# III. Geology

## A. Introduction

The succession of stratified geological formations and the associated igneous intrusions generally encountered within the domain of the Asbestos Field of the Northern Cape is grouped according to the currently accepted version of the geological profile in Table 2.

The deposits of crocidolite asbestos in the Northern Cape Province are confined strictly to the lowermost stage of the Pretoria Series (as currently accepted), Transvaal System. In the Cape Province this stage is known as the Lower Griquatown Stage and comprises banded ironstone, banded jasper, siliceous shale, amphibolite and tillite mainly, and subordinate layers of quartzite, dolomite and thin intercalations of volcanic material. All known economically workable deposits of crocidolite in this stage are confined to the lowermost substage referred to as the Banded Ironstone Substage. Because the chief purpose of this paper is to cast more light on the occurrences of crocidolite in the Cape Province, the geology of the Lower Griquatown Stage only will be discussed in detail.

At this stage it is necessary to draw attention to the apparent inconsistency concerning the contact between the Dolomite Series and the Pretoria Series. In the Cape Province the Banded Ironstone Substage which succeeds the main dolomite represents the lowermost portion of the Pretoria Series. In the Transvaal a similar succession of asbestos-bearing ironstone also succeeds the main dolomite, but because it lies immediately below the Bevet's Conglomerate, taken as the base of the Pretoria Series, the banded ironstone layer is included in the Dolomite Series. The contact between the banded ironstone and the dolomite in the Cape Province is transitional, indicating a continuous deposition of dolomite followed by banded ironstone. At present detailed work is being carried out by members of the Geological Survey in collaboration with geologists of the South African Iron and Steel Industrial Corporation Limited on the rocks of the Gamagara Formation and the Pretoria Series. These investigations may lead to an entirely new subdivision of the different stages now incorporated in the Pretoria Series. The author feels convinced that these investiga-

Table 2. - Geological formations in the Asbestos Field of the Northern Cape

| | | | |
|---|---|---|---|
| Tertiary and Recent Deposits | | | Wind-blown sand<br>Alluvium<br>Gravel and scree deposits<br>Surface-limestone |
| Pipes | | | Kimberlite |
| Dykes | | | Dolerite |
| Karroo System | | Dwyka Series | Tillite and shale |
| Waterberg System (Matsap Formation) | | Upper Matsap Stage | Quartzite and grit |
| | | Lower Matsap Stage | Mainly andesitic lava |
| Loskop System (Gamagara Formation) | | | Quartzite, conglomerate and shale<br>Basal conglomerate and quartzite |
| Sills and dykes | | | Diabase |
| Transvaal System | Pretoria Series | Upper Griquatown Stage | Banded ironstone and jasper, limestone, shale, quartzite and lava |
| | | Middle Griquatown Stage | Andesitic lava with interbedded tuff, chert and jasper |
| | | Lower Griquatown Stage | Tillite<br>Banded jasper and quartz chloritefels with subordinate siliceous shale quartzite and limestone<br>Riebeckite slate with intercalated chert<br>Banded ironstone with subordinate intercalations of pyroclastic material |
| | | Dolomite Series | Dolomite, limestone and chert |
| | | Black Reef Series | Quartzite, shale, limestone, dolomite, siltstone and mafic lava |
| | | Zoetlief Formation | Mafic and silica-rich lava, tuff, arkose, quartzite, shale and slate |

tions will prove the banded ironstone and associated jaspers in the Cape Province to be part and parcel of the Dolomite Series.

The Lower Griquatown Stage lies directly upon the Dolomite Series. A layer of shale generally overlies the main dolomite directly, but varies considerably in thickness from the south to the north in the area where the Lower Griquatown Stage is represented. In the Prieska area the shale attains a maximum observed thickness of 400 feet, but in the Northern Region the shale decreases in thickness to some 15 feet or less. The zone of shale is not always present in the Northern area and is therefore not indicated on Figure 1. There is also a remarkable difference in the total thickness of the succession from south to north as well as a conspicuous change of facies. For descriptive reasons therefore, the area in which the Lower Griquatown Stage is found, is divided into two separate regions which will be referred to as the Southern and the Northern Region, respectively. The Southern Region includes the area from Griquatown towards Prieska and Westerberg in the south whereas the Northern Region covers the area from Griquatown northward to beyond Pomfret.

For the detailed description of the geological characteristics of each region a type-area has been chosen in each. The type-areas have been chosen within those localised areas where active crocidolite mining is in progress, because these are the localities where the most detailed information about the distribution of the crocidolite-bearing zones could be obtained. For the Southern Region the area between Prieska and the Westerberg—Koegas asbestos mine is selected as the type-area whereas for the Northern Region the area immediately west and north of the village of Kuruman was chosen.

## B. The Northern Region

The Lower Griquatown Stage in this region, which covers the area from Griquatown in the south to beyond Pomfret in the north, differs very little in character from place to place. Differ nces in the total thickness and in the thicknesses of the individual substages are present but are not as considerable as the difference in thickness between the Northern and Southern Regions. Asbestos-bearing zones are found at certain stratigraphical

THE VERTICAL DISTRIBUTION OF ROCK-TYPES, ASBESTOS-BEARING ZONES AND MARKER-BEDS IN THE LOWER GRIQUATOWN STAGE, NORTHERN REGION

