I. Introduction

The history of crocidolite in South-Africa dates back to the years between 1803 and 1806 when a German geologist, H. Lichtenstein, on an expedition into the Orange River valley, came across an exposure of asbestos near Prieska. The lavender-blue colour of the mineral contributed to its first name viz. "Blau-Eisenstein" (Sinclair, 1955). Several years later, in 1831, the mineral was re-examined by Stromeyer and Hausmann, who proposed the name crocidolite, the name by which the mineral is still known today (Sinclair, 1955). Crocidolite is named from the Greek word κροκίς (nap or pile of cloth, generally: "a piece of wool").

Actual mining of crocidolite in the Cape Province commenced in 1893 when the Cape Asbestos Company, which to date still operates in the area, acquired surface- and mineral rights on a portion of land at Koegas in the Prieska District. In those early days of crocidolite-mining the mineral was chiefly recovered by Coloured inhabitants of the present Hay and Prieska Districts. The Coloureds, working in independent groups on a contract basis, sold the asbestos recovered by them to the Cape Asbestos Company. The mining methods applied at that time were rather primitive and embraced the exploitation of numerous small, isolated surface-exposures of non-oxidised fibre by pick and shovel. Individual deposits were mined to a limited depth only and the material recovered was hand-cobbed to separate the fibre adhering to the banded ironstone host-rock. The "cobs" were then sold to the Company.

The contributors who were responsible for their own discoveries of new exposures of crocidolite travelled far and wide in their hunt for new and more promising deposits. They finally traced crocidolite exposures from Koegas southwards to beyond Prieska and also to the north towards Griquatown and Kuruman, many miles from the original point of discovery. Evidence of their extensive wanderings and prospecting activities is revealed by the numerous shallow pits and excavations which today are found along almost the entire range of the Asbestos Mountains.

As time passed the increasing demand for asbestos fibre called for the gradual improvement of mining methods, ore treatment and the discovery of large, individual asbestos deposits. Shafts were sunk and underground mining for asbestos commenced on a systematic basis. Underground prospecting was carried out exclusively by development along a particular asbestos-bearing reef * and the stoping out of the entire fibre-bearing zone followed as development progressed. Because the fibre is commonly found in localised pockets the miners often ran into barren or unpayable ground, on which occasion prospecting drives were put in in different directions in the hope of locating another payable pocket. This manner of prospecting often led to a profusion of tunnels running in every conceivable direction and the large number of apparently unnecessary drives which are found today in many of the older mines bears testimony to the general unpredictable behaviour of crocidolite deposits. With the later incorporation of surface-drilling, firstly by means of jump-drills and lately by air-drills as well as diamond-drills, crocidolite deposits could be delimited and mining lay-outs could be planned before actual mining commenced.

Today several large mining companies operate in the entire area in which crocidolite is known to occur. Amongst the companies are the Cape Blue Mines (Pty.) Ltd., the pioneer company in the blue asbestos field, the Griqualand Exploration and Finance Company Ltd., the Kuruman Cape Blue Asbestos (Pty.) Ltd., Wandrag Asbestos (Pty.) Ltd., Danielskuil Asbestos Company Ltd., Dublin Consolidated Asbestos Mines (Pty.) Ltd., and the Glen Allen Asbestos Ltd. Lately a new group in the crocidolite field, Merencor Asbestos Mines Ltd., investigated an extensive area some thirty miles north of Kuruman and opened up several promising deposits of crocidolite. Apart from these bigger mining concerns there are also a number of smaller syndicates operating in this field, most of whom are contributors to one of the larger companies.

Techniques for the location of new crocidolite deposits have rapidly improved during the last decade. Where formerly outcrops of crocidolite were virtually regarded as the sole indication of possible fibre deposits at greater depths, attention is at present also focussed on certain geological structures which are associated with crocidolite deposits. The continuation of seams of crocidolite to great depths, not so long ago regarded as quite improbable, has been proved by drilling and deep-level mining at a number of localities.

Because of the diversity of present theories regarding

---

*The mineral occurs interbedded in banded ironstone and a single interbedded layer of asbestos is generally referred to as a <u>seam</u> or less often as a <u>band</u> of fibre. A group of closely spaced fibre seams that can be mined together as a unit is referred to as a <u>reef</u> whereas a group of reefs occurring close to one another, but separated by barren rock of varying thickness, is referred to as a <u>zone</u>.

the origin of asbestos and the differences of opinion as to whether the crocidolite deposits are associated with certain geological structures or not, the writer commenced an investigation of the crocidolite deposits in the Northern Cape Province in May 1963.

The purpose of the study was to throw more light on the mode of occurrence of crocidolite, the origin of the asbestos, the structural associations, if any, the mineralogy of the host-rock and the estimation of ore-reserves where possible.

The present investigation included the study of individual crocidolite deposits in the majority of asbestos mines which are being operated today in the entire Northern Cape Asbestos Field.

To fulfil this purpose detailed underground mapping was carried out in two of the operating mines in the Kuruman area, viz. the Depression (I2) and Eldoret (H1) asbestos Mines. Owing to the restricted underground development in the then new mine on Eldoret the complete structure with which the asbestos deposit is associated could not be unravelled. Attention was also given to the Warrendale Mine located on Botha (M2) and the Glen Allen Mine (R3) near Prieska. Available detailed underground plans of these two mines and a detailed assay-plan of the old portion of the Warrendale Mine helped considerably to demonstrate the relations between geological structures and economic deposits of asbestos. In addition to the work carried out at the mines mentioned above, additional underground observations were also made at the following asbestos mines in the Cape Province: Pomfret no. 2 Mine (B4), Bute Mine (C2), Koretsi South Mine (H1), Riries Mine (I1), England Mine (I1), White Rock Mine (I1), Whitebank Mine (I2), Owendale no. 2 Mine (M2), Groenwater Mine (M2), Black Ridge Mine (O3) and the Westerberg Mine (Q2).

