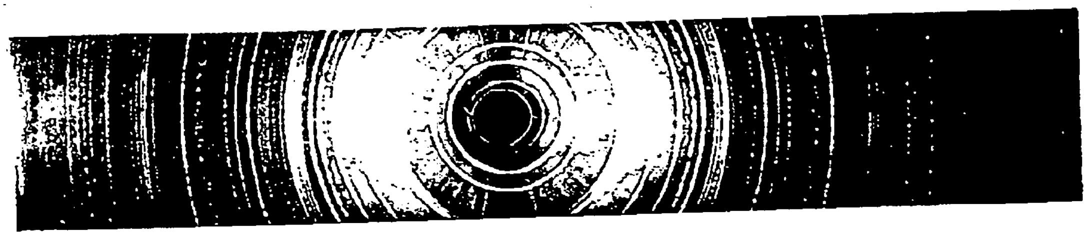
A print out was obtained of all the standards which fitted a particular line to find all the possible minerals present and to see which lines were common to several standards.

At the present time there are 75 standards stored in the computer and it would obviously take a considerable time to analyse the sample data with respect to these. To reduce this time the sample data was compared with the three most intense lines of the standard data (a similar procedure is used when comparing the data manually using the FINK index). It was considered that if the three most intense lines of the standard were not present, then the standard was not in the sample. This considerably reduced the number of standards. The effect of one standard being masked by another was also taken into account during the analysis.

DX7046.0043

APPENDIX A

Sample V1

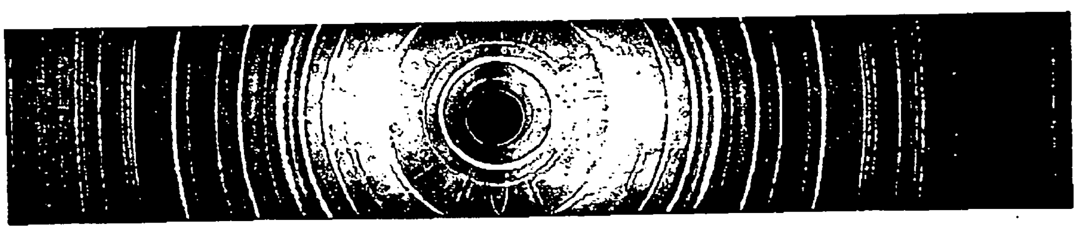


6 Unmatched lines   1.8022Å, 1.1937Å, 1.1416Å,
1.1325Å, 1.1097Å, 1.0974Å

Minerals included:- Talc, Serpentine, Chlorite, Magnesite

Most Probable Minerals Present:- Magnesite, Talc, Chlorite.

Sample V2



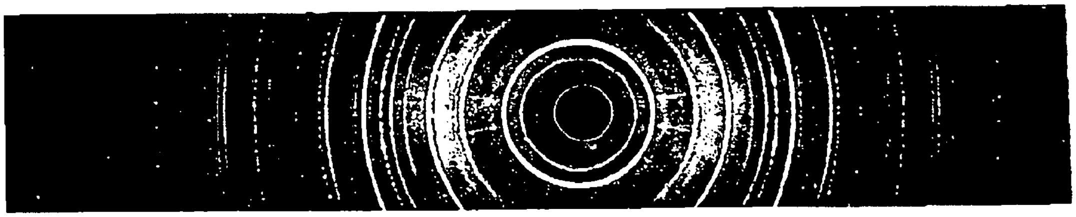
No Unmatched Lines

Minerals Included:- Talc, Chlorite, Magnesite, Ilmenite

Most Probable Minerals Present:- Talc, Chlorite, Magnesite.

DX7046.0044

Sample V3

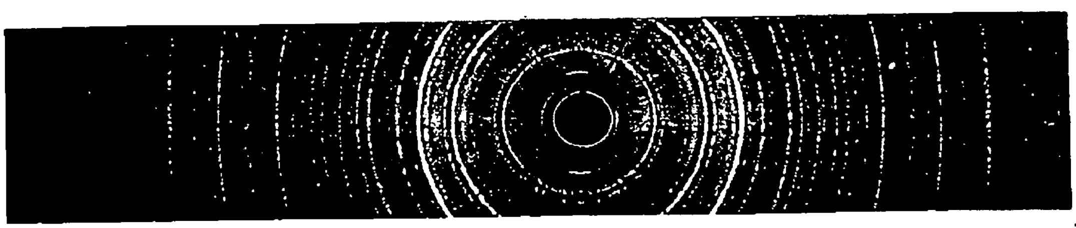


8 unmatched lines: 4.1907Å, 2.8139Å, 2.6749Å, 1.8501Å, 1.1828Å, 1.1510Å, 1.1092Å, 1.0690Å,

Minerals included:- Magnesite, Talc, Garnet, Antigorite, Ilmenite, Chlorite.