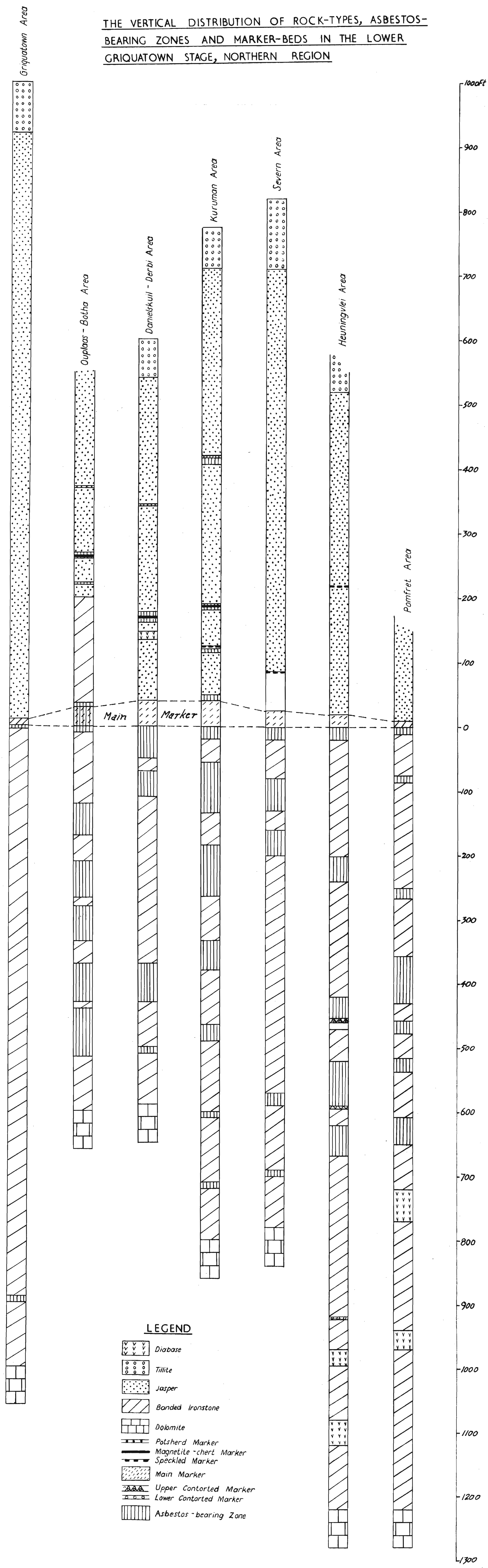


FIGURE I

horizons which can be correlated to some extent from one locality to another.

## 1. The Kuruman Area

The Kuruman area may at present be regarded as the biggest crocidolite-producing centre in the Cape Province. It includes several well-established asbestos mines located on different farms and belonging to a number of private concerns. The existing mines in this area are found from the farm Asbes (I2) in the south to that on the farm Koretsi (H1) in the north, which is situated in the Lower Kuruman Native Reserve. Other operating mines between these two points are Whitebank and Kuruman East both of which are located on the farm Whitebank (I2), Depression located on a portion of the farm Exit (I2) and Riries (I1), Mount Vera (I1), England (I1) and Eldoret (H1) each located on farms bearing the same name as the mine.

Along the stretch of country where these mines are located both the top and the base of the Lower Griquatown Stage are exposed at a number of places. The total thickness of this Stage which comprises the Banded Ironstone, the Jasper and the Tillite Substages varies little along the strike in the Kuruman area, and approximates some 1,500 feet. Several layers in the succession, most of which are found at certain stratigraphical horizons within the Jasper Substage, display particular characteristics so that they can be used as marker-horizons. These marker-beds are of great value to the prospector and serve as guides to estimate the depth at which particular crocidolite-bearing horizons may be intersected below surface. Some of these marker-beds are also indirect indicators of fibre development at depth.

The sequence of the constituent members of the Lower Griquatown Stage, their individual thickness and the vertical distribution of marker-beds in it are shown in Figure 1. The profiles in Figure 1 were compiled from information obtained from prospecting bore-holes drilled by several mining companies, from bore-holes drilled by the Department of Water Affairs, from information obtained in mine-shafts and from traverses at several localities.

Information used for compiling the profiles were obtained from the following bore-holes:

Bore-hole 1 on Leeuwvlei (N6), Hay District. Drilled by Griqualand Exploration and Finance Company Ltd.

Bore-holes DM12A on Botha (M2), Postmasburg District and DW19A on Pomfret (B4), Vryburg District. Drilled by Cape Blue Mines (Pty.) Ltd.

Bore-holes L24 on Lemoenkloof (M2), Postmasburg District, DB1 on Derbi, Postmasburg District and WBM 98 on Whitebank (I2), Kuruman District. Drilled by Kuruman Cape Blue Asbestos (Pty.) Ltd.

Bore-holes on Eldoret (H1), Kuruman District. Drilled by Merencor Asbestos Mines Ltd.

Bore-hole on Hove (C2), Vryburg District. Drilled by the Department of Water Affairs.

Additional information on the vertical distribution of rock-types, the asbestos-bearing zones and the marker-beds was obtained from a new mine shaft on Ettrick (I1), Kuruman District and from traverses surveyed on the following farms:

Merino (N5), Farm 566 (N6) and on Griquatown Commonage in the Hay District,

Skietfontein (L2) and farm 254 (L2) in the Postmasburg District. Heunar (D2) and Pomfret (B4) in the Vryburg District.

### (a) The Banded Ironstone Substage

The thickness of the Banded Ironstone Substage in the Kuruman area averages some 800 feet. It succeeds the Dolomite Series conformably, displaying a gradational contact characterised by alternating layers of banded ironstone, chert and thin intercalations of dolomitic limestone and shale. The upper limit of the Banded Ironstone Substage is marked by a layer of jasper which has an average thickness of 40 feet and is known as the Main Marker. This jasper layer displays certain characteristics which can be recognised from one locality to another and it therefore constitutes a valuable marker-bed.

Differences in the character of the banded ironstone are caused chiefly by a change in the thickness of individual alternating laminae of chert and magnetite, changes in the colour of the chert laminae, usually recognisable in fresh specimens only, and the predominance of chert over magnetite. On the whole the banded ironstone is a well-bedded, finely to coarsely laminated rock.

In the field the banded ironstones are characterised by a conspicuous banding due to an alternation of siliceous and ferruginous layers, the latter composed mainly of goethite, hematite (martite) and accessory magnetite.

These iron oxides cause the ferruginous laminae to be brightly coloured in shades of brown, black, red and yellow whereas the cherty laminae display whitish, greyish, greenish, red and bluish colours. In hand-specimens of material at depths below the zone of oxidation chert and other mainly siliceous laminae also display a wide variety in colour, generally the same as those from the surface, but the ferruginous laminae are black almost without exception.

The individual layers or laminae vary in thickness from paper-thin films up to about four inches. The thicker laminae may be lenticular in places, but as a general rule individual layers or laminae are remarkably constant and relatively uniform in thickness. This characteristic gives rise to exceptionally smooth bedding-plane surfaces along which paving-slabs of almost any desired thickness can be plied off. Occasional layers or lenses composed essentially of intricately interwoven, acicular crystals of soda-amphibole (riebeckite) are encountered. They are usually bluish in colour and vary in thickness from a fraction of an inch to a couple of feet. The riebeckite in these layers is generally referred to as mass-fibre, massive riebeckite or potential crocidolite. Because of the complete disorientation of the acicular crystals of amphibole in these layers they are very tough and some are strongly weather-resistant. Others which contain a fair amount of magnetite dispersed throughout the matted material weather to a soft, yellow, ochreous material. The toughness of these layers of massive riebeckite is especially realised in underground exploration and in bore-holes.

Cross-fibre crocidolite is found in seams of varying width at certain stratigraphical horizons within the banded ironstone. The width of these seams varies from less than a quarter inch to about two inches. Occasionally fibre of greater length is found in the area, but the average length is generally between half an inch and a three quarter inch. In surface-exposures the dark-blue crocidolite fibre is usually represented by yellow, ochreous griqualandite or in some places by well-silicified, yellow-brown "tiger's-eye". Silicification of crocidolite to form the semi-precious variety "tiger's-eye" is, however, not a common feature in the Kuruman area.

