

THE GEOLOGY  
OF PART OF THE  
VAN RHYNSDORP DIVISION, CAPE PROVINCE.

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CAPE PROVINCE.

ABSTRACT.

An area of approximately 440 square miles has been mapped in the southern part of the van Rhynsdorp Division. The Kheis System is represented by amphibolites and quartzites assigned to the Kaaien Series. A group of pre-Pink Gneiss phyllites, schists, arkoses, quartzites and a dolomitic marble are correlated with the Hilda Series of the Gariep System. A sheared tillite, that rests with a sedimentary contact on the Pink Gneiss on the farm Hoedverloor, is correlated tentatively with the basal tillite of the Kaigas Series in the Richtersveld area. The Nama System is represented by a group of limestones and dolomites now called the Basal Limestone Series, and also the Nuverus Series.

There are no post-Nama granitic rocks in the area and the gneiss of the Hoedverloor Hills has been shown to be a southerly continuation of the Pink Gneiss of the Nuverus area. The Pink Gneiss constitutes marginal phases of the Namaqualand crystalline complex and represents extensive granitisation of the Kheis System accompanied by lit-par-lit intrusion of the later acid differentiates of that complex. Modal values of a representative series of rock-types of the Namaqualand complex have been plotted on various diagrams, and it is possible to recognise three main types, viz. the Granodiorites, the Grey Gneisses and the Pink Gneisses. A dolerite sill of Karroo age was found in the area.

The pre-Nama sediments were folded on a rather intense scale, while the Nama rocks have been folded into gently pitching anticlines and synclines. Two sets of post-Nama, pre-Cape tension faults are recognised.

The Kners Vlakte peneplain, and its associated deposits, is described. These deposits include a group of calcareous gravels and conglomerates that may be of marine origin.

The economic resources of the van Rhynsdorp Division are discussed, and attention is drawn to hitherto unexploited clays and zircon sands.

New analyses include four of the Pink Gneiss, nineteen of the Basal Limestone Series, three of the dolomitic marble of the Hilda Series and one of well-water from the Hoedverloor stream.

Some notes are included on the pre-Cape sedimentary rocks of the western and southern Cape Province.

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## INTRODUCTION.

### The Location and Extent of the Area.

The area surveyed extends from just south of the Olifants River, between the villages of Vredendal and Vlermuisklip (latitude  $31^{\circ} 40'$ ), northwards to a line through the farm Potklei (latitude  $31^{\circ} 20'$ ). It is bounded on the east by the longitude line  $18^{\circ} 38'$  and on the west by longitude  $18^{\circ} 20'$ . Map No. 1 illustrates the extent of the area and its relationship to the surrounding region.

In order to obtain a clearer picture of the above area, a considerable number of localities in the surrounding region were visited and examined. The latter procedure was necessary because firstly the area surveyed in detail is extensively covered by wind-blown sand, and secondly in order to establish the continuity of formations occurring in the area with corresponding formations lying to the north.

The area surveyed in detail comprises about 440 sq. miles. Vredendal is the largest village, and is situated 222 miles by rail, and 192 miles by road from Cape Town. It is connected to van Rhynsdorp by a good gravel road.

Two maintained gravel roads follow both banks of the Olifants River from Vredendal to Vlermuisklip. The other roads in the area are of a low standard, frequently just cart tracks. Heavy red sand often obstructs traffic on the latter roads. A maintained road, used for the transport of gypsum, runs from Holrivier siding, past the Namaqualand Marble Company quarries, to the gypsum diggings at Bergplaas.

### The Purpose of the Investigation.

During July of 1945 the author examined some of the irrigation canal sections along the Olifants River, following a suggestion by Dr. A.L. du Toit that these sections

would probably throw some light on the relationship between the Malmesbury Series and the Nama System in the van Rhynsdorp area. Exposures along the right bank canal, between Klaver and the mouth of the Hol River, were examined, and the area to the north of the Hol River was visited. This reconnaissance survey suggested that a more detailed investigation of the present area would help to clarify the relationship between the Nama System of the Nuwerus-Bitterfontein area and the Malmesbury Series mapped by Dr. A.W. Rogers along the Olifants River on the Nieuwerust Sheet No.19 (1912).

On the latter sheet, the northern part of the farm Moedverloor is mapped as Malmesbury Series. On Moedverloor, in the neighbourhood of the Luiperskop Trigonometrical beacon, the author found some hard blue quartzites that seemed to agree with the description given by Rogers (22 p.36) of hard blue quartzites from the hills east and south-west of Nuwerus and Flominkberg, and assigned to the Nieuwerust Series by him. This suggested that the contact between the Nieuwerust and Malmesbury Series of Rogers would be found in the Moedverloor area.

The author also hoped to be able to establish a relationship between the Namaqualand granite to the north, and the younger, post-Malmesbury granite mapped by Rogers on Sheet No.19 in the south-western part of the van Rhynsdorp region.

#### Method of Geological Surveying.

The area was surveyed on the scale 1:50,000 (1 in. to 0.789 miles). Two plane-table sheets, 24 in. x 24 in., were used and were later combined onto one tracing.

Before going into the field the base maps were prepared in the following manner.

All the available trigonometrical beacons were plotted onto the maps by means of their co-ordinates, given for

Degree Sheet 58 (Trigonometrical Survey Office, Rosebank). Additional data, such as roads and rivers, were traced onto the maps by means of a pantograph from the topographical map 1:250,000, Calvinia, 3118. The latter information was necessarily inaccurate due to the magnification, and was intended only to serve as a guide. This information was erased and corrected where necessary as mapping proceeded in the field.

An overlap of 4 inches was allowed on the two plane-table sheets, both of which included the trigonometrical beacon of Zoutfontein. Two other carefully located points within the overlaps ensured the accurate fitting of the two sheets.

Locations in the field were made by the three-point method by means of a telescopic alidade. In the southern area sufficient trigonometrical beacons were available for the location of all plane-table set-ups. In the northern area it was found necessary to erect additional stone beacons on prominent hills which were then located from trigonometrical beacons.

A new type of universal clinometer was used for leveling and orientating the plane-table magnetically, for measuring dips, strikes and foliation directions, and for plotting these measurements onto the maps.

### The Physical Features of the Area.

#### Topography.

The topography of the area consists essentially of two elements, 1. a south-westerly extension of the Kners Vlekte peneplain, and 2. the higher ground and hills, over 1000 feet, in the northern and north-western portion of the area. These features are illustrated on Map No.1.

Looking towards the area from high ground near van Rhynsdorp, the extensive, sand-covered peneplain is observed with the high ground of the Moedverloor hills and the

Luiperskop ridge rising above the plain. The highest points in the area are Potkleikop, the elevation of which is not given in Degree Sheet 58, but which must be in the neighbourhood of 1,300 feet, Moedverlorenberg (1292 feet) and Luiperskop (1142 feet).

