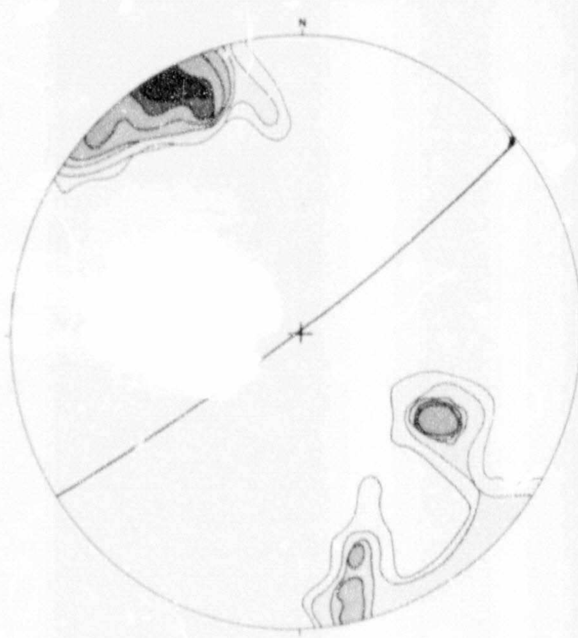

FIGURE 21A

SYNOPTIC PYEDIAGRAM OF JOINTS FILLED WITH ASBESTOS; 71 MEASUREMENTS CONTOURED AT 1.5%, 2.5%, 3.5%, 4.5%, 5.5%, 7.5%, 9.5% AND 11.5% INTERVALS.

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Apart from the above relationship to the folding, it has further been observed in the field that in the sharp anticlinal hinges of the folds (parallel to fold axis), the joints are sometimes more abundant than on the flanks. These joints are usually filled with quartz, siderite, magnesite and occasionally cross-fibre asbestos. In fig. 23a 71 measurements of joints filled with cross-fibre are indicated.

Present also in the area of investigation is a shear joint system trending NNE-SSW. This sytem is however not distinctly developed and very few measurements of this trend were recorded (see Map 2 and π plots on Map 5). In the area surrounding Malipsdrift, however, prominent sets are developed, especially in the Wonderkop fault area.

Apart from the main shear and tension joints, described above there are other minor joint sets. For instance, prominently developed flat joints are shown in Figures G, H and O on Map 5. These joint systems are, however, very complex and difficult to analyse.

In addition, a few miles away to the north-east but still in the same structural environment, a dyke which intruded along one of these joints, has itself been jointed. This would appear to indicate that in the Pietersburg area a later post-fold joint system is present, although the possibility of this system being contraction joints cannot entirely be excluded.

The final conclusions to be drawn from the above discussion are that the two main joint systems present in the area conform to the shear and tensional directions set up by the local forces responsible for the east-west folds. Other minor sets of joints post-dating the folding and later faulting in the area also appear to exist.