Generally cross-fibre seams, where exposed, are highly oxidized, yielding a soft, yellow, ochreous powder containing minute, hard and brittle fragments of quartz. Oxidation in one particular seam of cross-fibre crocidolite is not always complete, with the result that portions of the seam or sometimes even a single bunch of cross-fibres may still display its original blue colour. In old working-places and shallow prospecting-pits, where blue cross-fibre has been exposed, loose bunches of cross-fibre become soft and fluffy and cling to the rock surfaces like pieces of cotton wool. This fluffy material displays the characteristic blue colour of the fresh crocidolite fibres. It is of interest to note that in places where crocidolite fibre has been partly metamorphosed by intrusive diabase sills this same fluffy material is white in colour instead of blue and the cross-fibre, still in situ, displays a slight greenish colour.

A section through the Banded Ironstone Substage, obtained from a bore-hole drilled by diamond-drill on the farm Whitebank (I2), Kuruman area, is shown in Table 3. The position of the bore-hole is indicated on Folder 1. A detailed plan which shows the geology at the bore-hole site is not given for reasons of security.

Detailed information on the vertical thicknesses of the fibre zones intersected in this bore-hole and the percentage of asbestos fibre found in each are omitted. Because the information given in Table 3 has been obtained from one bore-hole only, small differences in the thickness of the Banded Ironstone Substage and in the detailed sequence of the banded ironstone types may be found in other portions of the Kuruman area. However, the above profile could be regarded as fairly representative of this Substage in the area.

From a study of the profile it is evident that except for minor intercalations of shale, dolomite, and chert the complete Banded Ironstone Substage is built of well-bedded, ironstone. The change in character of the banded ironstone is caused merely by a variation

## Table 3. - Detailed section of the Banded Ironstone Substage on the farm Whitebank, Kuruman District, as intersected in bore-hole WBM 98

(Drilled by Kuruman Cape Blue (Pty.) Ltd.)

(Elevations refer to height of intersections above the contact between massive dolomite and the Banded Ironstone Substage).

Main Marker

| Elevation above Dolomite (feet) | Thickness Feet | Description of Rock |
|---|---|---|
| 716 - 780 | 64 | Finely laminated, banded ironstone, oxidised. |
| 704 - 716 | 12 | Pale-greyish black, well-laminated, banded ironstone, slightly calcareous and containing a few thin intercalations of black, non-magnetic siliceous shale. |
| 703 - 704 | 1 | Pitch-black, hard and brittle, non-magnetic shale. |
| 687 - 703 | 16 | Grey-blue, well-laminated, banded ironstone with occasional seams of cross-fibre crocidolite and massive riebeckite. A single layer of black shale, 4 inches thick at 696 feet. |
| 686 - 687 | 1 | White-grey chert, calcareous and displaying "boudinage" structure. Foot-wall Marker, B Reef, Whitebank Mine. |
| 666 - 686 | 20 | Greyish-yellow, finely laminated, banded ironstone with intercalations of black shaly material and white, cherty material containing carbonate. |
| 643 - 666 | 23 | Light-brown, slightly calcareous chert with intercalations of finely laminated shale. |
| 590 - 643 | 53 | Finely laminated, banded ironstone, slightly calcareous. Chert laminae grey. Occasional seams of cross-fibre crocidolite and seams of massive riebeckite. Thin black shale, hard and brittle, at 640 feet. |
| 585 - 590 | 5 | Finely laminated banded ironstone with alternating laminae of white and grey chert; non-calcareous. |

| Elevation above Dolomite (feet) | Thickness Feet | Description of Rock |
|---|---|---|
| 579 - 585 | 6 | Finely laminated banded ironstone with laminae of alternating red and grey chert; non-calcareous. |
| 552 - 579 | 27 | Finely laminated banded ironstone with laminae of grey and greenish-coloured chert. Crocidolite seams at intervals and occasional seams of massive riebeckite; non-calcareous. |
| 527 - 552 | 25 | Finely laminated banded ironstone with laminae of alternating white and grey chert; slightly calcareous. |
| 474 - 527 | 53 | Coarsely laminated banded ironstone; magnetite laminae thin, laminae of white and grey chert medium-thick; single seams of massive riebeckite; calcareous. |
| 458 - 474 | 16 | Alternating layers of finely laminated banded ironstone, with laminae of brown and grey chert and coarsely laminated, banded ironstone with medium-thick laminae of white and grey chert, non-calcareous; seams of massive riebeckite towards base. |
| 418 - 458 | 40 | Coarsely laminated banded ironstone with laminae of white and grey chert; slightly calcareous. Several thin intercalations of black shale, hard and brittle. |
| 405 - 418 | 13 | Evenly laminated banded ironstone with laminae of white, grey and brown chert and interbedded seams of crocidolite; non-calcareous. |
| 358 - 405 | 47 | Coarsely laminated banded ironstone with laminae of white and greenish, and occasionally brown and red chert. Thin intercalations of black shale at unequal intervals. |
| 346 - 358 | 12 | Finely laminated banded ironstone with laminae of light-grey and greenish chert; slightly calcareous. Occasional thin intercalations of pitch black shale. |
| 268 - 346 | 78 | Finely laminated banded ironstone with laminae of white and brown chert and occasional seams of massive riebeckite; calcareous in lower portion but non-calcareous towards the top. |

| Elevation above Dolomite (feet) | Thickness Feet | Description of Rock |
|---|---|---|
| 263 - 268 | 5 | Finely laminated banded ironstone with laminae of brown chert and seams of massive riebeckite; non-calcareous. |
| 258 - 263 | 5 | Finely laminated banded ironstone with laminae of red and brown chert; slightly calcareous. |
| 256 - 258 | 2 | Finely laminated banded ironstone with laminae of white and brown chert; non-calcareous. |
| 246 - 256 | 10 | Finely laminated banded ironstone with laminae of white and dark grey chert; carbonate-rich. |
| 232 - 246 | 14 | Laminated banded ironstone with laminae of white and brown chert. Lenticular texture in chert laminae caused by small "lenses" of white chert in brown chert; slightly calcareous. |
| 228 - 232 | 4 | Finely laminated banded ironstone with laminae of white, green and brown chert; non-calcareous. |
| 222 - 228 | 6 | Laminated banded ironstone with laminae of white and green chert, bedding locally contorted; slightly calcareous. |
| 183 - 222 | 39 | Finely laminated banded ironstone with laminae of white and grey chert, varying in thickness from a fraction of an inch to four inches; calcareous in places. |
| 180 - 183 | 3 | Finely laminated banded ironstone with laminae of white and red chert; slightly calcareous. |
| 177 - 180 | 3 | Irregular laminated banded ironstone with laminae of white and grey chert; slightly calcareous. |
| 173 - 177 | 4 | Dark-black, hard and brittle shale, non-magnetic. |
| 148 - 173 | 25 | Finely laminated "shale" (banded ironstone) with laminae of white and greenish-coloured chert and magnetite; calcareous in part. |
| 143 - 148 | 5 | Finely laminated banded ironstone with white and grey chert laminae; non-calcareous. |