The high ground in the northern area is due to the relatively resistant nature of the granite and the Nuwe-rus quartzites as compared with the softer argillaceous and calcareous rocks of the southern and eastern areas which constitute part of the peneplain.

The whole of the extensive Kners Vlakte peneplain is structurally related to the soft argillaceous, arkosic and calcareous rocks of the region. It is bounded on the north and north-west by the granite and the quartzites of the Nuwe-rus Series, and on the east by the escarpment which is capped by Table Mountain Sandstone. The peneplain slopes gently from an elevation of approximately 800 feet in the northern area to about 350 feet near the Olifants River at Vredendal. A ridge of Table Mountain Sandstone, which extends from the Bulshoek irrigation barrage on the Olifants River to a point south of Vlermuisklip, rises to a height of nearly 900 feet south-west of the Olifants River and forms the south-western boundary of the peneplain.

#### Drainage.

Map No.1 indicates the courses of the main rivers in the area. With the exception of some streams in the north-western portion, all the rivers drain into the Olifants.

The Olifants River appears to be of very considerable age, and is in all likelihood related structurally to the series of Cretaceous faults that occur along its valley from above Citrusdal as far at least as Klaver.

The Groot Graafwater, Geelbeks, Sout and Varsche Rivers drain the Kners Vlakte area and rise in the mountainous country to the north and north-east. They all combine to

form the Hol River, which flows into the Olifants. The Tros Tros and Widouw Rivers rise on the escarpment lying to the east of van Rhynsdorp.

The Olifants River is the only one in the area that runs throughout the year, although the irrigation dams have limited its flow below the Bulshoek barrage. The larger of the other rivers generally have small pools of very brak water throughout the year, and the Sout River is reported to have small stretches of flowing water in the summer months in the limestone region below the poort at Gamsbokberg.

During the winter these rivers come down strongly for several days after rain, but cease to flow after about a week. As the flow diminishes, the rivers tend to silt up their beds. The following heavy flows cut down through the silt with the result that road drifts are frequently washed away. The drift across the Groot Graafwater, just above its confluence with the Sout River, was washed away during the winter of 1946, leaving new banks almost 6 feet high at this point.

Several of the river courses have been defined by the structures of the underlying rock formations. The Moedverloor stream originated in the soft argillaceous and arkosic rocks of the Hilda Series on the east side of the Potklei-Moedverloor fault. The Groot Graafwater has followed the strike of the Nama rocks, and has cut into the Basal Limestones and the arkoses of the lower Nuwerus Series along the north-eastern side of the Luiperskop ridge. The Groot Graafwater turns in a southerly direction near Rooiberg at the end of the Luiperskop ridge, and this change of direction may be due to the presence of a north-south fault lying to the east of the river which has confined itself to the softer arkoses of the lower Nuwerus Series; the harder quartzitic rocks of the upper Nuwerus Series lie to the east of the fault.

The stream, shown on Map No. 1 as Volstruis Leegte, is related to a small trough formed by strike faults in the Nuwerus quartzites, and also to the softer phyllitic horizons associated with these quartzites. Similar small streams were seen around Luiperskop associated with these phyllitic horizons.

Brink ( 4 p.10) writes as follows of the headwaters of the Groot Graafwater, "The subsequent nature of the streams in this area (Nuwerus) is also portrayed by the way in which the small stream running through Nuwerus in a southerly direction flows in the little graben of Witputs between the two strike faults".

Part at least of the course of the Sout River suggests a superimposed drainage. On the farm Quaggaskop, north-east of the bridge over the Sout River on the van Rhynsdorp -Nuwerus road, this river cuts across the strike of hard quartzites and conglomerates. Again at Gembokberg, the Sout River has cut a poort through the Basal Limestones at right angles to their strike. The Sout River may therefore have originated on the Knors Vlakte peneplain, and have had sufficient eroding power to cut through the resistant formations underlying the peneplain deposits without having suffered a deflection of its course.

The Tree Tree River cuts across the strike of the limestones and dolomites south-west of van Rhynsdorp, and on the farm Lower Aties it has cut a deep gorge into the dolomites of the Hilda Series.

All the rivers in the area show signs of recent rejuvenation, represented by between 15 to 20 feet of down-cutting. The significance of this feature is discussed elsewhere.

### The Climate of the Region.

The following information is based on extracts from a volume (34) supplied by the Assistant Director of Meteorological Services, Pretoria. Practically all the observations were made at Klaver, but they may be taken as typical of the van Rhynsdorp region as a whole.

#### Winds.

At Klaver the prevailing summer winds are west and south-west, and in winter north-west and south-west. At Garies the summer winds are mainly south, and the winter winds south and north. December to February is the windiest season.

#### Mists.

Mists from the sea are common in the early mornings in winter, but seldom occur in summer. These mists may restrict visibility until as late as 10 a.m. in the winter, and thus hinder survey work.

#### Rainfall.

From Cape Town to the Olifants River the annual rainfall decreases from 25 in. to 5 in. The mean annual rainfall for Garies is 5.1 in., for van Rhynsdorp 5.5 in. and for Klaver 6.6 in. The mean annual rainfall for the whole region is therefore approximately 5.5 in., and is confined almost entirely to the winter months.

#### Temperatures.

The January mean temperature along the Olifants River is 75°F, with occasional maxima between 100°F and 115°F. Mean temperatures at Klaver range from 75.3°F in January to 57.7°F in July.

Field work in the region should be confined to the winter months because of the high summer temperatures and

strong, dusty winds, that make outdoor work extremely unpleasant. During the winter, water is occasionally available in river beds and small stock dams, but it is almost entirely absent from these sources in summer.

#### The Vegetation of the Area.

The vegetation of the region falls into the "Coastal Succulent Bush" type of the semi-desert vegetation division given by Professor R.S. Adamson in "Vegetation of South Africa" ( p.190) in which he gives a full description.

In the area surveyed four main sub-types are recognised.

1. On the red drift sand, "twagras" (*Aristida brevifolia*) predominates, together with an occasional bright green "melkbos" (*Euphorbia* sp.), and some tall succulents. This sub-type occurs in the western portion, south of the Moedverloor hills and on both sides of the Olifants River away from the flood plain.

2. On the ridges formed by the Nuwerus quartzites and the granite in the northern and north-western area, both tall and short succulents (*Mesembryanthemum* spp.) occur, together with "kraalbos" (*Galenia africana*) on the more sandy patches.

3. The only trees in the area occur along the river beds. They are represented by the thorn tree (*Acacia karroo*) and wild tobacco (*Nicotiana glauca*).

4. Small, short succulents predominate on the extensive sheets of white quartz pebbles that have weathered out of the large quartz veins which frequently occur along the north-south faults.

Limestone sub-outcrops can frequently be traced by following a grey-green succulent, with small, almost spherical leaves, about 1 foot high and having a sooty

coloured stem. This plant responds rapidly to the first winter rains, becoming green, and greatly facilitates the mapping of partly concealed calcareous rocks.