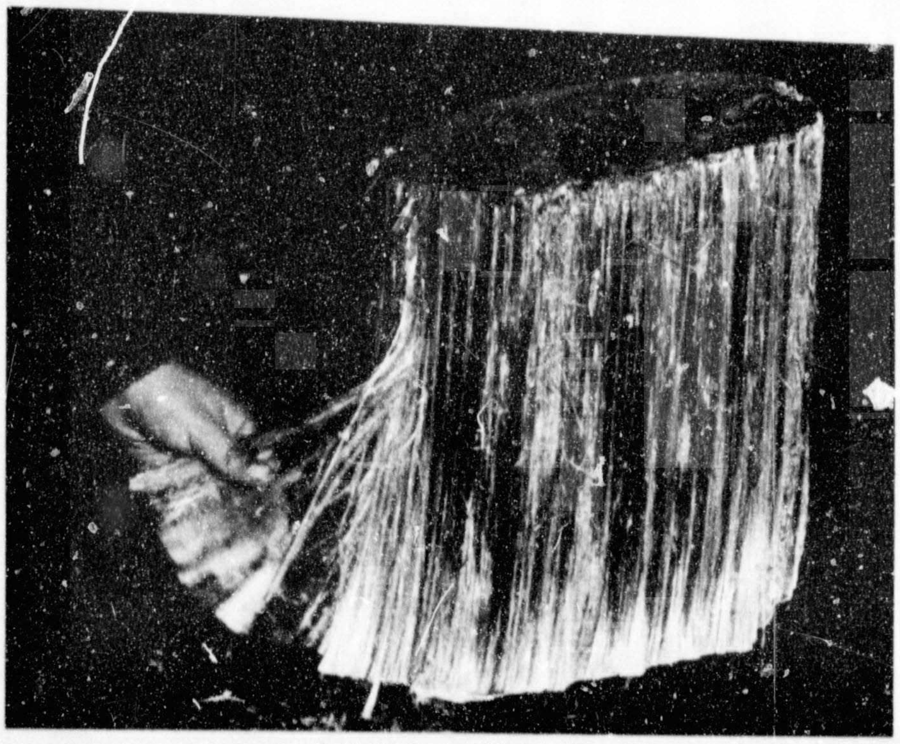

FIGURE 22.

PHOTO SHOWS A TYPICAL FRESH CROSS-FIBRE AMOSITE BAND DISPOSED AT RIGHT ANGLES TO THE BEDDING PLANES.

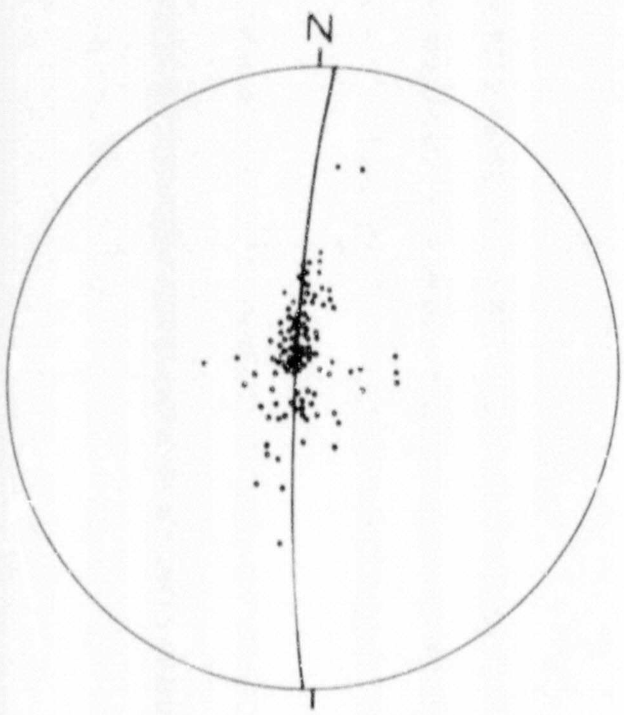

FIGURE 23

PLOTS OF FIBRE ORIENTATION. DIAGRAM INDICATES COMMON ORIENTATION OF THE FIBRE. FURTHER NOTE FIBRE IS ORIENTED PARALLEL TO THE P-MIN. STRESS DIRECTION OF THE EAST WEST FOLDS FOR COMPARISON SEE MAP 5 AS WELL AS SYNOPTIC PLOTS OF BEDDING LINEATIONS, JOINTS AND AXIAL PLANES.

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E. AMOSITE AND CROCIDOLITE

1. Distribution

These two fibrous minerals are restricted to certain zones in the banded ironstone succession traceable through the Pietersburg Field.

The main amosite "shorts" seams are found developed solely in the lower stratigraphical units of the ironstone succession, whereas the main crocidolite "shorts" seams are found developed only in the upper portions of the banded ironstone. The main "medium to long" amosite and crocidolite fibre seams are found developed in the central portions of the ironstone succession (Fig. 6).