Other mines which were not in operation during the course of the investigation or which had been worked out in the past were also visited and supplied valuable information. They include the Cairn Brae Mine (S4), Nauga Mine (R2), Buisvlei Mine (R3), Orange View Mine (Q3), Geduld Mine (R3), Erfrus Mine (Q3), Kameelfontein Mine (Q3), Klein Naauwte Mine (Q3) and the Stofbakkies Mine (R3), all of which are located in the Southern Region.

The investigation further included the study of the rock types constituting the different substages of the Lower Griquatown Stage in the field. Special attention was given to the rocks of the Banded Ironstone Substage, which is the host-rock of all the economic deposits of crocidolite exploited in this field.

Prior to this investigation various members of the Geological Survey had carried out detailed regional mapping in large portions of the area in which the Lower Griquatown Beds are exposed. Geological maps of these areas were available during the present study and expedited the investigation. Bore-hole results and drill-cores were obtained from several of the asbestos companies operating at present and provided valuable information with regard to the vertical distribution of asbestos-bearing zones in the Banded Ironstone Substage as well as the distribution of mineralogically different facies of the banded ironstone.

For the regional study of the different rock-types constituting the Lower Griquatown Stage it was necessary to do reconnaissance work in those areas which had not been remapped by the writer himself. Some of the areas where only reconnaissance work was done were recently remapped by members of the Geological Survey and by Mr. P.D. Fockema, geologist of Griqualand Exploration and Finance Company Ltd. and include most of the stretch of country between Danielskuil and Pomfret and around Koegas. The writer carried out regional geological mapping in the Danielskuil area, in the area immediately north of Griquatown and in the area between Griquatown and Prieska; a total of more than 1,000 square miles was mapped. Special attention was given to the areal distribution of marker-beds and the asbestos-bearing zones. Detailed measurements of the width and the vertical distribution of the asbestos-bearing zones were carried out at several localities whereas in others the vertical distribution was computed from bore-hole results obtained from private companies.

The study further included a mineralogical investigation of many specimens of the banded ironstone and the associated crocidolite. Microscopical, X-ray and differential thermal studies were carried out on the specimens.

A. Location and Extent of the Area

Crocidolite in the Cape Province is associated with the sediments of the Lower Griquatown Stage of the Pretoria Series, Transvaal System, in which the mineral is found as interbedded, conformable cross-fibre seams at different stratigraphical horizons. Being confined to the lowermost stage of the Pretoria Series in the Cape Province, economic deposits of crocidolite are found sporadically over the entire area covered by these rocks, the areal distribution of which is shown on the accompanying map (Folder 1).

The area in which the crocidolite-bearing rocks are found is bounded on the west and the east by longitudes 22° 15' east and 24° 15' east, respectively and on the north and the south by latitude 25° 40' south and 30° 00' south, respectively. This area embraces parts of the Divisions of Prieska, Hay, Postmasburg, Kuruman and Vryburg and measures some 300 miles in a north-south direction, commencing some 20 miles south of the township of Prieska and extending northward towards the border between the Republic and Botswana about 130 miles north of Kuruman (Folder 1). The stretch of land covered by the Lower Griquatown Beds reaches its maximum east-west dimension between Niekerkshoop and Griquatown in the southern region where it measures some 50 miles across (Folder 1).

The crocidolite-bearing formation is exposed as an almost continuous belt of hilly ranges from south to north. Outcrops of the rocks are excellently exposed in the southern portion of the belt, but from about 55 miles north of Kuruman towards the northern extremity of the area extensive portions of the Belt are covered with recent, wind-blown Kalahari sand.

In the Prieska area the most southerly outcrops of the crocidolite-bearing strata are exposed on Doorn-Berg Fontein (S4), located some 23 miles south-south- east of the village of Prieska. From this point the belt trends north-north-west to beyond Wester berg (Q2) which is located on the southern bank of the Orange River. The outcrops of siliceous and ferruginous rocks form a conspicuous range of hills known as the Doringberg Range. Crossing the Orange River towards the north and the east the belt continues northward as a series of hills trending north-south and is known as the Asbestos Mountains in the Hay District, i.e. south and north of the village of Griquatown, and as the Kuruman Hills in the vicinity of the village of Kuruman.

The Asbestos Mountains and the Kuruman Hills represent the eastern flank of a series of shallow, doubly plunging synclines separated by gentle anticlinal arches. The axes of these structures strike approximately parallel to the trend of the range of hills. Andesitic lava of the overlying Middle Griquatown Stage is preserved in the troughs of the major synclines whereas the underlying

Dolomite Series is exposed at a number of places on the eroded crests of the gentle arches.

Owing to repeated synclinal and anticlinal folding, combined with the distribution of the overlying andesitic lava, the belt of Lower Griquatown rocks extends northwards from a point west of Griquatown, as two separate branches of variable length and breadth. The westerly branch which represents the western flank of the Ongeluk-Witwater syncline extends northward to a point about 22 miles south-west of Postmasburg (Folder 1). The northern extension of this branch is exposed in the immediate vicinity and to the east of Postmasburg from where it continues northward to merge with the eastern belt some 16 miles north-east of this town. Not far north of this point the range of hills again separates into two branches, the western branch representing the western flank of the Dimoten syncline.