#### Agriculture.

Much of the old flood plain of the Olifants River has been brought under irrigation, and lucerne, vines and citrus are intensively cultivated on prepared terraces. Sub-tropical fruits will grow where sufficient water is available.

Over large areas the veld has a sheep-carrying capacity of about two to three morgen per sheep. Sheep farmers from Bushmanland trek into the area during the winter months.

#### Previous work.

The previous work in the region is dealt with rather fully below in order that a clear picture of the advance of geological knowledge of the region may be obtained.

The first geological surveys in the van Rhynsdorp Division were carried out by Rogers between 1900 and 1911. The reports of this work appear in the Annual Reports of the Geological Commission.

Rogers' work may be summarised as follows.

1. In 1904 (p. 12) he stated that the oldest rocks in the north-western part of van Rhynsdorp probably belong to the Malmesbury Series, and that they are continuous with the beds of that group described from the country to the south of the Olifants River (i.e. in the Piquetberg area).

The Kners Vlakte was considered to be underlain by the Ibiquas Series, which was said to be younger than the Malmesbury and separated from it by an overthrusting unconformity.

The granite in the area was older than the Ibiquas, but intrusive into the Malmesbury.

The sediments near Nieuwerust were called the Nieuwerust Series, and were thought to be the youngest sediments in the area, and to rest unconformably on the Ibiquas.

The following chronological table represents Rogers' conclusions in 1904.

Nieuwerust Series  
(unconformity)  
Ibiquas Series  
(overthrust unconformity)  
Granite  
Malmesbury Series

2. In 1911 Major J.G.W. Leipoldt drew Rogers' attention to the similarity between the lower Steinkopf Beds and the Nieuwerust Series, and also between the upper Steinkopf Beds and the Ibiquas Series; he suggested that the unconformity between the Nieuwerust and Ibiquas Series (as postulated by Rogers in 1904) did not exist. Rogers revisited the van Rhynsdorp area again in that year and revised his previous sequence as follows.

NAMA SYSTEM	{	Ibiquas Series (unconformity) Granite (post-Malmesbury) Malmesbury Series Nieuwerust Series pre-Nama Granite	conformable
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The Nieuwerust Sheet 19, 1912, is based on the above table.

In 1912 Rogers, in referring to the two granites of different ages in the western part of van Rhynsdorp, wrote that there are "two granitic gneiss masses in the area, one of which is older than the Nama formation and the other younger than the Malmesbury Series, but whether it is also younger than the Ibiquas is not known".

The latter conclusions by Rogers, concerning the age

of the two granites, were based on the following observations.

He had seen the sedimentary contact between the Nieuwerust Beds and the granite gneiss at several localities, for example Flamink Vlakte and Driekuil (22 p. 38). Of the latter locality he said, "The arkose (Nieuwerust Series) at the base of the formation here rests upon an old denuded surface of granite". This represents Rogers' pre-Nama granite.

On the farm Moedverloor (22 p.17), Rogers found evidence for an intrusive relationship between the Malmesbury Beds and the neighbouring granite, which he considered therefore to be a younger granite. Similar evidence was found on the farm Drooge Kraal to the west of Moedverloor (22 p.19).

3. In 1929, in "Handbuch der Regionalen Geologie", A.L. Hall (24 p.92) dealt with the Western Cape, or Nama Facies, of the Transvaal-Nama System. This work is based mainly on Rogers' earlier reports.

Hall says, "The Black Reef Series is represented by the Nieuwerust Series, found in several detached masses over the western part of the Cape Province between the Orange and Olifants Rivers near van Rhyndorp, but is not so far known from the country south of the Olifants River". He assigned the Steinkopf Beds to the Nieuwerust Series and also states, "In Namaqualand the Nieuwerust Series underlies the Malmesbury beds".

"With the Dolomite Series are correlated the Malmesbury beds (including the Aties group) and the Congo Series, but in some of these there is a considerable development of argillaceous besides calcareous rocks".

The Ibiquas Beds, together with the French Hoek Beds, were correlated by Hall with the Pretoria Series.

Under the heading of "The post-Nama Granites of the Cape Province" (24 p.113), Rogers stated in 1929, "The

granite intrusive into the Nama sandstones, slates and limestones of the Moedverloor hills of van Rhynsdorp must have a boundary against the pre-Nama granite which forms the floor on which the basal Nama beds of Nieuwerust rest, but no satisfactory character is yet known by which individual outcrops of the two (granites) can be distinguished".

The chronological table of 1929 was much the same as that given in 1912.

TRANSVAAL SYSTEM	[	Pretoria Series	NAMA SYSTEM	]	Granite (post-Nama)
		Dolomite Series			Ibiquas Series (slight unconformity)
		Black Reef Series			Malmesbury Series Nieuwerust Series Granite (pre-Nama)

In 1945 Dr. W.C. Brink ( 4 p.i) completed a geological survey of the Nuwerus area and established the following sequence of the sediments. "The Nama sediments are unfossiliferous and rest unconformably on the Basement rocks (Pink Gneiss and Kheis). The succession is sub-divided into the Nuwerus series, the local equivalent of the Kuibis series, and the Schwarzkalk series, which now replaces the earlier terms Malmesbury and Ibiquas series. Since there is no break in the deposition of the upper Nama in this area, and as the conglomerates and grits of the Bezondermeid-Breektaand sector, formerly taken as typical of the unconformable base of the "Ibiquas series", are now considered as the normal second arenaceous phase of the Schwarzkalk of this area, the term "Ibiquas series" is abandoned!"

Brink questioned the intrusive nature of the granite contact on Moedverloor and Drooge Kraal since he considered that all the granite of the van Rhynsdorp region is of the same age, that is his "Namaqualand Granite". He was, however, unaware of the pre-granite Hilda Series on Moedverloor.

An abbreviated table of the sediments in the van Rhynsdorp area, based on the present survey, is given below. The classification given by Hall in 1929 is added for comparison.

<u>Present survey</u>		<u>Hall (1929)</u>
NAMA SYSTEM	{ Schwarzalk Series Nuwerus Series Basal Limestone Series  (unconformity) Kaigas Series  (unconformity) Pink Gneiss	{ Ibiqas and Malmesbury Nieuwerus Series Malmesbury (Aties group)
GARIEP SYSTEM	Hilda Series  (unconformity)	Two granites
KIEIS SYSTEM	Kaaien Series	Schists of sedimentary origin in the gneiss (Rogers 1912).

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THE FORMATIONS PRESENT, AND THE GEOLOGICAL  
HISTORY OF THE AREA.

The following table includes the geological formations present in the area, together with the main rock types represented in them. No rocks of the Schwarzkalk Series were mapped in the area, but this series is included for the sake of completeness.