The several fibre seams within each of these zones are also developed in certain well defined stratigraphical units in the ironstone succession. They are very persistent and can be followed for long distances along the outcrops. For instance, the "Main Amosite Shorts Horizon" can be traced from the farm Holkloof in the west to the Montana Mine in the east, a distance of approximately 24 kilometres. The three "Voorspoed Shorts Horizons" are also traceable from west of the Malips River to approximately 16 kilometres east of the Tubex Mine (through which it passes), a distance of approximately 40 kilometres.

Between the fibre bearing zones and horizons are stratigraphical units showing very little or no fibre development. A typical example of this is seen in the Barren Gritty Zone (Zone F) which occur between the "Main Shale Marker Bed" and the "Voorspoed Shorts Zone" (see previous discussion on page 24 and Figure 7.) In this zone no cross-fibre is developed. Two other well defined, broad stratigraphical units, which also show no fibre development, are zones A, B and the bottom three sub-zones C_1, C_2 and C_3 of the Broad Irregular Banded Cherty Formation (refer to previous discussion on page 18 and Figure 6). Within the fibre bearing zones there are also a few other stratigraphic units developed up to 4 metres thick which also contain very little or no fibre. They are however, thin and insignificant.

FIGURE 24

EXAMPLE SHOWS AN AMOSITE FIBRE BAND IN THE CREST OF AN ANTI-CLINE AND TROUGH OF A SYNCLINE. NOTE THAT THE FIBRE IS GENERALLY ORIENTATED PARALLEL TO THE AXIAL PLANES IN THE HINGE OF THE FOLDS. ON THE LIMBS THERE IS A SLIGHT TENDENCY FOR A SPLAYING OF THE FIBRE. (APPROX. HALF NORMAL NOTE).

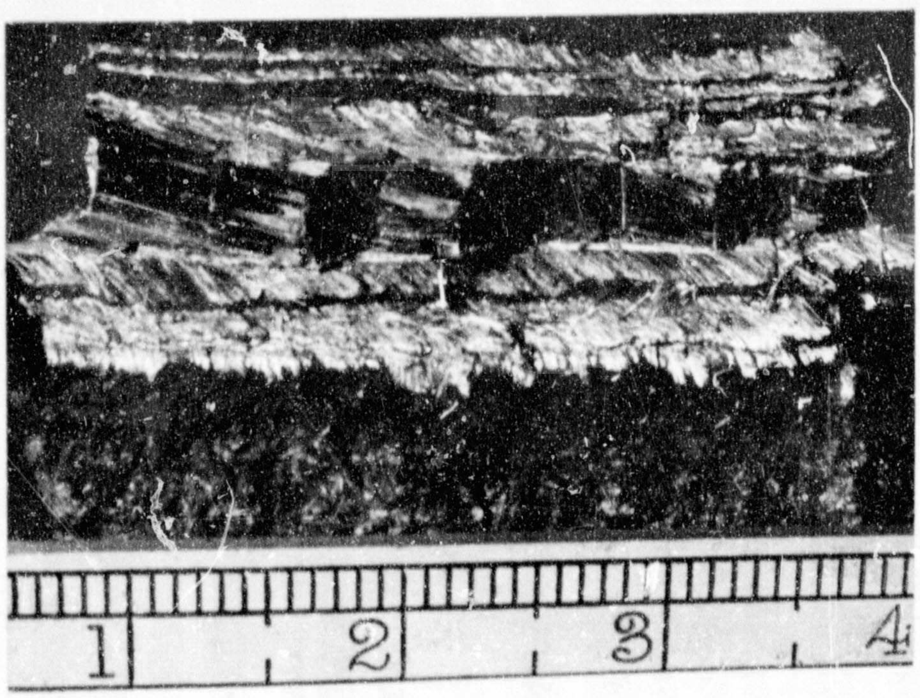

FIGURE 25

EXAMPLE OF A SLIP FIBRE BAND. NOTE SURROUNDING FIBRE BANDS ARE RELATIVELY UN-DISTURBED.