The eastern branch forms a continuous belt of high ground from south of Griquatown to about 50 miles north of Kuruman where the topography flattens out and the rocks of the Lower Griquatown Stage are covered over large stretches with wind-blown sand. Farther north in the environment of Heuningvlei and again in the vicinity of Pomfret the sediments of the Lower Griquatown Stage build a series of low hills which rises as a distinct feature above the surrounding featureless, sand-covered plateau. East-north-east of Pomfret outcrops of these sediments are sporadically encountered until the border of Botswana is reached.

Deposits of crocidolite asbestos of economic importance are found at several centres throughout the entire area occupied by the rocks of the Lower Griquatown Stage. The best known and so far the most promising deposits are located in the area north and south of Prieska, including the Westerberg, Koegas, Glen Allen and Cairn Brae mines, south of Danielskuil, between Danielskuil and Kuruman, immediately west and north of Kuruman, the area around Heuningvlei and the Pomfret area which is the locality situated farthest north, where crocidolite asbestos is being mined.

Owing to the recent fluctuations in the market price of crocidolite and partly as a result of insufficient reserves of asbestos or the low grade of the available material, several small crocidolite mines in the Northern Cape Asbestos Field were closed down during the past two to three years. Because of this the number of operating mines in the Prieska area is limited to three only, viz. the Westerberg (Q2), Koegas (Q2) and Glen Allen Mines (R3) (Folder 1).

Until about a year ago mining of crocidolite in the Griquatown area was in progress at the Blackridge mine (O3) located some 38 miles west of Griquatown. Mining operations at this centre have ceased since, with the result that no operating mines are located at present in the Griquatown area.

In the area immediately south and west of Danielskuil and north-east of Postmasburg some five asbestos mines are at present in operation. These mines are located on the farms Ouplaas (L2), Owendale (M2) and in the old Groenwater Native Reserve (M2) near Postmasburg. The Warrendale mine situated on the farm Botha (M2), about 14 miles south-south-west of Danielskuil has closed down recently.

Mining activities for crocidolite asbestos in the area between Danielskuil and Kuruman are at present concentrated on the farms Greyling (Ptn. of Bolham, K2), Bretby (K2), Strelly (J2) and Bestwell (Ptn. of Bestwood, J1). The latter farm is situated on the western limb of the Dimoten syncline whereas all the others are located on the eastern belt of the Lower Griquatown Beds.

The Kuruman area which stretches from about 7 miles south-west of the town to some 30 miles north-west thereof includes several operating mines and is today probably the biggest crocidolite-producing area in the Cape Province. Well established asbestos mines are located on the farms Asbes (I2), Whitebank (I2), Depression (I2), Riries (I1), Mt. Vera (I1), England (I1), Eldoret (H1) and Koretsi (H1), the latter farm being located within the Lower Kuruman Native Reserve. A shaft has recently been sunk on the farm Ettrick (I1) to start with the development of an apparently promising new mine.

On the farm Amy's Hope (F1) located not far north of Tsineng (G2) payable deposits of crocidolite fibre have been proved by drilling and mining on one portion of this farm is already in progress. Between this point and the next, at the Bute Asbestos Mine (C2), located in the Heuningvlei area farther north, no operating asbestos mines exist today. The Bute Asbestos Mine is the only operating mine in the Heuningvlei area.

The crocidolite asbestos mine located farthest north in the Northern Cape Province is the Pomfret Asbestos Mine (B4) situated on the farm bearing the same name. Crocidolite has also been mined on the farm Constable (B3) in the vicinity of the Pomfret Mine and future exploration could well prove payable crocidolite deposits in the environment.

Except for those centres where crocidolite mines exist today, mining of and prospecting for this mineral during the past were carried out at a large number of localities in the Northern Cape Province. To indicate the wide distribution of crocidolite in the Lower Griquatown Beds a list of crocidolite-bearing localities has been compiled from available sources of information and the farm names are given in Table 1. The inclusion of a particular locality in the list does not necessarily imply that crocidolite is found in economic quantities at that locality.

Table 1. - Crocidolite-bearing localities in the Northern Cape Province

District	Locality	Remarks
Prieska	Asbestos Reefs Ptn. of Keikams Poort Pr Q 2-2	13 miles SSE of Prieska
	Brakpoort Annexe Ptn. of Brakpoort O.363	6 miles N. of Prieska
	Buis Vlei V.W. Q 9 - 19	10 miles NW of Prieska
	Enkeldewilgeboomfontein O.347	10 miles NNW of Prieska
	Geduld, Ptn. Middelwater Pr Q 1 - 34	14 miles NW of Prieska
	Geelbeksdam Ptn. Rietfontein V.W. Q 8 - 15	14 miles E of Marydale
	Glen Allen Ptn. Buis Vlei V.W. Q 9 - 19	10 miles WNW of Prieska
	Kalkfontein Pr. Q 3 - 11 (Nauga Mine)	14 miles NW of Prieska
	Keikams Poort Pr. Q 2 - 2 (Cairn Brae Mine)	14 miles SSE of Prieska
	Kliphuis O. 359	6 miles N of Prieska
	Kransfontein O. 358	8 miles NNE of Prieska
	Lovedale Ptn. Prieska Poort V.W. Q 6 - 1	18 miles SE of Prieska
	Middelwater Pr. Q 1 - 34	20 miles NW of Prieska
	Naauwgekneld V.W. Q 6 - 9	8 miles NW of Prieska
	Nauga V.W. Q 6 - 3	22 miles NW of Prieska