Most Probable Minerals Present:- Antigorite, Talc, Garnet, Magnesite.

Sample V4



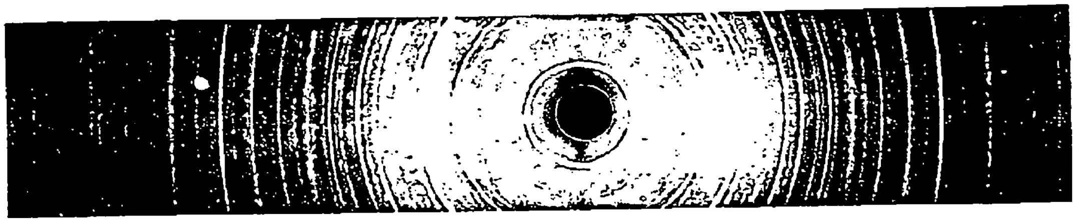
11 unmatched lines:- 6.3638Å, 2.3413Å, 1.9201Å, 1.7828Å, 1.4322Å, 1.3571Å, 1.3271Å, 1.3111Å, 1.2754Å, 1.1802Å, 1.1525Å.

Minerals Included:- Biotite, Chlorite, Chalcopyrite, Quartz

Most Probable Minerals Present:- Quartz, Biotite, Chlorite.

DX7046.0045

Sample V5

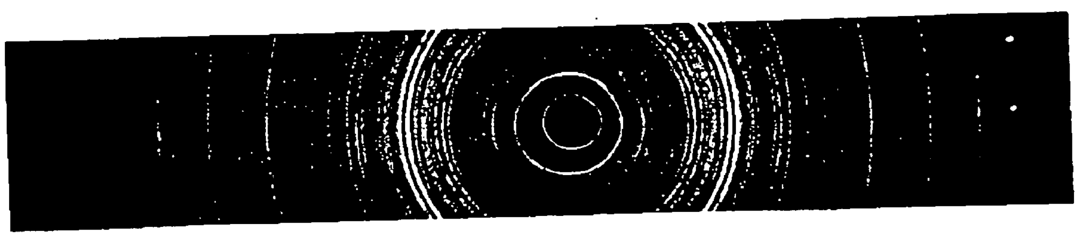


14 unmatched lines:- 3.6731Å, 2.3401Å, 1.9175Å, 1.8463Å, 1.717Å, 1.5938Å, 1.4807Å, 1.3725Å, 1.3560Å, 1.3438Å, 1.3285Å, 1.3117Å, 1.276Å, 1.1338Å.

Minerals Included:- Biotite, Chlorite, Quartz, Mica.

Most Probable Minerals Present:- Biotite, Quartz, Chlorite.

Sample V6



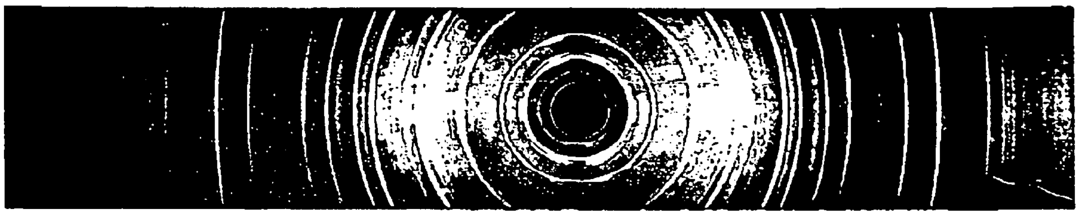
8 unmatched lines:- 5.566Å, 3.268Å, 1.8459Å, 1.7965Å, 1.433Å, 1.433Å, 1.1513Å, 1.1296Å, 1.113Å.

Minerals Included:- Mica, Olivine, Chlorite, Antigorite, Garnet, Ilmenite, Quartz, Biotite.

Most Probable Minerals Present:- Quartz, Mica, Chlorite, Garnet, Biotite.