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Within the fibre bearing zones, long and occasionally short amosite fibres are usually found associated with ironstone of a very fine, soft graphitic shaly character. These rocks defined by Hall (1930) as "amosite slates" are entirely non-magnetic and have a dark grey to light greenish colour. The "amosite slates" consist of fine quartz, siderite, nontronite and soft graphitic material. At the contacts of these shaly horizons irregular bands, lenses and "blobs" of chert and magnesite are usually developed. The porphyroblastic crystals of magnesite developed within these shaly zones seldom exceed a few centimetres in size. The amosite "shorts" fibre seams are also found associated with a siliceous type ironstone, consisting of medium to broad, irregular banded white chert bands, separated by paper thin ill-defined, massive looking, magnetite bearing bands.

The crocidolite fibre seams are developed in a true banded type ironstone. This rock is usually an even, fine to medium banded rock (layers varying in thickness from infinitely fine to 5 mm.), consisting of alternating bands of grey cherty material and dark massive magnetic material. With the exception of one seam in this area (Main Pisga Asbestos Horizon), crocidolite is found associated with a screen of magnetite at its contacts. Generally, the ironstone in which crocidolite is developed is fine, regular and more distinctly banded than the ironstone in which amosite is developed. Broadly, (based on the distribution of amosite and crocidolite) there appears to be a zoning in the ironstone succession from an amosite bearing formation at the base of the succession to a crocidolite bearing formation at the top of the succession and in the central portions of the ironstone succession, a broad zone containing both amosite and crocidolite (see Page 21 and 22). The significant conclusion to be drawn is that original chemical variations from the bottom to the top of the ironstone succession, appear to have been responsible for this zoning effect. Laterally, and on a more regional scale, a similar effect, which can be described as a facies change in the rock, is present. In the Chuniespoort area and farther west mainly crocidolite is developed, whereas in the Penge-Havercroft area to the east only amosite is found. A transition zone, in which both amosite and crocidolite occur as described above are present in the Malipsdrift and surrounding area.

2. Mode of Occurrence

Amosite and crocidolite bands and seams have a fairly wide range of common characteristics, which are discussed below:-

(a.) Cross-Fibre Occurrence

In cross-fibre seams the individual fibres are generally orientated at right angles to the bedding planes, with mostly sharp and straight contacts (Fig. 22). Fibre of this nature predominates over all other types of occurrences.

Cross fibre is found only where the formations are horizontal or slightly dipping. Where the formations are steeply dipping, the fibre makes a distinct angle with the bedding planes referred to as angled or oblique fibre.

The 160 measurements taken on the orientation shows the fibre to have a common orientation (Fig. 23). This would not have been possible in this tightly folded area if, as postulated by Cilliers and Genis (1964), the bedding planes were responsible for the orientation of the fibre. One would rather have expected some kind of splayed orientation. In other words, if the bedding planes were responsible for the fibre orientation, the fibres should have been splayed in a much more pronounced "fan-like" manner than is observed.

In the Malipsdrift area where the bedding has been considerably folded, it is found that in the centre of any one fold, the fibre is orientated parallel to the cleavage associated with the folds and also the axial planes of the folds (Figure 24). On the limbs there is a tendency for a very slight splay such as generally exhibited by cleavage planes away from the fold axis. A common characteristic of similar folds is the fact that the cleavage planes are aligned parallel to the axial planes near the centre of the fold. Moving away from the centre and towards the limbs of such folds, the cleavage planes also have a tendency to a slight splay.

This also applies to the fibres in what appear to be related to axial planer cleavage formation. On the limbs of folds the fibre orientation makes a distinct angle with the bedding planes, as opposed to the crestal areas where the fibre is aligned at right angles to the bedding planes.