District	Locality	Remarks
Prieska	Orange View Ptn. Buis Vlei V.W. Q 9 - 19	16 miles NNW of Prieska
	Prieska Poort V.W. Q 6 - 1	7 miles WSW of Prieska
	Prieska Town Lands Pr. F. 1 - 9	
	Redlands Ptn. Keikams Poort Pr. Q 2 - 2	20 miles SSE of Prieska
	Riverside Prieska Town Commonage Pr. F 1 - 9	5 miles W of Prieska
	Rooidam Ptn. Karabee Pr. Q 1 - 6	7 miles SSE of Prieska
	Stofbakkies O. 360	3 miles N of Prieska
	Westerberg Ptn. Rietfontein V.W. Q 8 - 15	14 miles ENE of Marydale
	Wilgebooms Dam O. 348	12 miles N of Prieska
	Zaragabie Prieska Town Commonage Pr. F 1 - 9	4 miles W of Prieska
Hay	Avondrust O 10	8 miles SW of Griquatown
	Blaauwboschkuil 380	12 miles NE of Niekerkshoop
	Blaauwboschpoort 349	9 miles SSW of Niekerkshoop
	Blaauwputs 340	11 miles SW of Niekerkshoop
	Blackridge 193	38 miles W of Griquatown
	Breckenridge 192	38 miles W of Griquatown
	Bultfontein 327	8 miles SE of Koegas
	Consolidated Farm 210	36 miles WNW of Griquatown
	Doradale 9	6 miles SW of Griquatown
	Durandt se Pan 55	4 miles NNW of Griquatown
	Duitseput 53	10 miles NNW of Griquatown
	Elandsfontein 395	17 miles SSW of Griquatown
	Griquatown Town Lands	
	Groot Doorn	9 miles SSW of Griquatown
	Groot Naauwte 339	5 miles SW of Niekerkshoop
	Hopefield Estate O 551 and O 552	16 miles N of Griquatown
	Hounslow 323	2 miles NW of Koegas
	Kafir Krans 379	8 miles NE of Niekerkshoop

District	Locality	Remarks
Hay	Kameelfontein 338	13 miles SW of Niekerkshoop
	Kameelpoort 368	5 miles SE of Niekerkshoop
	Klein Naauwte 346	15 miles SW of Niekerkshoop
	Klipfontein 381	12 miles NE of Niekerkshoop
	Klipnek 132	13 miles NE of Niekerkshoop
	Koegas 324	30 miles W of Niekerkshoop
	Krans Hoek 396	14 miles SW of Griquatown
	Kwakwas 318	5 miles NE of Koegas
	Leelykstaat 320	7 miles NW of Koegas
	Leeuwvlei 553	21 miles NNE of Griquatown
	Lockshoek 567	13 miles NNW of Griquatown
	Martlow 13	12 miles SSW of Griquatown
	Merwehoop (ptn. of Middelplaats 6)	7 miles W of Griquatown
	Naauwpoort 144	8 miles NE of Niekerkshoop
	Pannetjie (ptn. of Naauwhoek 5)	3 miles W of Griquatown
	Pypwater 321	5 miles NNW of Koegas
	Rooisand 345	11 miles SSW of Niekerkshoop
	Sandfontein 356	7 miles S of Niekerkshoop
	Spioenkop 383	15 miles ENE of Niekerkshoop
	Stilverlaat 315	12 miles N of Koegas
	Kloof 148	7 miles NE of Niekerkshoop
	Vaalkop	12 miles SSW of Niekerkshoop
	Zeekoeneus 357	10 miles S of Niekerkshoop
Postmasburg	Barker Ptn. Carter Block 458	8 miles SW of Danielskuil
	Billinghurst Ku Q 4 - 24	20 miles NW of Danielskuil
	Botha Ptn. Carter Block 458 (Warrendale Mine)	12 miles SSW of Danielskuil
	Brits Ptn. Carter Block 458	15 miles SSW of Danielskuil
	Crawley Ku Q 9 - 1	20 miles NW of Danielskuil
	Danielskuil Town Lands	
	Derbi 196	13 miles N of Danielskuil
	Doornfontein 307	21 miles NE of Postmasburg
	Doornvlei 305	6 miles W of Danielskuil
	Dunrovin 260	6 miles NNW of Danielskuil
	Farm 492	4 miles SE of Postmasburg