	Tertiary to Recent deposits	{ Aeolian sands, River gravels, Gypsum and calcrete, Calcareous conglomerates, Mud conglomerates, Siltcrete
	Karoo Age	Dolerite
NAMA SYSTEM	Schwarzkalk Series (Nuwerus area)	{ Upper shale.  quartzites, feldspathic sandstones, grits and conglomerates.  Lower shale with a limestone phase near its base.
	Nuwerus Series	{ Purple and blue quartzites with associated mauve and pink phyllites.  Lower quartzites with alternating arkoses, shales and feldspathic grits.
	Basal Limestone Series	{ Pale blue to blue-black limestones with several dolomite horizons.
	Kaigas Series	{ Grey feldspathic quartzite, Tillite.
	Pink Gneiss	{ Granitised arkoses, quartzites etc. of the Kheis System and poss- ibly the Hilda Series.

GARIEP SYSTEM	Hilda Series	{ Metamorphosed phyllites, arkoses, feldspathic sandstones, quartzites and conglomerates with a dolomite horizon.
KHEIS SYSTEM	Kaaien Series	{ Metamorphosed quartzites, schists and amphibolites in the Pink Gneiss.

The oldest rocks found in the area are those of the Kheis System. These rocks occur as isolated masses, varying greatly in size, distributed in the Pink Gneiss. There is strong evidence that the Pink Gneiss represents extensive granitisation of the Kheis System. No formations of pre-Kheis age, from which the latter were derived, have been recognised in the region. If such rocks were originally present, they have no doubt been granitised and are now represented by portions of the Pink Gneiss.

The Kheis System appears to have been strongly metamorphosed on a regional scale prior to the formation of the Pink Gneiss. This view is supported by the fact that all the Kheis rocks observed have attained a much higher grade of metamorphism than the rocks of the Hilda Series near the contacts between the latter and the Pink Gneiss. The regional metamorphism of the Kheis System must therefore be of pre-Hilda age.

The Hilda Series occurs in the area surveyed as a south-east trending horst faulted against the Pink Gneiss on the north-west side on the farm Moedverloor, and also along the Olifants River between Vredendal and Vlermuisklip. It is essentially an argillaceous and arkosic formation with a dolomite and an arenaceous phase near the top. This series is of pre-Pink Gneiss age and is cut by a pegmatite from the latter on the farm Moedverloor. The neighbouring Pink Gneiss has induced the formation of thermal metamorphic minerals in certain schists and the

dolomite of the Hilda Series.

The Pink Gneiss occurs in the north-western portion of the area. Its eastern contact is a faulted one, and sand conceals outcrops between the Pink Gneiss of the Hoedverloor hills and the Basal Limestones of the Nama System at Vlermuisklip. This Pink Gneiss is continuous with similar rocks of the Nuwerus area, and is of the same approximate age as the Grey Gneiss of Namaqualand. There is evidence that it corresponds to the Pink Gneiss of the Kakamas area, and that it represents extensive granitisation of the Kheis System.

A tillite, succeeded by a grey felspathic quartzite, rests with a sedimentary contact on the Pink Gneiss on Hoedverloor. Its contact with the Hilda Series is a faulted one. Since it is of post-Pink Gneiss age, and probably pre-Nama, it has been correlated very tentatively with the basal Tillite of the Kaigas Series recorded by Söhnge and de Villiers (27 p.267) in the Richtersveld.

The Nama System is represented in the area by the Basal Limestones and the Nuwerus Series; no rocks of the Schwarzkalk Series were mapped in the area. The Basal Limestones are a local phase of the Nama System that were apparently deposited in a marine trough to the south of the Nuwerus area.

One dolerite sill was mapped in rocks of the basal Nuwerus Series at Gembokberg. This dolerite is correlated with the Karroo dolerites.

Tertiary deposits are represented by silcretes, a calcareous conglomerate possibly of marine origin, mud conglomerates, river gravels, gypsum, calcrete and wind blown sands.

Two main periods of faulting are recognised. The older period is represented by north-south trending tension faults with a downthrow on the east side, and characterised by extensive vein-quartz filling. The younger set of faults

trend in a north-west south-east direction in general. These faults are frequently marked by breccias cemented with limonite.

Both sets of faults are of post-Nama age, and there is evidence that they are of pre-Cape age.

THE KHEIS SYSTEM.

In the area surveyed there occurs a group of regionally metamorphosed rocks intimately associated with the Pink Gneiss. The greatest development of these rocks is seen as a roughly east-west trending belt, about four miles long by one mile wide, on the farm Potklei in the extreme north-western section. This belt is built up of highly sheared and contorted sericitic quartzites with some minor phases of mica schists. The numerous patches of amphibolites and granulites in the neighbouring gneiss are correlated with the Potklei rocks which are assigned to the Kaaien Series of the Kheis System. The Potklei quartzites and the amphibolites constitute therefore the most southerly known development of the Kheis System.

These rocks were not investigated in detail because the much more extensive development of this and other phases of the Kheis System in the Bitterfontein-Nuwerus area has been exhaustively treated by Brink ( 4 p.15 et seq.).

In the van Rhynsdorp Division the Kheis rocks have reached a much higher state of metamorphism than the Hilda Series has attained, and must therefore have suffered metamorphism on a regional scale prior to the deposition of the sediments of the Hilda Series and the formation of the Pink Gneiss. In this connection it is interesting to note Brink's conclusions regarding the metamorphic rocks around Bitterfontein railway station ( 4 p.21), "There is apparently no relation between the grade of metamorphism attained in a rock and its distance from the granite contact, a fact which suggests that the granite was not responsible for the metamorphism".

The extensive granitisation of the Kheis System, which resulted in the formation of the Pink Gneiss, is discussed on page 84. The quartzites on Potklei and the amphibolites and

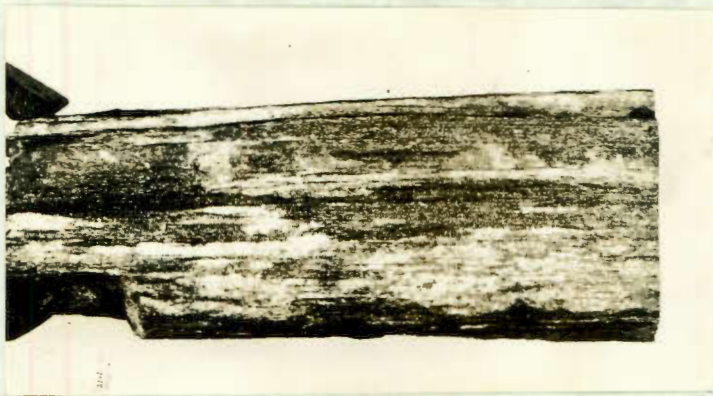
granulites in the surrounding gneiss appear to represent Kheis rocks that survived granitisation; while the original formations of arkosic composition are now represented by the Pink Gneiss.