| Elevation above Dolomite (feet) | Thick- ness Feet | Description of Rock |
|---|---|---|
| 117 - 143 | 26 | Massive white-grey chert with intercalations of grey chert and occasional thin bands of hard and brittle black shale. Chert calcareous in part. Little magnetite present. |
| 104 - 117 | 13 | Black shale, hard and brittle. Several intercalated layers of pyrite. Non-magnetic. |
| 86 - 104 | 18 | Grey and white banded chert, bedding distorted; slightly calcareous. |
| 83 - 86 | 3 | Dark-grey chert alternating with subordinate layers of dark-grey shale; slightly calcareous. |
| 75 - 83 | 8 | Dark-grey dolomite. |
| 70 - 75 | 5 | White-grey banded chert and interbedded thin layers of pyrite. |
| 60 - 70 | 10 | Dark-grey dolomite with intercalations of chert. |
| 49 - 60 | 11 | White and grey banded chert, calcareous in part. |
| 46 - 49 | 3 | Hard black shale, non-magnetic, interbedded with thin layers of dolomite. |
| 43 - 46 | 3 | Alternating layers of dark-grey dolomite and black chert. |
| 39 - 43 | 4 | White and grey chert. |
| 0 - 39 | 39 | Alternating layers of grey dolomite and greyish-black chert. |
| | 62 | Massive grey dolomite with disseminated pyrite (Logged by B. Free) |

in the individual thicknesses of the alternating laminae of magnetite and chert and the colour of the latter. The thickness of the chert laminae varies from finely to coarsely laminated, but the variation in thickness of individual magnetite laminae is less obvious. The change in the colour of the chert laminae is generally caused by the relative amounts of microcrystalline quartz, minnesotaite and stilpnomelane. The chert laminae are generally quite free from disseminated magnetite grains. Carbonate is fairly abundant in the chert laminae of particular zones and where the chert laminae are composed chiefly of microcrystalline quartz and accessory carbonate the colour of the laminae is usually white or light grey. The presence of carbonate is easily detected by using a weak solution of hydrochloric acid. From the columnar section given above it is obvious that carbonate is a common constituent of the banded ironstone. More details about the constituent minerals of the banded ironstone will be given under the description of the petrology of these rocks.

Another feature of the banded ironstone is the frequent occurrence of thin intercalations of dark "shale". They are especially abundant towards the base of the banded ironstone succession and play an important role as marker-beds in all the existing asbestos mines in the Kuruman area and for that matter in the entire area in which crocidolite is mined in the Cape Province. In the mines they are referred to as siltstone, mudstone or shale and display a characteristic conchoidal fracture. The rock is usually pitch-black in colour and quite often carries pyrite. In the zone of oxidation this rock-type weathers to a deep-yellow, clay material. Not all the so-called "siltstone" intercalations found in bore-hole core and in underground workings were examined under the microscope but all of those which were examined point to the possibility that this rock-type is actually a recrystallised volcanic glass or tuff (p. 148 ).

Further evidence obtained from the detailed section through the Banded Ironstone Substage is that the contact between this substage and the underlying dolomite of the Dolomite Series is clearly transitional. The transition from pure dolomite to banded ironstone takes place over a vertical distance of some 200 feet in which distance the succession is characterised by alternating layers of banded chert varying in colour from white to black, with all gradations of grey in between, grey dolomite and black shale. It is also shown that the uppermost layer of banded chert (Table 3, 117 to 143 feet) becomes slightly magnetic owing to the presence of disseminated grains of magnetite in some laminae and is succeeded directly by finely laminated banded ironstone in which magnetite laminae are a prominent feature. The chert found in the transition-zone between dolomite and banded ironstone is conspicuously banded owing to alternating laminae, each composed of different quantities of microcrystalline quartz, minnesotaite and carbonate mainly. Stilpnomelane is generally present in subordinate amounts, but may become abundant in particular laminae in the banded chert.

## (b) The Jasper Substage

This substage follows conformably on the Banded Ironstone Substage and is distinguished from the latter by its predominantly siliceous, more irregularly banded and thickly bedded nature. It is composed mainly of yellow-brown to dark-brown, poorly bedded jasper containing subordinate intercalations of banded ironstone at several stratigraphical heights. The substage also contains a number of thin layers which display conspicuous characteristics and accordingly serve as excellent marker-beds. The Substage reaches an average thickness of 670 feet in the Kuruman area.

The main components of the Jasper Substage can be tabulated as follows:-

(v) The "Potskerf" or Potsherd Marker
(iv) Jasper with subordinate bands of massive riebeckite-rock (Riebeckitite)
(iii) The Magnetite-chert Marker
(ii) The Speckled Marker
(i) The Main Marker.

The stratigraphical distribution of the Marker-beds and their chief characteristics are listed in Table 4.

In the following pages additional information on the different marker-beds as well as the jasper layers between them is given under separate headings.

### (i) The Main Marker

Topographically the Main Marker almost invariably forms a prominent cliff or ledge immediately below the general gentle slope formed by rocks of the overlying Jasper Substage. The marker-bed is well exposed over long distances on a number of farms eg. Whitebank (I2) and Eldoret (H1). The jasper layers in the Main Marker differ from those in the overlying Jasper Substage in this respect that the bedding-planes of the former are strongly warped and give rise to irregular, uneven and undulose bedding-plane surfaces. In addition these apparently contorted layers of jasper contain numerous lenses or drawn-out, lenticular bodies of greyish-yellow chert set in a matrix of darker, yellow-brown, jaspery material. The lenticular bodies are generally arranged with their major axes at an angle to the direction of dip of the rocks and are flattened in the plane of the bedding.