District	Locality	Remarks
Postmas-burg	Farm 308	17 miles WNW of Danielskuil
	Farm 251	7 miles N of Danielskuil
	Garingkloof (Ptn. of Skietfontein 252)	6 miles NNW of Danielskuil
	Grasmere	20 miles NW of Danielskuil
	Groenwater 453	14 miles NE of Postmasburg
	Jacobsfontein 501	18 miles SSW of Danielskuil
	Klipvlei 456	9 miles WNW of Danielskuil
	Ouplaas 304 (Ou-plaas Mine)	5 miles SW of Danielskuil
	Owendale Ptn. Carter Block 458 (Owendale Mine)	9 miles SW of Danielskuil
	Rietfontein 309	18 miles WNW of Danielskuil
	Rooipoort 473	8 miles E of Postmasburg
	Warrendale Ptn. Carter Block 458	11 miles SSW of Danielskuil
Kuruman	Amyshope (Amyshope Mine)	16 miles NNW of Tsineng
	Asbes Gr. 4/1937 (Asbes Mine)	8 miles W of Kuruman
	Bestwell Mine (Gathlose Native Reserve)	25 miles SW of Kuruman
	Bestwood Ku Q 4 - 14	25 miles WSW of Kuruman
	Boxmoor Ku Q 5 - 1	9 miles WSW of Kuruman
	Bosrand, Ptn. Newstead Ku Q 4 - 29	18 miles SSW of Kuruman
	Bretby Ku Q 3 - 22 (Bretby Mine)	26 miles S of Kuruman
	Carrington Ku Q 10 - 4	8 miles SW of Kuruman
	Cubbie Ku Co 5 - 35	16 miles SSE of Kuruman
	Eldoret B 1335/1914 (Eldoret Mine)	24 miles NW of Kuruman
	Elgon Gr. 7/1927	12 miles WNW of Kuruman
	England B 1334/1914 (England Mine)	24 miles NW of Kuruman
	Ettrick Ku Q 8 - 6 (Ettrick Mine)	12 miles W of Kuruman
	Exit Gr 8/1927 (Depression Mine)	11 miles WNW of Kuruman
	Fairholt Ku Q 4 - 8	8 miles W of Kuruman
	Gamohaan Gr. 9/1924	8 miles NW of Kuruman

District	Locality	Remarks
Kuruman	Gamolilo Ku F 4 - 1	9 miles N of Tsineng
	Greyling Ptn. Bolham Ku Q 8 - 25	31 miles S of Kuruman
	Happy Valley, Ptn. Cubbie Ku CO 5 - 35	23 miles S of Kuruman
	Horeb 4774/1926	11 miles N of Tsineng
	Hurley Ku Q 6 - 15	28 miles S of Kuruman
	Koretsi Lower Kuruman Native Reserve (Koretsi South Mine)	27 miles NW of Kuruman
	Lambley Ku Q 6 - 6	6 miles W of Kuruman
	Langley Ku Q 9 - 25	10 miles SSW of Kuruman
	Lower Kuruman Native Reserve	12 to 33 miles NW of Kuruman
	Mansfield Ku Q 6 - 21	16 miles S of Kuruman
	March 4648/1948	16 miles N of Tsineng
	Mt Roper Gr. 1/1925	14 miles WNW of Kuruman
	Mt Vera Gr. 15/1923	18 miles NW of Kuruman
	New Castle Ku Q 7 - 25	19 miles SSW of Kuruman
	Newstead Ku Q 4 - 29	16 miles SSW of Kuruman
	Riries Gr. 6/1923 (Riries Mine)	16 miles WNW of Kuruman
	Saamwerk 2952/1928	20 miles NNW of Tsineng
	Strelley Ku Q 5 - 4	12 miles SSW of Kuruman
	Ventersrust Ku F 2 - 5	13 miles N of Tsineng
	Whitebank Ku Q 10 - 19 (Whitebank Mine)	8 miles WNW of Kuruman
	Wonderwerk Block AA Ku F 2 - 1	29 miles SSE of Kuruman
	Woodstock Ku Q 6 - 19	8 miles SSW of Kuruman
Vryburg	Bute Vr. C.O. 1 - 61 (Bute Mine)	12 miles N of Heuningvlei
	Campden Vr. C.O. 1 - 68	19 miles NNE of Heuningvlei
	Cheddar Vr. Q 11 - 28	2 miles E of Pomfret
	Clifton Vr. C.O. 1 - 44	8 miles SW of Heuningvlei
	Constable Vr. Q 11 - 28	5 miles W of Pomfret
	Conway Vr. C.O. 1 - 65	15 miles N of Heuningvlei
	Deal Vr. C.O. 1 - 57	8 miles NNE of Heuningvlei
	Halifax Vr. C.O. 1 - 56	9 miles NE of Heuningvlei

District	Locality	Remarks
Vryburg	Heuningvlei Native Reserve, Heunar B724/1931	
	Hove Vr. C.O. 1 - 55	5 miles N of Heuningvlei
	Howden Vr. C.O. 1 - 64	17 miles NNE of Heuningvlei
	Perth Vr. C.O. 1 - 38	11 miles SSW of Heuningvlei
	Pomfret Vr. Q 11 - 28 (Pomfret Mine)	41 miles NE of Heuningvlei
	Shuenuic Vr. Q 11 - 28	5 miles E of Pomfret
	Tay Vr. C.O. 1 - 31	16 miles SSW of Heuningvlei
	Tseloan Vr. C.O. 1 - 45	8 miles SSW of Heuningvlei

B. Previous Work

The earliest description of the country north of the Orange River, as far north as Kuruman, is that by Martin Henry Charles Lichtenstein who travelled through the area between the years 1803 and 1806. Although few geological observations were recorded by him he collected many minerals from the area including crocidolite asbestos, first described as "Blau Eisenstein" (Rogers, 1937, p. 6).

A number of observations on geological aspects of the Griqualand West area were recorded a few years later by W.J. Burchell who left Cape Town in 1811 on his long trek into the unknown hinterland.

Amongst other observations Burchell recorded the occurrence of "primitive limestone" over a great tract of country north of the Gariep (Orange River), and of "clay-slate" which overlay it (Rogers, 1937, p. 6 - 7).