The numerous hornblende-granulites and amphibolites occur as isolated lenses distributed at random in the gneiss. They show a very frequent tendency to lie parallel to the foliation of the enclosing gneiss and this feature suggests that they lay in the bedding of the original sediments. The same characteristic was also observed in the Sout River area, described below, where similar amphibolites occur parallel to the foliation of the intimately associated gneisses, schists and granulites of Kheis age. From these field relations therefore, it appears that the amphibolites represent original intermediate and basic igneous rocks, possibly lava flows, associated with the Kheis sediments. In all probability the amphibolites had attained their present degree of metamorphism prior to the period of granitisation responsible for the formation of the Pink Gneiss.

Brink has recorded several occurrences of hornblende-granulites in the northern area, and concludes, "... that these granulites are the outcome of recrystallisation of originally banded rocks, which, if they had been sediments, must have been of very abnormal constitution so as to have yielded the observed minerals".

The typical rocks of the Potklei area are sericitic quartzites and quartz-sericite schists, all highly sheared and showing small-scale contortions. Photographs Nos. 1 and 2 illustrate two rocks from Potklei.

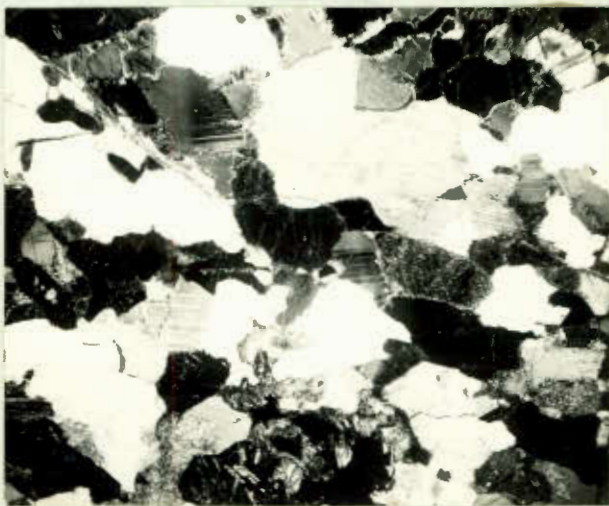
Microphotograph No. 3 shows the texture typical of the amphibolites. The specimen photographed was collected near the farmhouse on Elandsfontein about 10 miles north-west of Potklei.



No. 1 . A sericitic quartzite from  
the Kaalen Series on Potklei.  
(just under natural size.)



No. 2 . A contorted quartz-sericite  
schist from the Kaalen Series on  
Potklei.  
(just under natural size.)



No. 3. A plagioclase-amphibolite  
from Elandsfontein.  
Crossed Nicols. X20.

During a visit to the Sout River area (to the southwest of Bitterfontein and not the Kners Vlakte Sout River) the author was able to examine the rocks that appear on Sheet 19, Nieuwerust, as "Malmesbury Series". There are present in this group of rocks, mica schists, garnet schists, amphibolites and quartzites, some of the latter similar to those seen on Potklei. All these rocks, together with the associated pink and grey gneisses, are strongly foliated and can be correlated with the Kheis rocks described by Brink from the Nuwerus-Bitterfontein area. Good exposures across the foliation are available along the banks of the Klein Goerap and Sout Rivers, and this area should prove of value in any future investigation of the Kheis System in southern Namaqualand.

THE HILDA SERIES.

In the area surveyed there occurs a group of sedimentary rocks younger than the Kheis System but older than the Pink Gneiss. Phyllitic and arkosic rock-types predominate, but a persistent dolomitic marble, quartzites and conglomerates make their appearance near the top of the group. Several schistose phases carrying low-grade metamorphic minerals were observed, and these appear to indicate a zone of thermal metamorphism associated with the Pink Gneiss. This group was originally included in the Halmesbury Series by Rogers and appears as such on Sheet 19, Nieuwerust, but it is now correlated with the Hilda Series of the Gariep System described from the Richtersveld area by Söhne and de Villiers (27 p.264).

The Hilda Series forms the middle member of an extensive formation now called the Gariep System, which occurs in the Richtersveld and the southern Sperrgebiet of South-West Africa. There are grounds for considering that the Gariep System corresponds to the Damara System of South-West Africa, but the authors of the Richtersveld paper have decided to introduce a local name on account of the large area of unmapped and geologically almost unknown country between the two type areas.

There is, unfortunately at the present time, only a very brief description of the Hilda Series from the type area, but the author was informed by Dr. de Villiers that the series which occurs on the farm Hoedverloor appears to correspond more closely to the Hilda Series than to any other formation in the Richtersveld. The following is the description given by Söhne and de Villiers of the Hilda Series (27 p.265). "Following conformably on the Black Hills series in both areas (Hilda Trigonometrical beacon and north of the Aurus waterhole to the south of

Geinaggas in South-West Africa) is the Hilda Series, composed of arkose, schist and marble".

The following description, given by du Toit, of the Marble Series of the Damara System (8 p.45) is given for comparison with the rocks of the van Rhynsdorp region. If the Gariep System corresponds to the Damara System, the Hilda Series represents the Marble Series.

"The succeeding Marble Series is best developed in the Karibib and Omaruru districts where it builds high ranges, being made up predominantly of crystalline limestones and dolomites with intercalations of phyllites, biotite-schists and amphibolites that stretch regularly for miles.

"The marbles are of various colours, white, grey, yellow and black, ..... Where altered by the granite, the marbles become coarsely crystalline calc-silicate rocks in which the following minerals may be developed - tremolite, hornblende, wollastonite, scapolite, diopside, chondrodite, graphite, etc. The limestones may pass laterally into graphitic schists".

Since the correlation of sedimentary rocks on lithological grounds from such widely separated areas is an extremely unsafe procedure, the above descriptions are given for comparative purposes only, and the author feels that the age relationships discussed below are of more value in the tentative correlation of the rocks of the van Rhynsdorp region with those of the Hilda Series of the Richtersveld.

The oldest rocks mapped in the Richtersveld area belong to the three series of the Kheis System. Following a period of time, during which the Kheis rocks were folded and eroded, the sedimentation of the Gariep System commenced, and this in turn was succeeded by an orogenic period.

The intrusion of the Grey Gneiss was probably largely

contemporaneous with the latter part of this orogeny, and widespread granitisation of the older rocks took place.

The geological history of the Richtersveld as described above, finds a close parallel in the southern part of van Rhynsdorp. The Kheis System is represented by the highly metamorphosed rocks of the Nuwerus-Bitterfontein area, and on the farm Potklei in the present area a group of strongly sheared sericitic quartzites and mica schists have been correlated with the Kaaien Series. The rocks assigned to the Hilda Series were deposited after the Kheis rocks had suffered metamorphism on a regional scale. Then followed the formation of the Pink Gneiss by the extensive granitisation of the older rocks, particularly those of the Kheis System. There is evidence that the Pink Gneiss belongs to the same general period of igneous activity as the Grey Gneiss, being possibly a marginal phase of the latter.

These events are summarised in the following table.