Table 4. - The Stratigraphical distribution of the Marker-beds and their chief characteristics

| Marker-bed | Stratigraphical Position | Thickness | Rock-type | Characteristics |
|---|---|---|---|---|
| "Pot-skerf" or Potsherd Marker | 220 to 240 feet above Magnetite-Chert Marker | Nine inches to three feet | Chert and ferruginous chert | Disc-like fragments of white and grey chert are set in a matrix of ferruginous chert and orientated parallel to or at different angles to the bedding. The marker-beds is reminiscent of a tectonic breccia. |
| Magnetite-chert Marker | 50 to 60 feet above the Speckled Marker; 140 to 160 feet above the Main Marker | One to two feet | Thickly laminated banded ironstone | Laminae of magnetite (hematite-goethite in outcrop), up to half an inch thick alternate with laminae of white-grey chert of approximately same thickness. Crocidolite, silicified in outcrop, is associated with the marker-bed in many places. |
| Speckled Marker | 80 to 90 feet above Main Marker | Six inches to four feet | Poorly bedded to massive, chocolate coloured, jasper enclosing concretions of yellow-brown chert | Massive nature and colour of jasper and its conchoidal fracturing. Presence of concretionary structures of different colour. |
| Main Marker | Immediately above Banded Ironstone Substage | Average of 40 feet | Poorly bedded jasper and intercalations of well-bedded banded ironstone | Bedding-planes are strongly warped. Lenses and lenticular bodies of yellow-grey chert, reminiscent of "boudinage" are found in the yellow-brown jasper. Upper 16 to 24 inches composed of a zone of fragmental rocks very similar to the Potsherd Marker. |

The uppermost 16 to 24 inches of the Main Marker is characterised by a zone of fragmental rocks which consists of disc-like fragments composed of white to grey chert, set in a matrix of brownish, cherty material. The chert fragments look like flat discs with approximately oval or circular outlines when viewed perpendicular to the bedding-planes. The diameter of the discs varies from about two to five inches. The flat sides of these discs are generally orientated parallel to the stratification of the adjacent layers of jasper, but discs inclined at a low angle to the stratification and some perpendicular thereto are not uncommon. The width of these discs in cross-section varies from about a quarter inch to more than half an inch. (Plates I and II).

The zone of fragmental rocks belonging to the Main Marker becomes far more prominent towards the south in the area between Kuruman and Danielskuil and beyond where it attains thicknesses ranging from two to about five feet (Plate I).

Following immediately above the Main Marker in the Kuruman area is a zone of banded ironstone 15 to 30 feet thick, which in some localities is the host to seams of crocidolite and massive riebeckite. This banded ironstone zone is succeeded by layers of poorly bedded jasper displaying a yellow-brown to dark-brown colour and having smooth and shiny weathered surfaces. At about 60 to 70 feet above the Main Marker the jasper becomes more ferruginous over a short distance. Bedding in this portion is better developed and the rock attains the character of a banded ironstone.

(ii) The Speckled Marker

This marker-bed varies in thickness from about six inches to a maximum observed thickness of four feet. Despite its habit to attenuate quite rapidly over relatively short distances it remains persistent over the greater part of the Kuruman area. The rock constituting the band is composed of a matrix of dark-brown to chocolate-coloured, cherty material in which light-brown to yellow-brown concretionary structures are distributed at random. These concretionary or nodular bodies are referred to as "speckles" from which the name Speckled Marker is derived. The rock has a perfect conchoidal fracture and, except for the apparent absence of bedding-planes and the presence of the "speckles", it resembles the jasper found immediately below and above it.

The concretionary bodies or "speckles" are subangular to subrounded and display different forms in outcrop, varying from rectangular through oval to perfectly round. Generally the concretions are spherical, slightly flattened in the plane of the bedding, or ellipsoidal. Their sizes vary from less than a quarter inch to about three quarters of an inch in diameter (HH 359).

Two types of concretionary bodies have been observed. Some are composed of light-yellow, cherty material and apparently no other mineral constituents except in some specimens in which a number of minute specks of dark-brown to black, ferruginous material are present at irregular intervals. The majority, however, display a partial to well-defined concretionary structure. In the latter type (SectionHH 79) the outer edge of a "speckle" is defined by a very thin, dark-brown to black rim of closely spaced grains of hematite and goethite. In exceptional cases it is accompanied by lenticular, curvilinear streaks of magnetite. This rim of dark-coloured material generally accentuates the circular or oval outline of the concretionary structure. It is followed inwards by a layer composed of microcrystalline quartz as the matrix in which xenoblastic to poikiloblastic crystals of hematite and goethite are distributed at random. Occasionally these crystals, accompanied by irregular grains and minute granules of the same iron oxides, tend to form curved streaks approximately parallel to the outline of the outer ferruginous rim of the bodies.

The core of the bodies is usually darker in colour than the zones which immediately surround them owing to the concentration of iron oxide in the cores. Some of the ferruginous cores are remarkably angular and display square, rectangular and also triangular forms (Section HH 79). Others again are subrounded whereas in others the core may be split in two separate portions cemented by the same material which surrounds the complete core. Some of the cores are composed of alternating laminae of ferruginous and less ferruginous material, thus displaying a conspicuous banded structure. One particular core consists of a lamina of almost pure microcrystalline quartz, 0.8 mm thick, bounded on both sides by laminae 0.8 and 3.8 mm thick respectively, which are composed of microcrystalline quartz in which goethite is dispersed. This phenomenon of clearly banded portions surrounded by material displaying concentric growth would indicate that the cores of the concretions represent fragments of a laminated rock around which concretionary growth took place. In other concretions the bulk of the material in them is composed of massive riebeckite which is silicified to varying degrees along the outer edges.

It should be mentioned that several thin layers similar in appearance to the Speckled Marker are found in close proximity with this marker and generally below it. These layers are, however, much thinner and are as a rule far less persistent. The concretionary bodies in these layers are also less abundant so that portions of a particular layer may be devoid of any concretionary bodies over several yards. Another "speckled" layer of this type is present some 65 feet higher in the succession, but this layer is also only developed sporadically. A phenomenon which aids in the recognition of the true Speckled Marker is the presence of ferruginous, fairly well-bedded jasper, which grades into banded ironstone in places, closely below or above this marker. Crocidolite is developed at intervals along the ferruginous zone.

In the Kuruman area and farther north towards Heuningvlei the Speckled Marker serves as an excellent marker-bed, but it becomes less reliable to the south of Kuruman where several thin layers similar in appearance to the Speckled Marker are found at odd intervals in the jasper, none of them very persistent (eg. on Carrington, J2).

(iii) The Magnetite-chert Marker

Above the Speckled Marker yellow-brown to brown jasper continues for some 50 to 60 feet before the next layer which serves as a marker-bed is encountered. This marker-bed is locally referred to by prospectors as the "Quartzite" or "Sandstone Marker". Engelbrecht (1962), in a short paper on the marker-beds in the Kuruman area, coined the name Magnetite-chert Marker for this particular layer. Although the chert layers or laminae in this marker-bed strongly resemble medium-grained quartzite in surface-exposures they are actually composed of micro-crystalline quartz and are therefore of non-clastic origin. In the present paper therefore, the name Magnetite-chert Marker as proposed by Engelbrecht, will be retained.