The next European traveller whose route crossed the Griqualand West area was Robert Moffat who journeyed through the area around 1854. Moffat made quite a number of interesting geological observations and referred, amongst others, to the "ribbonned schists" which constitute the Griquatown Beds (Rogers, 1937).

In the early eighteen-seventies the area was traversed by G.W. Stow (1874) who, by making remarkably accurate geological observations, was the first person to establish the general stratigraphical succession of the geological formations in the area.

Rogers (1905) gave the first comprehensive account of the stratigraphy of Griqualand West in which account he upheld Stow's classification as far as the Campbell Rand (Dolomite), Griquatown (Pretoria) and Matsap Series are concerned. Apart from clarifying the stratigraphy of the area Rogers also gave some detailed descriptions of certain structural features between Prieska and the border of Botswana. This was followed by further accounts by him (1906 and 1907) of the stratigraphical succession.

Rogers and Du Toit (1908 & 1910) surveyed the Hay and Prieska divisions of the asbestos-field during 1904 and 1905 and published a geological map of the area.

Hall (1918) after re-examining the asbestos occurrences in the Cape Province and other parts of the country published a memoir on the mode of occurrence and the distribution of asbestos in South Africa. This memoir which contains much valuable information on asbestos in South Africa was later revised by him and a second edition was published in 1930. Hall (1930) attributed the formation of crocidolite to the recrystallisation <u>in situ</u> of material, for the greater part already present in the banded ironstone, under the influence of increased temperature caused by some process analogous to load and not to the reactions caused by circulating solutions.

Peacock (1928) published a paper on the nature and the origin of amphibole asbestos in South Africa and regarded the process of crocidolite formation as a mild, static, non-additive metamorphic process resulting in the chemical union of the necessary constituents already <u>in situ</u>.

Truter and co-workers (1938), during an investigation of the geology of the area around Olifantshoek, made several observations on the banded ironstone and the associated crocidolite deposits. Most of Hall's views (1930) with regard to the origin of crocidolite were endorsed by these workers, but in addition they suggested a possible relation between crocidolite formation and the intrusion of diabase sills, which they concluded may have had an additive or "reinforcing effect" on the process.

Du Toit (1945) discussed the sedimentary history of the asbestos-bearing rocks, vizualising a quiet sea in which colloidal sediments were deposited. He concluded that crocidolite is essentially a stress-mineral and is the product of dynamic metamorphism.

Visser (1944) made a study of structural features in the Griqualand West area and stated that, "despite the diverse opinions on the time and mode of origin of crocidolite asbestos, there are indications in many of the larger workings that the deposits are genetically related to the widespread post-Matsap disturbances" (p. 250).

Visser (1958) discussed the different geological formations in the Griquatown area and again pointed out the relation between the structural features and the formation of crocidolite.

Cilliers (1961) gave a detailed explanation of the possible origin of the banded ironstone and related rock-types which form the host-rock of the crocidolite deposits in the Cape Province. He came to the conclusion that although crocidolite deposits are in places associated with folding, this association is purely incidental and stated that "the amphibole asbestos was not formed as a result of stress set up during periods of regional folding, but crystallised directly from a colloidal precipitate of parent material" during diagenesis of the sediments. According to him pre-existing magnetite laminae or "screens" acted as initiating surfaces from which the growth of the cross-fibre crocidolite commenced. In a number of papers subsequently published by the same author he upheld the same ideas.

Genis (1964) endorsed most of the ideas put forward by Cilliers except that he regards the thin magnetite laminae which are generally present adjacent to fibre seams to be "screens" through which the amphibolite crystals penetrated during crystallisation thus causing their minute, hair-like dimensions.

Detailed studies on the chemistry of crocidolite and the associated rocks from the Cape Province were carried out by a number of observers. These studies revealed, among other things, the presence of certain primitive oils and amino-acids in the chemical composition of both the crocidolite and the banded ironstone host-rock, apparently indicating the activity of primitive organisms during the deposition of the sediments (Harrington, 1962 and Harrington et al, 1963).

At the present time two geologists, Messrs P.D. Fockema and C.J.B. Dreyer, are proceeding with studies on the mode of occurrence of crocidolite in certain parts of the Northern Cape Asbestos Field. Both investigators are in favour of a relationship between structural control and the origin of crocidolite (personal communication).

II. Physical Features

A. Topography

The rocks belonging to the Lower Griquatown Stage generally form conspicuous hilly ranges projecting above the adjacent undulating plateau underlain by the Dolomite Series and the Dwyka tillite to the east and largely occupied by lava of the Ongeluk Stage to the west. In the southernmost portion of the area in which the Lower Griquatown beds are found, south, west and north of Prieska, these rocks form the so-called Doringberg Range. This range of mountains composed of banded ironstone and related siliceous, ferruginous, jaspery rocks, and intruded by comparatively thick diabase sills, stretches from a point 20 miles south of Prieska in a north-north-westerly direction past the town to Westerberg on the southern bank of the Orange River, a distance of some 50 miles. The rocks which constitute the Doringberg Range form a group of hills with a rather complex physiography.

The Orange River which cuts through the asbestos-bearing strata between Prieska and Westerberg follows a meandering course exploiting joint-systems, and other structural lines like the contours of plunging synclines (Folder 1, Q3). The present-day flood-plains of the river are often about a thousand feet below the peaks of the adjacent mountain ranges. The western edge of the Doringberg Range generally forms a steep slope which is parallel to a persistent fault-zone known as the Doringberg Fault.