<u>Richtersveld area.</u>	<u>van Rhynsdorp area.</u>
Intrusion of Grey Gneiss accompanied by granitisation of the older rocks.	Formation of the Pink Gneiss by extensive granitisation of the Kheis and possibly part of the Hilda Series.
Orogenic period.	Possible folding of the Hilda Series.
Deposition of the Gariep System.	Deposition of the Hilda Series.
Folding of the Kheis System.	Regional metamorphism of the Kheis System.
Deposition of the Kheis System.	Deposition of the Kheis System.

The above table shows that in both areas there was only one phase of sedimentation between the Kheis and the intrusion of the Grey and Pink Gneiss.

The author feels that on the above grounds there is sufficient justification in correlating tentatively the post-Kheis, pre-Pink Gneiss sediments of the van Rhynsdorp

region with the Gariep System. The author feels further that such a tentative correlation is to be preferred to the introduction of a new local name at the present time while the pre-Cape formations of the south-western part of the Union are undergoing intensive study and reclassification.

The Hilda Series in the area surveyed.

The Hilda Series in the area surveyed has been affected by several phases of rather severe earthmovements, and the resultant faulting thus prevents a complete description of the succession and of the thickness of the various component rocks. Extensive sand-cover also adds to the difficulties of correlating the outcrops throughout the area, but certain horizons, such as the dolomitic marble<sup>x</sup>, have aided in the correlation of the rocks of the Atlas and Vredendal area with those occurring on the farm Moedverloor.

Rocks of the Hilda Series constitute a horst on the farm Moedverloor, faulted on the north-east and south-west against the Nuwerus Series, and bounded in part on the north-west side by the Potklei-Moedverloor fault. The south-eastern portion of this horst is mainly sand-covered but it appears along the Hol River to the south of the Zoutfontein Trigonometrical beacon.

The majority of the rocks on Moedverloor are deeply weathered and fresh sections can only be obtained in some of the stream beds. The north-western portion of the horst is extensively veined with quartz, most of which appears to be related to faulting. This area is illustrated by Photograph No. 4.

<sup>x</sup> Shown on Map No. 2 by a capital D superimposed on the orange colour.



No. 4 . . . The extensive development of vein-quartz in the Hilda Series on Moedverloor.

In this area phyllites and arkoses predominate, with several minor horizons of sericitic quartz-schists. Some magnetite schists were also observed. In the small stream bed, a mile to the east of the old farmhouse, a weathered felspathic grit is cut by a pegmatite from the adjacent Pink Gneiss. A coarse-grained quartzite appears to lie near the bottom of the succession. All these beds have relatively high angles of dip and several of the less weathered schists are strongly cleaved.

Higher up in the succession phyllites and sericite schists appear and the dolomitic marble occurs near the top. The marble appears to be overlain by a thin bed of phyllite, weathered to a pink sericitic clay, which in turn is followed by about 50 feet of alternating quartzites and conglomerates. The marble appears in the Moedverloor stream opposite the farmhouse and at several other points for about a mile downstream. Opposite the farmhouse the marble has been partly replaced by jasper due to the circulation of iron- and silica-bearing solutions in small fault zones. The marble is again exposed about a mile and a half to the east of the farmhouse at the Namaqualand Marble Company quarries, where it is underlain by a biotite

schist. Prospecting operations with a diamond drill revealed a thickness of over 80 feet of marble at No.3 quarry, though it is doubtful if this represents the true original thickness since the marble is known to have been faulted off at this locality. A description of a typical core obtained during prospecting operations at these marble quarries is given below.

Bore-hole core in Hilda dolomite at Namaqualand Marble Company quarries, Moedverloor.

<u>Depth below surface.</u>	<u>Core description.</u>
<u>0-10 feet</u>	2 feet pale blue marble with mica. 6 feet of white. 1 foot of white with blebs of quartz $\frac{1}{8}$ " across. 1 foot mottled blue-white.
<u>10-20 feet</u>	1 foot of streaky blue with pink patches. 5 feet mottled blue-white with mica. 4 feet cream.
<u>20-30 feet</u>	1 foot of cream with thin bands of quartzite. 3 feet mottled blue-white. 3 feet near white. 2 feet white with mica. 1 foot streaky blue.
<u>30-40 feet</u>	2 feet of streaky blue with mica. bands. 1 foot pale blue. 7 feet of white with small blebs of quartz.
<u>40-50 feet</u>	1 foot white with green streak. 1 foot white with mica. 1 foot mixed marble-schist (breccia indicating zone of movement). 2 feet blue-cream. 5 feet micaceous blue.
<u>50-60 feet</u>	6 feet micaceous blue. 2 feet mottled blue-cream with pink tinge. 1 foot biotite schist. 1 foot blue-cream.
<u>60-70 feet</u>	7 feet blue-cream. 3 feet pale blue with pink tinge.
<u>70-80 feet</u>	3 feet blue-cream. 3 feet blue-cream with blebs of quartz. 4 feet micaceous blue-cream.
<u>80-90 feet</u>	10 feet cream with mica. Coarse-grained quartzite at 90 feet.

This core shows that the biotite schist occurs interbedded with the base of the marble, while other cores showed that the schist bands increase in thickness and number with depth, until they become dominant. The quartzite at the bottom of the core described above was encountered in several other holes and is approximately 4 feet thick. Pieces of a white, fibrous mineral were observed in one core and a search of the surface outcrops revealed small patches of tremolite in the marble in No.1 quarry.

In the following table three analyses are given of the dolomite at the marble quarries. No.1 quarry is near the base of the dolomite, No.2 nearer the middle and No.3 near the top.

The Dolomite at the Namaqualand Marble Co. Quarries.

	No.1 quarry	No.2 quarry	No.3 quarry
Silica & insol. silicates ...	0.16	1.55	2.25
(Fe, Al) <sub>2</sub> O <sub>3</sub>	0.86	0.44	0.71
CaCO <sub>3</sub>	56.03	54.43	54.73
MgCO <sub>3</sub>	42.80	43.67	42.03
	99.85	100.09	99.72

Analyst: G.T. Lamont.

The quartzites and conglomerates that appear to lie above the marble in the succession cap the ridge behind the quarries. Their exact relation to the marble is partly obscured by the fault which runs parallel to the ridge and cuts the marble off on the south-west side. Their appearance at intervals in the direction of the marble in the Hoedverloor stream opposite the farmhouse, suggests however that they occur about 20 to 30 feet above the marble in the succession. The quartzites are coarse-grained and frequently have a pitted appearance due to the weathering out of original felspar grains which are still

partly represented by kaolin. The quartz grains are colourless. The conglomerates consist of pebbles, up to one and a half inches in diameter, of vein-quartz and a fine-grained white quartzite, and are illustrated in Photograph No.5.



No.5. The conglomerate in the Hilda Series on Moedverloof.

A patch of Hilda rocks outcrops through the sand-cover about three miles south-west of the Zoutfontein Trigonometrical beacon, and it was possible to determine very approximately the following thicknesses and succession at this locality.