DX7046.0046

Sample V7

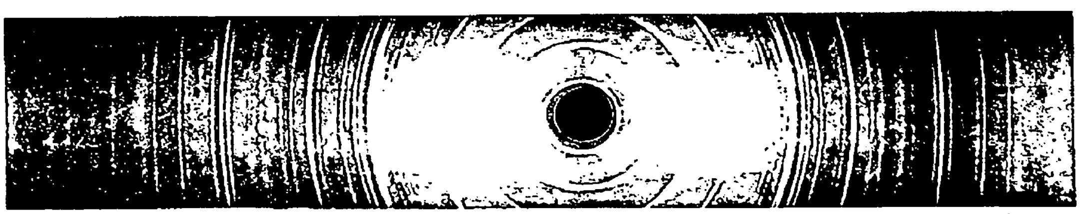


7 unmatched lines:- 2.3014Å, 1.4387Å, 1.3679Å, 1.3114Å, 1.1948Å, 1.1785Å, 1.1318Å.

Minerals Included:- Talc, Biotite, Mica, Chlorite, Antigorite, Quartz.

Most Probable Minerals Present:- Biotite, Mica, Talc, Chlorite.

Sample V8



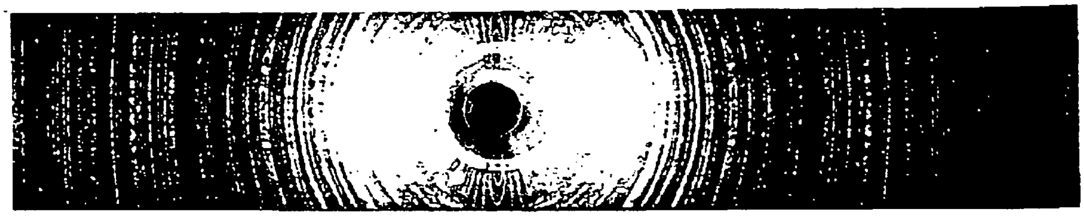
6 unmatched lines:- 2.1055Å, 1.4322Å, 1.3054Å, 1.1949Å, 1.1319Å, 1.0978Å.

Minerals Included:- Muscovite, Chlorite, Ilmenite.

Most Probable Minerals Present:- Chlorite, Ilmenite.

DX7046.0047

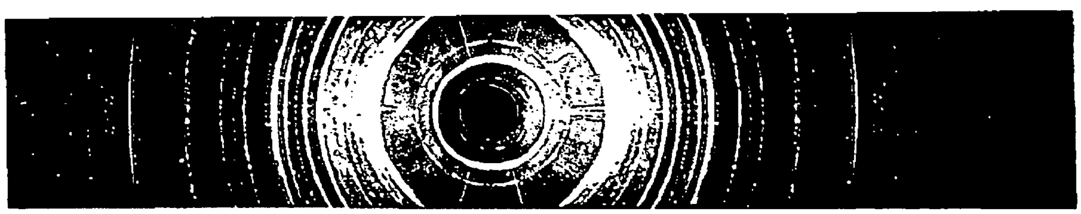
Sample V9



Minerals Included:- Garnet, Chlorite, Actinolite, Talc.

Most Probable Minerals Present:- Actinolite, Talc, Chlorite, Garnet.

Sample V10

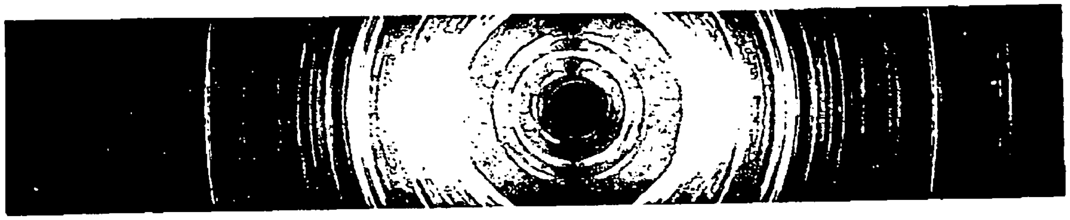


Minerals Included:- Talc, Chlorite, Magnesite, Quartz, Dolomite

Most Probable Minerals Present:- Talc, Chlorite, Magnesite

DX7046.0048

Sample V11

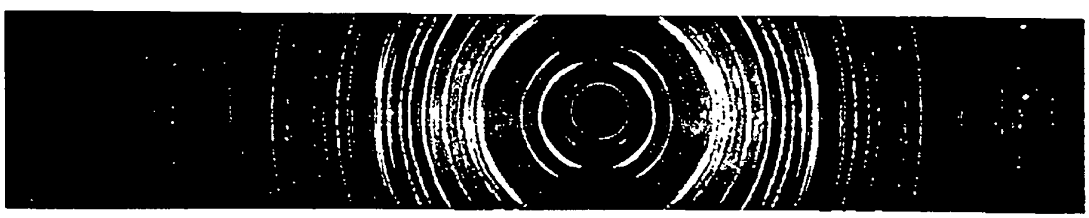


5 unmatched lines:- 1.3675Å, 1.3095Å, 1.1926Å, 1.1336Å, 1.1169Å.