The hilly range immediately north and east of the Orange River at Prieska, which continues to beyond Griquatown, is known as the Asbestos Mountains. Between these towns the stretch of hilly country occupied by the Lower Griquatown Stage measures some 40 miles in an east-west direction. From a point west of Griquatown the Asbestos Mountains split into two separate belts. The western belt of hills, capped by rocks of the Matsap Formation in places, is known as the Matsap Hills and represents the western flank of the Ongeluk-Witwater Syncline. This range is composed of rolling hills with moderate relief and is interspersed with a ramifying network of sand-filled valleys; it becomes gradually less conspicuous to the north until eventually it forms a series of isolated, elongated "inselberge" separated by valleys filled with wind-blown sand.

The eastern belt continues northward towards Danielskuil, Kuruman and Severn and forms an almost continuous, elevated tract. From Danielskuil to beyond Kuruman the range is known as the Kuruman Hills, but in the environment of Severn it is known as the Rooiberge. In the Severn area and farther north towards the border of Botswana Recent Kalahari sand covers extensive areas underlain by rocks of the Lower Griquatown Stage.

From Prieska to beyond Kuruman the eastern edges of the Asbestos Mountains and the Kuruman Hills project sharply above the flat dolomite terrain on the east and form a prominent landmark over a wide area. The western flank of this range is characterised by gentle dip-slopes which gradually merge with the flat-lying country to the west.

From a point north-west of Danielskuil a range of hills with low relief branches off and forms the western flank of the Dimoten Syncline. It continues only for a short distance before it disappears underneath wind-blown sand. North-east of Postmasburg the western flank of the Ongeluk– Witwater Syncline is represented by a series of rolling hills of banded ironstone and jasper which trend in a south-westerly direction to just beyond Postmasburg. From the above description of the separate belts of Lower Griquatown Stage rocks it is clear that there exists a strong relation between surface-relief and the geological formation over the entire area covered by these rocks.

The eastern belt which fades out towards Severn in the Vryburg District reappears as a series of hills which trend north-south in the environment of Heuningvlei and continues for a distance of some 30 miles. This hilly tract, locally known as the Makuba Range, seldom rises more than 500 feet above the surrounding sand-covered plain. Towards the northern extremity of the Makuba Range the chain of hills swings gradually to the north-east, although the regional strike of the strata which build them remains approximately north-south, and eventually disappears underneath a blanket of Kalahari sand.

Outcrops of Lower Griquatown beds reappear some 30 miles farther north-north-east and form a series of low-lying hills in the vicinity of Pomfret. At this locality the chain of isolated hills trends in an east-west direction conforming to the regional strike of the strata, which has now swung through an angle of 90°. Widely spaced, isolated, elevated spots representing poor outcrops of the Lower Griquatown beds continue towards the border of Botswana.

The mountainous chain formed by rocks of the Lower Griquatown Stage in the Cape Province ranges in elevation from about 4,000 feet to some 6,000 feet above mean sea-level, but seldom projects more than about 800 feet above the surrounding flat country. The elevation of the Doringberg Range in the south is in the proximity of 4,400 feet above sea-level with the trigonometrical beacons Westerberg 20 (4,360 feet, Q2), Middelwater 11 (4,420 feet, Q2) and Prieska 32 (4,488 feet, R3) located on some of the highest peaks.

From Prieska towards Griquatown and Danielskuil there is a gradual increase in the average elevation of the Asbestos Mountains and farther on in the Kuruman Hills. From north of Prieska to immediately north of Niekerkshoop the elevation is still around 4,000 feet above sea-level (Kransfontein 30, 4170 feet (R4); Klipfontein 30, 4229 feet (Q4), but it increases gradually farther north. A few miles north of Griquatown, elevations exceeding 5,000 feet are recorded (Hope 21, 5299 feet (N6). From the latter point the average elevation increases in a northerly direction from 5,742 feet (Ouplaas 32, L2) to a maximum of 6,086 feet at trigonometrical beacon Gakarusa No. 8 (K3) about 20 miles due north of Danielskuil.

From this point, about 30 miles south of Kuruman, the elevation of the mountain range gradually decreases to the north with several high peaks like Gamohaan 11 (5,277 feet, I2) and Gamopedi 12 (4,264 feet, H1) north of Kuruman. In the region of the Rooiberge between Tsineng and Severn the highest peak is that of Bakenkop (F2) which is 4,162 feet above sea-level. In the Heuningvlei area the maximum recorded elevation in the Makuba Range is that of Tselwangkop (D2) which has an elevation of 4,016 feet above sea-level.

Evidence of two periods of prolonged erosion, one in pre-Karroo and the other in comparatively recent times are found within the area occupied by rocks of the Lower Griquatown Stage. Rocks belonging to the Dwyka Series occupy fairly large erosional troughs in the south and towards the north of the area. North of Eldoret and in the Lower Kuruman Native Reserve bore-holes sunk for water penetrated shales believed to be of Karroo age. They are preserved in a transverse valley at present covered by wind-blown sand and it is believed that the valley in which the shales have been deposited was scoured out during the Dwyka glaciation.

Dwyka tillite is also found in the Prieska area where again the deposits are associated with glacial troughs. The present-day topography is apparently largely due to erosion by rivers during late Tertiary and Recent times, followed, during the return to more arid conditions, by large-scale filling of the valleys by wind-blown sand.