From the above discussion it is obvious that the fibre lies in the structural a - b plane as defined by Cloos (1947), Ramsay (1963) and others. Furhtermore, the fact that the fibres have a common orientation (see Figure 23), suggests a definite direction of growth in this a - b plane. In the absence of any course sediments such as conglomerates or grits, as well as the absence of oolities in the dolomite, there is no way in which the minimum - stress direction could be directly determined. However indirectly from the overall characteristics of the folds and fibre display, the determination can be made as follows :- As already described it was concluded by the writer that the fibres lies in the structural a - b plane. It was noted, that the poles of the fibre (see Figure 23) fall on the bedding plane great circle (see Figure 11 and figures on Map 5) and are concentrated in a specific maximum 90° away from the b - axis. Furthermore, this maximum of fibre orientation corresponds to the minimum stress direction as defined by the a - c and a - b joints discussed in a previous section (see Page 43 and Figure 21) This, in addition to direct field observation which shows fibre orientated parallel to the axial planes of the folds, are the main reasons for concluding that fibre is structurally controlled and that fibre growth corresponds to the minimum a - stress direction of the younger east-west trending folds.

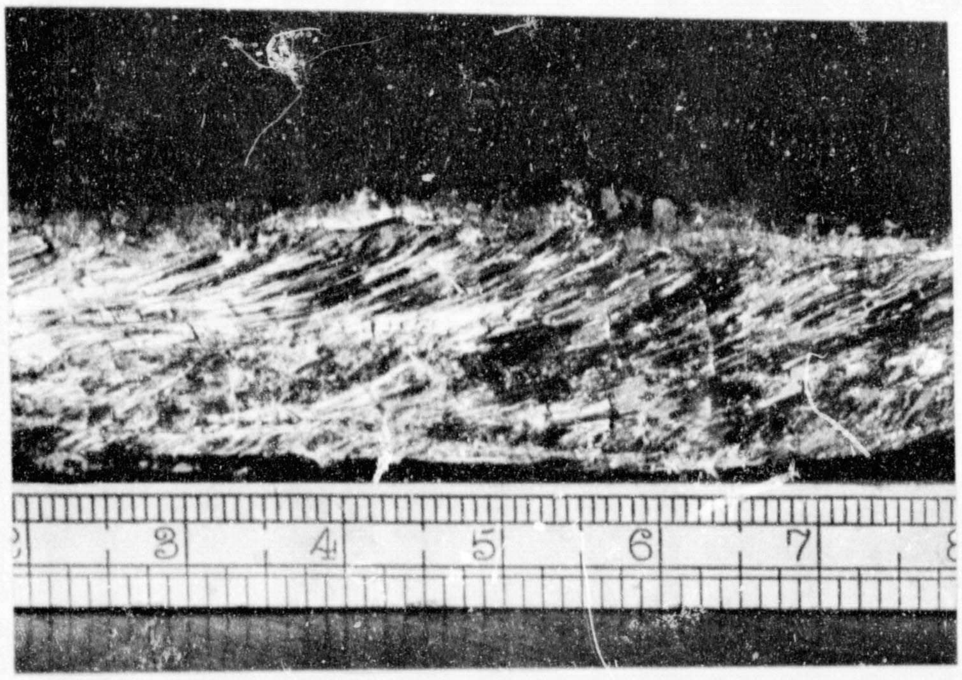

FIGURE 26

PHOTO INDICATES "ANGLED" FIBRE DISPOSED AT AN OBLIQUE ANGLE TO THE BEDDING PLANES.

FIGURE 27

EXAMPLE SHOWS "WAVELIKE" BEHAVIOUR OF FIBRE. THIS BAND OF FIBRE APPEARS TO HAVE BEEN PUSHED APART, WITH SUBSEQUENT FILLING OF THE FRACTURE WITH MASSIVE GRAPHITIC MATERIAL. (HALF NORMAL SCALE).

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The possibility exists that the fibre could also fall along the line of intersection of the axial planes of the east-west and north-south folds. There is, however, no evidence for this, as so little data on the axial planes of the north-south folds is available in the area under discussion. This aspect is being investigated in the Penge area (approximately 55 kilometres to the south-east of Bewaarkloof), where data on the north-south trending folds is more freely available.