Minerals Included:- Talc, Olivine, Chlorite, Rutile, Ilmenite.

Most Probable Minerals Present:- Talc, Chlorite, Rutile, Ilmenite.

Sample V12



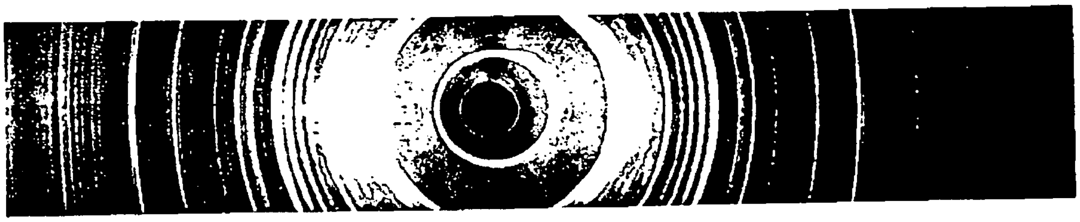
9 unmatched lines:- 3.2537Å, 1.8445Å, 1.8018Å, 1.4388Å, 1.2052Å, 1.1406Å, 1.1241Å, 1.1083Å, 1.095Å.

Minerals Included:- Talc, Olivine, Chlorite, Magnesite, Antigorite, Ilmenite.

Most Probable Minerals Present:- Talc, Chlorite, Magnesite.

DX7046.0049

Sample V13

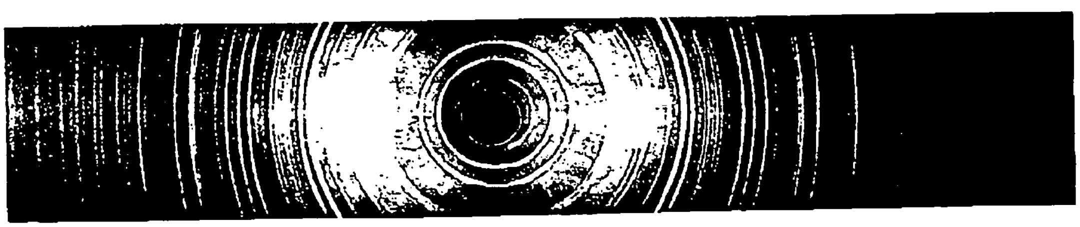


10 unmatched lines:- 3.046Å, 1.8471Å, 1.8077Å, 1.4448Å, 1.3084Å, 1.2061Å, 1.1833Å, 1.1448Å, 1.1172Å, 1.1061Å.

Minerals Included:- Talc, Olivine, Chlorite, Magnesite, Garnet, Rutile, Ilmenite.

Most Probable Minerals Present:- Talc, Chlorite, Garnet, Rutile.

Sample V14



Minerals Included:- Talc, Chlorite, Olivine, Magnesite, Antigorite.

Most Probable Minerals Present:- Magnesite, Talc, Chlorite.

DX7046.0050

CONCLUSIONS

Optical examination has shown that there are a number of minerals associated with the talc ore which could possibly contaminate the final talc product from the Vermont Mine. These minerals include chlorite, magnesite, biotite, muscovite, quartz, actinolite, tremolite and idocrase. Other minor minerals which may be present include garnet, zircon, rutile, ilmenite and the sulphides pyrrhotite, pentlandite, pyrite and chalcopyrite.

The amphibole minerals were found in discrete locations and not disseminated throughout the talc ore and were not asbestiform in character. Serpentine mineral was found in the specimens located at the centre of the orebody but no fibrous components were observed.

The electron microscope examination of the powdered specimens showed that the occurrence of lath-like particles was low with the exception of the specimen V_9 which contained amphibole mineral and in which lath-like amphibole particles could be readily identified by selected area electron diffraction patterns. The talc specimens produced particles which were thin and plate-like in form. The X-ray results confirmed the majority of the mineral phases identified by optical means. No attempt was made to confirm the sulphide minerals which were readily visible in several of the samples.

Special care was taken in the examination of specimens V_1, V_2 and V_3 which were associated with serpentine mineral. Electron microscopy of these specimens showed that the serpentine polymorph chrysotile was not present in these specimens and the serpentine phase could therefore be considered to be antigorite.

F.D. POOLEY
Project Supervisor

DX7046.0051