Biotite-quartz schist	50 feet
Dolomitic marble	200 feet
Quartz-sericite schist	50 feet
Platy, felspathic quartzites	200 feet
Alternating phyllites, grits, quartzites and arkoses.	800 feet
	<u>1,300</u> feet

In the Tsee Tsee River, below the Nuwedrif Trigonometrical beacon, the dolomite forms steep cliffs for almost a mile along the river banks. Further upstream towards Aties the dolomite passes under the graphitic

phyllites described on page 44, and the Basal Limestone Series. The contact is partly a faulted one. On the left side of the river, just south of the silcretes near the Nuwedrif beacon, there is a sink-hole in the dolomite, locally known as Swaarweergat. The dolomite in this area is underlain by phyllites which appear again above the dolomite beneath the succeeding felspathic sandstones. The dolomite at Swaarweergat must be in the neighbourhood of 200 feet thick. Between Swaarweergat and the railway cutting, near the railway bridge over the Troe Troe River, several outcrops of the top of the dolomite were seen through the thin phyllites, felspathic sandstones and grits. In the railway cutting, a hundred yards on the Vredendal side of the Troe Troe River bridge, the following sequence was determined.

Fine-grained arkose grading into felspathic quartzite

Decomposed phyllite (2 feet)

Dolomite

The felspathic quartzite has a pitted appearance and is very similar to the pitted quartzites associated with the conglomerates capping the ridge behind the marble quarries on Moedverloor. These arkoses and felspathic quartzites appear again above the dolomite near the road bridge over the Olifants River near Vredendal.

The dolomite occurs along the Olifants River between Vredendal and Klaver, associated with phyllites, felspathic sandstones and arkoses, and the arkoses and phyllites exposed near the Doorn River bridge, can, in all probability, be correlated with the Hilda Series.

There would appear to be a tendency in the Hilda Series to become more arenaceous above the dolomite. There are several occurrences of dolomite along the left bank of the Olifants River between Vredendal and Vlermuisklip,

and these are followed in the sequence by grits and sheared quartzites associated with grey phyllites. Strongly sheared, coarse-grained sericitic quartzites, occurring as thin lenses up to about 2 feet thick associated with grey phyllites, were observed at several places between Vredendal and Vlermuisklip. The quartzites frequently carry flattened pebbles of vein-quartz and occasional pegmatite, and these rocks resemble the sheared tillite occurring on Moedverloor. The rather abnormal, rapid alternation of coarse-grained arenaceous rocks and phyllites seems to indicate a tillitic phase.

These rocks appear to lie higher in the sequence than the dolomite, but the extensive sand-cover in this area obscures their relationship to the latter.

The phyllites of Bakleiplaas differ from any other formation in the Hilda Series described so far. They are similar in general appearance to the phyllites seen in parts of the Kners Vlakte, on the van Rhynsdorp-Nuwerus road south-east of Flaminkberg and those that underlie the Basal Limestones at the Gembokberg poort (p.48). They are also similar to some of the "Malmesbury" phyllites of the Western Province, such as those near Moorreesberg and at the foot of Mitchell's Pass. The Bakleiplaas phyllites are strongly cleaved and veined with quartz and vary in colour from dark grey to dark brownish-green. Referring to these phyllites and the sericitic quartzites mentioned above, Rogers wrote (21 p.145), "Very similar gritty rocks (the sericitic quartzites) crop out along the Olifants River at Naast Drift, where they overlie the whitish crystalline limestone or marble of Vredendal and underlie the great body of sericitic phyllites seen at Bakkely's Plaats (Bakleiplaas) and Melkboom, where the marble comes in again on the left bank of the river".

Arkoses, quartz-sericite schists and thinly-bedded,

platy, felspathic sandstones occur along the right bank of the Olifants River between Vredendal and Vlermuisklip. About a mile below the road bridge at Vredendal there are occasional outcrops of the grits, sheared quartzites and phyllites described above, and from their field relations appear to lie above the dolomite in the succession. The platy felspathic sandstones are well developed just above the right-bank irrigation canal south of Liebendal siding, and are illustrated by Photograph No.6. Between this point and the mouth of the Hol River strong faulting hinders an interpretation of the true sequence. The faults are marked by massive quartz-veins (Photograph No.7) and limonite-cemented fault-breccias.



No.6. Platy, felspathic quartzites south of Liebendal siding.



No. 7. Quartz-veins marking faults in the Hilda Series south of Liebendal Siding.

Small sheared garnets were observed in a platy sandstone just below the limestone quarries at Hol River.

Between Hol River and Viermuisklip extensive sand-cover intervenes, but several outcrops of weathered phyllites, arkoses and quartz-sericite schists were observed. The presence of some arenaceous phases near the mouth of the Hol River suggests that the rocks in this vicinity occur above the dolomite in the Hilda Series.

It is possible that certain of the rocks described above, such as those at Bakleiplaas and Gamsbokberg, do not belong to the Hilda Series. Since however they cover very small portions of the area surveyed, they have been included in the Hilda Series, and their accurate correlation will have to await an investigation of their relationships in the southern Kners Vlakte area.

The possible occurrences of post-Kheis, pre-Pink Gneiss sediments in the northern part of the van Rhynsdorp Division.

In the vicinity of the occurrences of Kheis rocks in the Klein Geerap and Sout Rivers mentioned on page 21, the

author observed some arkoses and phyllites very similar to those occurring in the Hilda Series on Moedverloer. These phyllites and arkoses have not attained the high grade of metamorphism seen in the neighbouring Kheis rocks, and it is possible that they represent an outlier of the Hilda Series which may have led Rogers to map all the rocks of this area as "Malmesbury Series" on Sheet 19, Nieuwerust.

In the author's opinion part of the Kners Vlakte is underlain by sediments which are of pre-Nama age and may therefore correspond to the Hilda Series mapped in the present area. The arkoses, which occur just above the road-bridge over the Sout River on the van Rhynsdorp-Nuwerus road, and similar rocks on Douse-the-Glim may be quoted as examples. The phyllites and schists beneath the outliers of Nuwerus quartzites to the south-east of Flaminkberg have already been mentioned.

Brink has observed a group of pre-Nama rocks in the Breektaand-Guaap sector ( 4 p.91) which appear to have been metamorphosed to a lesser extent than the typical Kheis rocks in the area surveyed by him. The rocks of the Nuwerus area which have attained this lower grade of metamorphism include sheared quartzites and arkoses, shaly layers and a limestone north of Guaap that "shows some signs of recrystallisation but no reaction between the quartz, felspar and calcite".

These occurrences are of interest since they appear to indicate a wider distribution of the Hilda Series than has been demonstrated by the present survey of the southern portion of the van Rhynsdorp Division.