The Marker-bed is strongly weather-resisting and in spite of its small thickness it outcrops prominently, frequently figuring as a low ledge.

Individual layers of chert are generally devoid of ferruginous material, but in places equigranular grains of magnetite are dispersed through the matrix of microcrystalline quartz. Where exposed these magnetite grains are generally altered to hematite and goethite and in many places are completely removed through weathering. In the latter case the surface of the chert layer is minutely pitted so that superficially it resembles a fine- to medium-grained quartzite. Where the disseminated grains of iron oxides are still present in the chert layers they display a finely spotted surface. Occurrences of this type are well preserved on England (I1) and at the Paradise Island prospect in the Lower Kuruman Native Reserve (G2).

(iv) Jasper with subordinate layers of massive riebeckite-rock

The Magnetite-chert Marker is succeeded by another thickness of yellow-brown jasper in which yellow-brown to reddish-brown layers of ferruginous and siliceous mudstone and shale become prominent. From closely below the Magnetite-chert Marker to about 220 to 240 feet above it the Jasper Substage is characterised by the frequent occurrence of thin, hard, blue layers of massive riebeckite. Their thickness ranges from a couple of inches to about one foot and they are characterised by a general dark-blue to brown colour in which isolated patches may display a deep blue colour. These riebeckite layers are composed chiefly of densely matted laths of riebeckite and are strongly weather-resistant. In the uppermost riebeckite layers crocidolite is sporadically developed as thin seams which generally fade out within a couple of inches along the direction of strike of these rocks. Irregular fractures in these layers are often filled with disorientated, acicular crystals of riebeckite or with slightly blue-coloured quartz. The cross-fibre which occupies the vertical and near-vertical fractures in the massive riebeckite layers looks like crocidolite superficially, but it is generally hard and brittle.

Certain layers of siliceous mudstone and shale in the succession in which the riebeckite layers are developed and also certain layers towards the top of the Jasper Substage contain concretions and septarian nodules of various shapes (Sp. HH 553-555). The concretions in these layers range in size from less than a quarter of an inch to more than six inches in diameter and are distributed at random in the layers. Their shape generally varies from subspherical to discoidal, but elongated bodies are also common (Plate III). Internally the concretions are concentrically banded, separate bands displaying different colours. In specimens collected from surface-exposures all the concentric bands in the concretions are almost exclusively composed of very minute grains of chert and accompanied by hematite (martite) and goethite. Large crystals of martite with irregular outline and commonly including remnants of magnetite are unequally distributed in the matrix of chert. The outer edges of the concretions form smooth surfaces which distinguish them sharply from the enclosing rock.

The concentric layers are traversed by a series of concentric and radiating cracks which are filled with yellow or slightly green quartz (von Backström, 1963).

At and closely below the upper limit of the jasper succession in which the septarian-bearing beds are found a series of closely-spaced massive riebeckite layers generally forms a conspicuous cliff. These layers are particularly well displayed on Ettrick (I1). The riebeckite layers are separated by layers of jasper which often display the same bedding-plane irregularities as the jasper layers in the Main Marker.

At the latter locality isolated lenses and lenticular bodies of massive riebeckite, measuring less than a foot along their major axes, are embedded in the jasper layers. These riebeckite lenses are often present as nodular, pear-shaped bodies which may be rounded along the one edge whereas the other point tapers out gradually along the plane of stratification. The bedding in the enclosing jasper commonly conforms to the shape of the massive riebeckite bodies. The banding below a body remains fairly straight whereas that above curves down and comes to rest upon the lower bedding-plane away from the tapering end of the body. The vertical dimensions of a particular pear-shaped massive riebeckite body may range from about four inches from the one end to about half an inch at the tapering end (Plate IV).
The asymmetrical form of the massive riebeckite bodies and the general conformity between their outer edges and the banding in the jasper would suggest that the lumps of amphibolitic material represent fragments of material which at one stage or another came to rest

like fragments or discs set in a matrix of dark-grey to brown, ferruginous chert or jasper. When viewed perpendicular to the plane of bedding the fragments are present as subangular to subrounded discs. The discs vary from less than one inch to about four inches in length and are seldom more than half an inch thick. In cross-section the fragments are commonly oriented parallel to or at a low angle to the stratification. In some places individual fragments or a group of adjacent fragments adopt a position at right angles or nearly so to the bedding. Where three or four closely separated fragments attain a near-vertical position the general tendency for them is to fan out on one side thus forming a pattern similar to a fowl's track. Because of the presence of such patterns some prospectors refer to this band as the "Hanepoot" Marker (Eng. "crow's-foot Marker").

The edges of many of the fragments are slightly rounded, but the majority are angular to subangular and tapered. Longer ones are frequently bent so that one portion of the shard lies parallel to the stratification whereas the rest of the body lies at an angle to the stratification. In other exposures again a fragment may have both ends bent up like the rim of a saucer. (Plate V).

On weathered surfaces the fragments almost invariably display a white-grey colour which forms a strong contrast with the brown, ferruginous ground-mass. The cementing material is always more ferruginous than the fragments themselves. On the whole this rock-type corresponds very much with the thin zone of fragmental rock which constitutes the upper portion of the Main Marker.

The layers of fragmental rocks which are found in the succession above the Potsherd Marker are similar in appearance to this marker-bed, except perhaps that the thickness of individual fragments in the upper beds is greater. In areas where only three such layers were observed only the uppermost one contains fragments of red-coloured jasper.

Above the Potsherd Marker prominent layers of siliceous mudstone and shale (HH 355) are present, individual beds varying in width from a few feet to more than 30 feet. All these rocks are ferruginous and silicified. Snuff-box structures are common in many of these layers, and carbonate enters into the composition of the uppermost layers.

(vi) The Origin of the Marker-beds

The Main Marker in the Kuruman Area, as pointed out on p. 37, contains fragmental material at its top. This zone becomes more conspicuous towards Danielskuil where, south of the village, two other zones are developed lower down. The zones are very similar to the Potsherd Marker and most probably have the same mode of origin. For this reason the origin of both these marker-beds will be discussed simultaneously.

The zone of fragmental material at the top of the Main Marker is remarkably persistant, displays some degree of sorting in places (p. 78) and apparently retains the same stratigraphical position. These characteristics would imply that it may represent an intraformational breccia. The Potsherd Marker is less persistent and in some localities is found to occupy different stratigraphical positions. However, the difference in stratigraphical height is seldom more than a few feet.

In both marker-beds the disc-like fragments are composed of almost pure chert whereas the cementing material is conspicuously ferruginous. Should these zones of fragmental material be regarded as of tectonic origin it would be difficult to explain why the fragments and the cementing material are so different in composition.