The reason that this relationship of fibre orientation and structure has not been observed before is that in the many mildly folded or low, even dipping areas (Penge and Kuruman areas), where the main compressive stress was horizontal or at a low angle (revealed by the vertical axial planes of the folds), the fibre growing in the direction of least stress (vertical) gives an apparent right-angled relationship to the bedding planes.

(b.) Slip and Oblique Fibre

Slip fibre bands are orientated parallel to the bedding (Figure 25). In the area investigated this type of fibre is rarely developed. This fibre is only developed in local areas surrounding fault zones and in tightly folded concentric type folds. In the Maxwell Kloof area and in the Tet Fibre Horizon, one or two examples, as described above, were found next to one of the minor faults. Moving away from a fault or tightly folded area slip fibre occurrences quite often change laterally into cross-fibre bands. Occasionally there are also one or more fibre bands within a certain seam, which differ from the other seams in angular relationship to the bedding planes as exemplified in Figure 25.

Oblique or angles fibre, constitutes the bulk of the fibre in the Malips area. In this case the fibre is found orientated at an angle of less than 90° to the bedding planes (Figure 26). This type of fibre occurrence is very noticeable on the limbs of the folds.

As previously described the fibre, having grown in the direction of least stress (vertical) will show this angular relationship with respect to dipping formations.

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Figure 28

Photo shows rapid variation of fibre lengths. Note that the small displaced fibre portions can be pushed back to fit original positions.

Figure 29

Photo shows a single fibre band that has been sheared and displaced.

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(c) Wavy Fibre Seams.

The walls of cross and slip fibre bands are occasionally irregular and wavy, of such a configuration that the opposite walls do not normally match. The confining walls from which the fibre is most easily separable are sharp and well defined (Figure 27). The partings clearly portrayed in this figure consist of fine grained graphitic material but frequently quartz, siderite, haematite and magnetite, are also present. Figures 28 and 29 also show wavelike partings within the seam and rapid variation in length is reflected, for the most part, in the central portions of fibre seams.

These regular, wavelike partings, which cut sharply through the fibre, are believed to be post-fibre slip cleavage shears. However, as a result of the difficulty of measuring the shear planes, there is no quantitive evidence in support of this statement. There are also numerous instances where these partings do not contain any filling material but are, in fact, clean cut and generally do not extend over long distances (Fig. 30).

Apart from this regular, wavelike fashion, fibre quite often displays an irregular character where the "ends" of the fibre are quite jagged and uneven and cannot be outlined by a single undulating surface contact (Fig. 31). This appears to indicate a crystallisation process only half finished after complete consolidation of the ironstone formation. Bands and layers of rock have been pushed ahead of these growing fibres and in certain instances, forms cross-cutting relationships with the bedding planes (Fig. 31). The gangue material in between represents the residue material after cessation of fibre growth. It consists mostly of siderite, quartz, magnetic and fine graphitic material.