B. Climate and Drainage

Because climatic conditions, especially the annual rainfall, have a bearing on the depth of oxidation of the banded ironstone and the related crocidolite-bearing rocks in the region a summary of these conditions would be appropriate.

The climate of the entire area is semi-arid, with mild to cold winters and hot summers. The coldest month is July, when severe ground-frost generally is found over the low-lying areas which flank the mountain ranges. In exceptionally cold winters, snow could be of common occurrence on the high range in the environment of Danielskuil. A wide range in temperature is experienced between farms located on the mountain ranges and those located only a few miles away on the bordering Ghaap Plateau to the east. This is especially the case in the environment of Kuruman where the difference in temperature is such that rose trees flourish during winter and paw-paw trees are grown on farms located in the Kuruman Hills, whereas severe frost is experienced on the farms at the foot of the hills.

The average rainfall figures do not only differ largely from the southern to the northern extremities of the region but may also differ remarkably within a relatively restricted area. The average rainfall for the country around Prieska and Niekerkshoop is about 9 inches per year, but that for the near-by area around Griquatown, taken over a period of some 50 years, is more than 12½ inches.

Going farther north the annual rainfall increases gradually, and reaches an average of 15 inches, ranging between about 7 and 22 inches at Kuruman. Towards the border of Botswana there is again a slight decrease in the annual rainfall, which generally varies between 10 and

15 inches.

Most of the rain in the entire area falls during the summer months, generally in the form of violent, localised thunderstorms. In the area bordering the Orange River, dry water-courses which originate in the hilly country flanking the river, have cut deep ravines, all of which lead to the Orange River. Farther north towards Griquatown and beyond, the water-courses which originate in the hilly country flanking the river, have cut deep ravines, all of which lead to the Orange River. Farther north towards Griquqtown and beyond, the water-courses originating in the mountains gradually become shallower until their contours merge with the general level of the adjacent sand-covered plains.

Drainage-channels away from the elevated tract formed by the Lower Griquatown beds are therefore seldom well developed and are often partly or wholly erased on account of the encroachment of wind-blown sand. Except for the Orange River, all other prominent drainage-channels in the area are dry for the major part of the year and carry flowing water only during exceptionally good rainy seasons. An example of such a drainage-channel is the Matsap "Loop" which towards the northern extremity of the Matsap Hills is the only well-defined drainage-channel in the area between Griquatown and Postmasburg, but it hardly ever carries any water. The area immediately north of Danielskuil is drained by tributaries of the Gamagara "Loop" which runs to the west of the Kuruman Hills. Run-off courses in the eastern portion of this area continue towards the Kuruman River along the eastern edge of the mountain range.

The Kuruman River (Folder 1) runs north, almost parallel to the Kuruman Hills, from near Kuruman till it reaches Tsening where it swings west, cuts across the Lower Griquatown beds and continues to the west. Just before crossing the Lower Griquatown beds it is joined by the Matlowing River from the east. Both rivers are well defined, but they seldom carry any flowing water.

Farther north towards Severn the main drainage-channel in the area is the Mashowing River which runs in a north-westerly direction as far as Severn where it cuts across the trend of the Roiberge, continues to the west and eventually joins the Kuruman River. The Kgokgole River with tributaries from the Heuningvlei area runs south-west across suboutcrops of the Lower Griquatown beds to join the Mashowing River a couple of miles west of Severn.

The sand-covered stretch between the northern extremity of the Makuba Range and the hilly country around Pomfret is traversed by the Papani "Laagte" which continues in a northwesterly direction and ultimately joins the Molopo River on the border of Botswana.

C. Vegetation

Throughout the entire area the vegetation is decidedly xerophytic. In the southern portion around Prieska and Griquatown the "driedoring" (Rhigozum trichotomum) is the most characteristic shrub. It generally grows in the valleys amongst the mountains and on the sand-covered flats west of the Asbestos Mountains. In the mountainous ground, especially around Griquatown and farther north to beyond Kuruman the "haakdoring" (Acacia detinens) is the most common thorny shrub often growing so luxuriantly on rocky outcrops and slopes covered with scree that progress is much impeded. The "wild sage" (Tarchonanthus camphoratus) a thornless shrub, although preferring the dolomite flats, is often well represented along the longitudinal valleys amongst the banded ironstone and jasper hills.

Camelthorn trees (Acacia giraffae) are found sparsely on the sand-covered flats amongst the hills in the southern portion of the area, but they gradually increase in number towards the north. From south of Kuruman to beyond Pomfret in the north the camelthorn and the related "Vaalkameel" (Acacia haematoxylon) grow in large numbers. These two species prefer the dolomite country to the east of the Kuruman Hills, the Rooiberge and the flats underlain by the Ongeluk lava west thereof. They very seldom grow on the banded ironstone and related rocks and if found in an area where the latter rock-types are common they are invariably rooted in dolerite or diabase. Outcrops of dolerite dykes in the area covered by the Lower Griquatown beds are scarce and the usual linear arrangement of Acacia in these areas often serves as a guide to detect suboutcrops.

Other species frequently encountered in the area are, among others, the shepherd's tree (Boschia albitrunea), "wilde granaat" (Rhigozum obovatum), and "soetdoring" (Acacia Karroo).

Many varieties of perennial and annual grasses are found along the stretch of the Lower Griquatown beds. The most common and also most cumbersome species found over the greater part of the area is the "steekgras" (Aristida burkei) which flourishes on shallow soil. On the deeper soils the sharp-pointed Bushman grasses Aristida ciliata and A. obtusa are the most abundant.