It is suggested that the fragmental material originated during periods when the floor or portions of the floor of the depositional basin were exposed. Structures similar to mud-cracks developed and with subsequent burial the fragments were cemented by more ferruginous chert. Slight currents could have contributed to the disorientation of the disc-like fragments. It is possible that some discs were transported over very short distances causing some degree of rounding.

The Speckled Marker contains concretions, some of which have cores that are clearly laminated. This would indicate that concretionary growth took place around solid particles (p. 39). In other concretions or "speckles" the cores are composed of massive riebeckite or silicified massive riebeckite. Pear-shaped bodies of massive riebeckite are also found in certain beds above the Speckled Marker (p. 42). The relation between the boundaries of such bodies and the bedding of the enveloping jasper would indicate that the riebeckite is of extraneous origin.

It is suggested that many of the "speckles" in the speckled marker originated through concretionary growth around clots of volcanic ash which sunk to the floor of deposition. Riebeckite developed from the volcanic material. Many cores of riebeckite were subsequently silicified to such a degree that the original material can no longer be distinguished.

The magnetite-chert marker differs from the banded ironstone only in the thickness of the individual magnetite and chert laminae and therefore is regarded as having had an origin similar to that of the banded ironstone, viz. through the intermittent precipitation of iron hydroxides and silica.

(c) The Tillite Substage

The Jasper Substage is succeeded by the Tillite Substage which, according to the currently accepted correlation, represents the upper limit of the Lower Griquatown Stage. The tillite again is succeeded by andesitic lava of the Middle Griquatown or Ongeluk Stage.

This Substage attains a thickness of some 50 to 80 feet and is composed of a heterogeneous and unsorted assemblage of angular fragments and subrounded to well-rounded cobbles, cemented by medium-grained, reddish- to purple-brown, gritty material. Weathered surfaces of the rock commonly display dark-brown to black colours caused by encrustations of oxides of iron and manganese. Pebbles and fragments composed of yellow-brown jasper predominate and have evidently been derived from the immediately underlying Jasper Substage. Pebbles of quartz, quartzite, dolomite, shale and red jasper are found occasionally, whereas pebbles of black and grey chert, probably derived from the Dolomite Series, are fairly frequent. In places the tillite displays some degree of sorting, shown by a decrease in the sizes of the fragments and pebbles from the bottom towards the top of the substage. In such places pebbles and fragments in the basal portion of the tillite vary in size from half an inch to about five inches in diameter and decrease towards the top where they are much smaller on the average. Purple-brown sandstone and grey, feldspathic, gritty layers are present as discontinuous intercalations towards the top of the tillite.

Conglomerate has been recorded in the tillite where it outcrops on the border between the farms Hope and Ventersrus (F2) some 40 miles north-west of Kuruman (De Villiers, 1961, p. 6). The pebbles in this conglomerate band are described as poorly to well rounded and slightly flattened. They are mainly composed of greyish-green and black chert and are found together with smaller pebbles of red jasper and white quartzite. The majority of the pebbles vary in diameter from a quarter inch to four inches. They are poorly sorted and are cemented by grey to light-brown, sandy and felspathic material. In the area where the conglomerate is present the tillite attains a thickness of about 110 feet. In the Kuruman area the tillite is exposed at a few places only and although well-rounded pebbles are encountered in these outcrops no definite band of conglomerate could be distinguished.

### (d) The Vertical Distribution of the Crocidolite-bearing Zones

As mentioned in previous pages, crocidolite occurrences in the Lower Griquatown Stage are restricted to certain stratigraphical horizons. Because of large-scale mining and drilling in the Kuruman area the vertical position of the crocidolite-bearing zones has been established quite well. Additional information with regard to the vertical distribution of these zones was also obtained from geological mapping and from bore-hole results with the result that the present knowledge of the distribution of the most important crocidolite-bearing zones is fairly complete. Except for the main stratigraphical zones in which commercial deposits of crocidolite are known to occur, occasional seams or groups of seams may be developed at elevations in between the main zones. Occurrences of this type are, however, seldom found and so far have not yielded concentrations of crocidolite of any economic importance. Because the vertical distribution of the crocidolite-bearing zones are, best defined in the Kuruman area, their distribution in this area will be used for the correlation, where possible, of the distribution of similar zones in other areas located in the Northern Region.

In the Kuruman area the asbestos-bearing rocks can be subdivided into about eleven separate zones. Four of them lie within the Jasper Substage and are of no great economic importance. The remainder are found in the Banded Ironstone Substage and include several important crocidolite-producing zones.

In the Kuruman area it is customary to divide the crocidolite-bearing zones into an upper group and a lower group with the Main Marker as the line of subdivision. These zones are locally referred to as "horizons" and those occurring above the Main Marker are called the Upper Asbestos "Horizons". They are again subdivided into a First Upper "Horizon", Second Upper "Horizon", etc. based on the relative vertical distances at which each is found above the top of the Main Marker.

The same subdivision is applied to the crocidolite-bearing zones below the Main Marker, except that their positions are given in relation to the vertical distance between them and the base of the Main Marker. These Lower Asbestos "Horizons" are accordingly subdivided into a First Lower "Horizon", Second Lower "Horizon", etc.

The term "horizon" as used in geological nomenclature, refers to a surface separating two beds and hence has no thickness (Howell, 1957). This term can therefore not be retained in the description of the asbestos-bearing zones in the Kuruman area and is accordingly replaced by the term "zone" in the text. For purposes of brevity the upper zones will often be referred to as the First Upper or Second Upper without adding the word "zone". The same applies to the lower zones which will be referred to as the First Lower, Second Lower, etc. The subdivision of the various asbestos-bearing zones is given in Table 5.

Table 5. - Subdivision of Asbestos-bearing Zones in the Kuruman Area

| | |
|---|---|
| Upper Asbestos Zones | Fourth Upper Zone<br>Third Upper Zone<br>Second Upper Zone<br>First Upper Zone |
| | MAIN MARKER |
| Lower Asbestos Zones | First Lower Zone<br>Second Lower Zone<br>Third Lower Zone<br>Fourth Lower Zone<br>Fifth Lower Zone<br>Sixth Lower Zone<br>Seventh Lower Zone |

(i) The Lower Asbestos Zones

These crocidolite-bearing zones constitute the sole source of crocidolite in the Kuruman area as well as in almost the entire Northern Region. Their subdivision into First, Second, Third, etc. Lower Zones in the Kuruman area became a custom in all operating mines in the area, but their subdivision from mine to mine is not very consistent. This is mainly because there exists quite a variation in the width of, and in the number of individual fibre-bearing layers of banded ironstone which may constitute one zone. Because of this variation and the frequently complete absence of crocidolite at

... the Main Marker, the same

more so-called "horizons" in different mines, a usage which has greatly hampered the correlation of crocidolite-bearing zones from mine to mine.