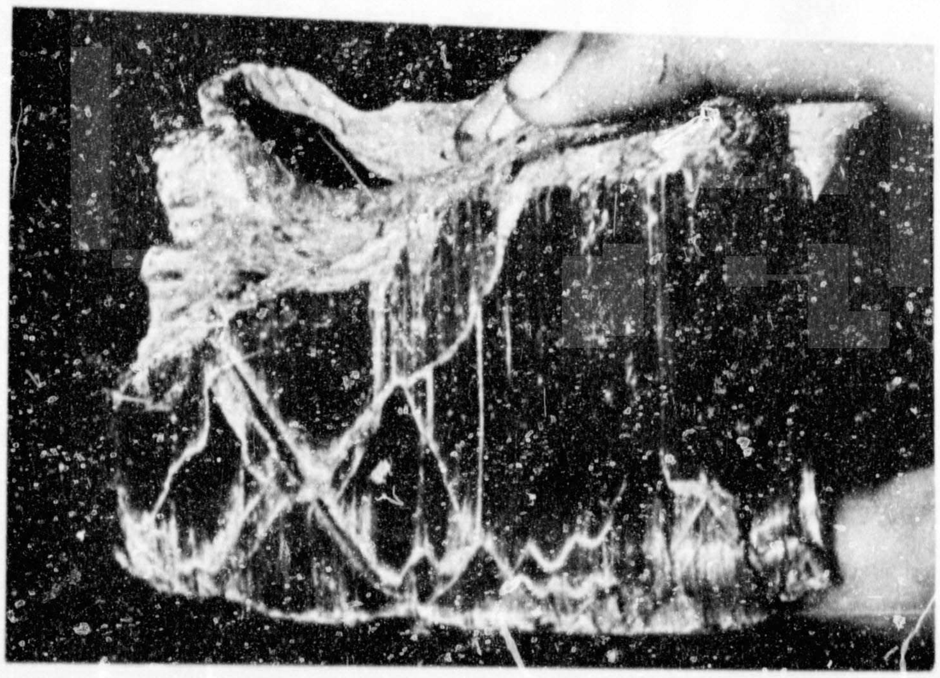

Figure 30

Specimen shows a fibre seam with no filling material in the shear planes present at base of the sample (normal scale).

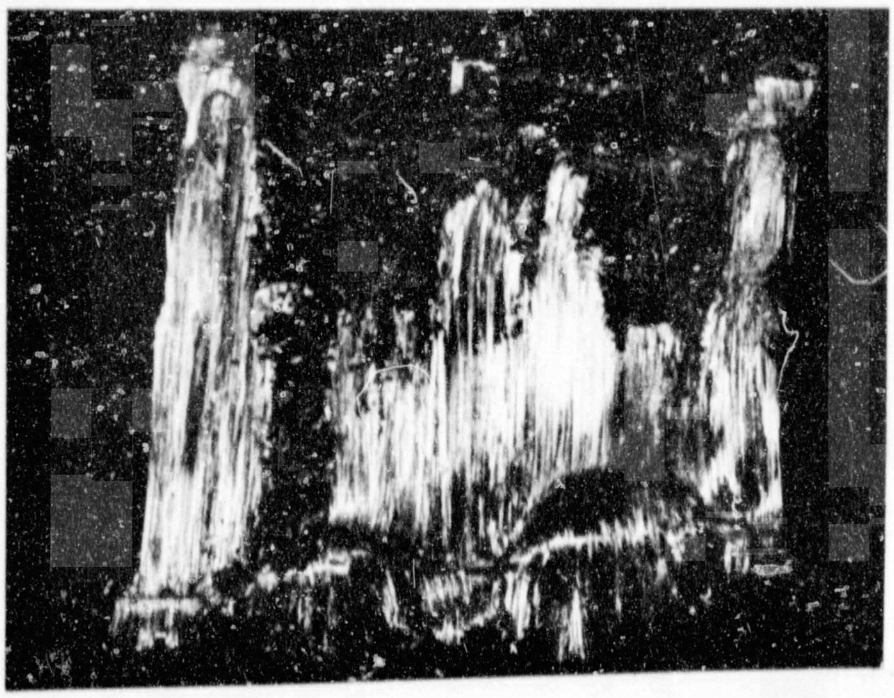

Figure 31

Specimen shows an "uneven" and "jagged" fibre band formed as the result of unequal growth. Note "cross-cutting" relationship of the fibre (normal scale).

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(d.) Cone in Cone Structure

These structures are certain conical protuberances of fibre, which in cross-section approximate equilateral triangles (Fig. 32). The cones are mainly developed with the apices upwards and the axes parallel to the fibre orientation. In some examples the cones are elongated, domelike structures. These elongated, domelike structures appear to correspond in trend to the east-west fold direction. Because of the extreme difficulty in obtaining exact and reliable results no measurements were taken of this. In some instances these domelike, elongated structures resemble minor anticlinal folds. Note the specimen in Figure 33 clearly show a minor anticlinal structure, with fibres orientated parallel to the axial plane. In cross-section, the fibres show a conelike structure. Where the minor folds plunges steeply in both directions, an elongated, conelike structure is produced.