If the accompanying figure 2 is consulted the reader will see that the subdivision into separate asbestos-bearing zones can be done in quite a number of ways. Where crocidolite-bearing layers of banded ironstone are vertically close to one another the writer has regarded them as belonging to the same zone or where continuous fibre-bearing layers of banded ironstone at one locality coincide in vertical position with a number of separate layers at another centre, the separate groups of fibre-bearing strata, although in places separated by fairly thick partings of waste, are collectively also regarded as belonging to the same zone. Many of the current sub-divisions in the mines will naturally not coincide with the subdivision into separate zones as used in this paper, but with the information available at present the regional subdivision of crocidolite zones in the Kuruman area as given here is, with the present knowledge, regarded as the most logical.

## First Lower Zone

This zone is present immediately below and in places partly within the lowermost portion of the Main Marker. In the Kuruman area this zone is well developed in the Asbes and the Whitebank Asbestos Mine, but at the latter mine it is found at a shallow depth below surface, within the oxidized zone, and is therefore of no economic importance, at least not within the first 200 feet below the surface. At this mine the First Lower reaches a thickness of some 45 feet, a large portion of which is located within the lower portion of the Main Marker.

At Asbes Mine the First Lower attains a thickness of some 35 feet, some of the crocidolite seams also being located within the Main Marker. Here the crocidolite-bearing strata are found below the zone of oxidation and are mined. Except for the localities mentioned above, the First Lower is usually poorly developed in the Kuruman area, but fairly persistent although often represented by only a few very thin seams or a group of crocidolite seams which are found at irregular intervals below the Main Marker.

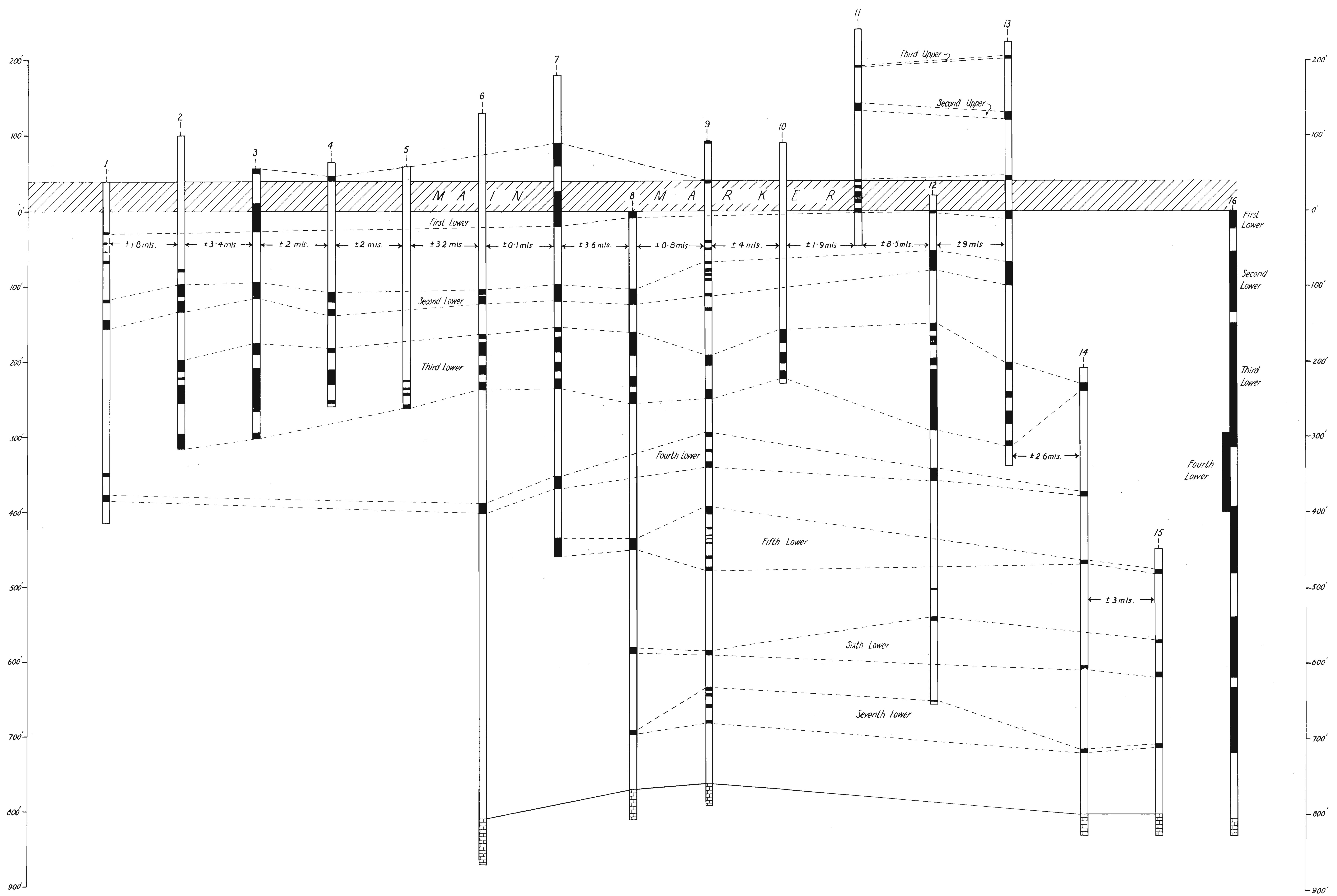


FIGURE 2 THE VERTICAL DISTRIBUTION OF CROCIDOLITE-BEARING INTERSECTIONS WITH REFERENCE TO THE MAIN MARKER, KURUMAN AREA

LEGEND

Mineralised intersections

Banded ironstone or jasper

Dolomite

1 .... Bore-hole on Fairhall ($I_2$)
2 .... Combined results from bore-holes on Hartland ($I_2$)
3 .... Shaft of Asbes Mine on Asbes ($I_2$)
4 + 5 .... Bore-hole on Lombley ($I_2$)
6 .... Bore-hole on Whitebank ($I_2$)
7 .... Shaft of Whitebank Mine and bore-hole results
8 .... Surveyed profile on Whitebank
9 .... Surveyed profile on Whitebank (after Engelbrecht, 1965)
10 .... Shaft of Depression Mine
11 .... Shaft of Ettrick Mine
12 .... Bore-hole on Riries ($I_1$)
13 .... Bore-hole and survey data on Eldoret and Koretsi ($H_1$)
14 .... Surveyed profile in Native Trust North-east of Riries (after Drewes 1963)
15 .... Surveyed profile in Native Trust North-east of Orcadia (after Drewes 1963)
16 .... Generalised columnar section of the distribution of crocidolite-bearing zones