The heights of the cones normally vary from a fraction of a millimetre to approximately 5 centimetres. In exceptional cases they have been found to exceed 10 centimetres. Cones are usually found developed in the central portions of elongated, lenticular fibre deposits, discussed later (Page 68). Furthermore, the fact that "waste" cones are also found precludes the generally accepted opinion that they have formed due to unequal growth of fibre. In Figure 34 a cone structure is indicated containing no fibre at all. This cone was clearly produced by folding. The conclusion from the above must be that both "waste" and fibre cones must have been produced in a similar manner. It would appear that cones (which should not be confused with "irregular fibre" or described on page 62) have been formed by shearing and folding (figures 30 and 33).

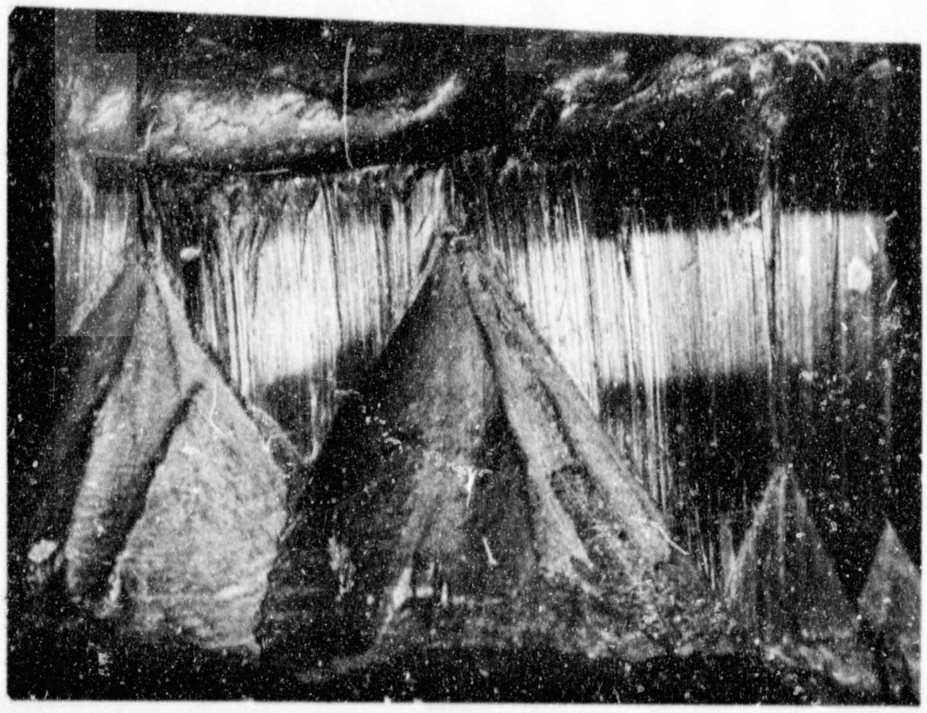

FIGURE 32

EXAMPLE SHOWS TWO ASBESTOS CONES. NOTE AXES OF THE CONES COINCIDE WITH THE ORIENTATION OF THE FIBRE (HEIGHT OF CONES ARE APPROX. SIX CENTIMETRES.

FIGURE 33

EXAMPLE OF AN ASBESTOS CONE IN SECTION. THE PHOTO CLEARLY INDICATES POST FIBRE FLATTENING AND SHEARING TO HAVE DEFORMED THE ASBESTOS BAND INTO THIS CONICAL SHAPE. THE ASBESTOS BAND APPEARS TO HAVE ACTED IN AN INCOMPETENT MANNER WITH TRANSLATION OF THE FIBRE PARALLEL TO THE AXIAL PLANE AS THE RESULT OF FRACTURE CLEAVAGE DEVELOPMENT. NOTE THE CENTRAL PORTION OF THIS CONE CONTAINS ALMOST NO FIBRE.

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