THE KAIGAS SERIES

A tillite, succeeded by a quartzite, occurs on the farm Moedverloor. These rocks rest with a sedimentary contact on the Pink Gneiss, and all the other contacts against the neighbouring Hilda Series are faulted ones. From these field relations therefore, all that can be said regarding the age of the tillite is that it is younger than the Pink Gneiss. The tillite and quartzite are correlated, very tentatively, with the tillite recorded at the base of the Kaigas Series in the Richtersveld by Söhne and de Villiers (27 p.267).

The tentative correlation is based on the following considerations. The most recent published work on the numerous tillites that occur in the pre-Cambrian rocks of South Africa is that of Söhne and de Villiers on the geology of the complex Richtersveld region where at least seven distinct tillites have been recorded. The Moedverloor tillite is younger than the Pink Gneiss and must therefore also be younger than the tillites in the Kaalen Series and the Black Hills and Holgat Series of the Gariep System. The four tillites of post-Pink Gneiss age occur at the base of the Kaigas Series, in the Numees Series, in the basal-Nama Nabas Series and in the Dwyka Series. In correlating the tillite at Moedverloor with those of the Richtersveld area, the Numees and Dwyka tillites are rejected for the following reasons. In the type area at Numees limestone bands are intimately interbedded with the tillite, but no calcareous phase was seen in association with the Moedverloor tillite. These grounds of rejection are admittedly rather insecure, but in the light of the present incomplete knowledge of these formations over a wide tract of intervening country, they seem permissible.

An intensive search of the Moedverloor tillite failed to reveal any pebbles, such as banded jaspers, characteristic

of the Dwyka. The existence of banded jasper in the nearest known outcrops of Dwyka tillite is proved by its frequent occurrence in the river gravels of the van Rhynsdorp region, having been transported there by the rivers rising on the escarpment to the north-east. The sheared condition of the Moedverloor tillite also seems to exclude its correlation with the Dwyka.

There remain therefore for consideration the Nabas tillite and the basal Kaigas tillite. The Nabas tillite may be excluded on the grounds that no other tillite has been observed in the van Rhynsdorp region associated with basal Nama beds. The Nama beds at Gembokberg were followed from the unconformable contact between the Basal Limestones and schists and phyllites, belonging possibly to the Hilda Series, into the Nuwerus Series with no sign of a tillitic phase. Also, although the sheared condition of the Moedverloor tillite may be related to the extensive faulting in its immediate neighbourhood, it appears to have been affected by more severe earthmovements than are known to have involved the Nama sediments of this region. It must be mentioned however that there is a similarity in appearance between the quartzite overlying the Moedverloor tillite and a quartzite associated with the basal Nuwerus conglomerates at Flaminkberg. This similarity prompted the author to examine these basal conglomerates at Flaminkberg for striated pebbles, but none were found in the limited section covered.

Descriptions given by Rogers of beds resting on the gneiss and assigned by him to the Nieuwerust Series, are worthy of note. These descriptions include the following. "The Nieuwerust beds are highly micaceous for a few feet from the gneiss, and these mica schists ..... enclose thin broken bands of quartzite" (23 p.38). " .... on Rendavel there are good exposures of much sheared conglomerates, arkoses and

sandstones of this outlier. The boulders and pebbles are of greater variety than in any of the Nieuwerust beds yet described, though they are rather sparsely scattered through the highly sericitic matrix. One granite boulder two feet long was noticed and smaller ones of pegmatite, quartzite, vein-quartz, felspar-quartz schists and slaty rocks occur" (23 p.39). Referring to a conglomerate on the Karoetjies Kop shore, Rogers wrote (23 p.39) ".... the rock has been very much sheared. The pebbles and boulders are not closely packed; they consist of gneiss, quartzite, quartz and slaty rocks. .... The largest boulder of gneiss seen, a porphyritic variety, is eight feet long".

The author is inclined to doubt the correlation of these conglomerates and quartzites with the basal beds of the Nama System which occur in contact with the gneiss of the van Rhynsdorp region. The highly sheared condition of these beds, the presence of quartzites, schists and slaty rocks and boulders two and eight feet long seem to be more in keeping with the features of the Moedverloor tillite than with the typically unsheared basal conglomerates of the Nama System. It is possible therefore, that a tillite of post-Pink Gneiss, pre-Nama age has a relatively wide, though patchy distribution in southern Namaqualand.

It is suggested that the Moedverloor tillite and quartzite, and possibly the rocks as described above by Rogers, be correlated tentatively with the tillite at the base of the Kaigas Series in the Richtersveld region.

The tillite on Moedverloor occurs in the stream-bed several hundred yards south of the old farmhouse. It lies with a sedimentary contact against the Pink Gneiss at this locality and is succeeded by a blue-grey quartzite. The tillite is strongly sheared and has a foliation parallel to the gneiss-tillite contact. This foliation makes an angle of about 70° with that of the adjacent gneiss, a feature which

affords additional proof of the sedimentary contact. The tillite, which dips steeply towards the gneiss, shows rapid lateral variation in thickness and is absent in places between the gneiss and the quartzite. The greatest thickness of tillite observed was 50 feet. Thin bands of quartzite appear in the tillite near the top where it passes into the main quartzite. Between 50 and 100 feet of quartzite occur between the tillite and the fault which cuts these rocks off against arkosic grits and phyllites of the Hilda Series on the north-eastern side.

Outcrops of the quartzite occur along the west bank of the Moedverloor stream between the locality described above and a point on the road approximately half a mile north of the present farmhouse. The tillite appears to be absent between the gneiss and the quartzite over most of this distance, but outcrops again at the point on the road mentioned above. This important exposure is unfortunately surrounded by sand but the tillite and quartzite may rest on the Hilda Series in this neighbourhood. No other outcrops of these rocks were seen in the area surveyed.

In the field the tillite appears as a light grey, strongly sheared, micaceous matrix in which are set numerous inclusions ranging from boulders at least three feet in length, through pebbles to fine-grained material indistinguishable from the matrix. Characteristic tillitic features, such as the haphazard distribution of boulders and lack of sorting or layering, are demonstrated by the Moedverloor occurrence. As is the case with several of the pre-Cambrian tillites in the Union, subsequent shearing has obliterated practically all signs of original striations on the inclusions. The larger boulders are sheared and are generally aligned with their longer axes parallel to the foliation of the matrix, features often observed in the Numees tillite.

The majority of the inclusions in the tillite are gneiss, but vein quartz and a light coloured quartzite are also represented. Occasional pebbles of pegmatite similar to the ones that occur in the neighbouring gneiss were also observed. The gneiss boulders resemble some varieties of the Pink Gneiss of the area, but are usually lighter in colour due possibly to leaching. The sheared and partially decomposed nature of the gneiss inclusions render reliable microscopic identification impossible.

Under the microscope, the matrix of the tillite is seen to consist of an ill-sorted mixture of angular quartz and microcline-felspar grains with occasional small pieces of gneiss. Sericite occurs in the groundmass and frequently forms wisps surrounding the larger grains. The parallel arrangement of the porphyroblastic biotite suggests that this mineral is related to the shearing. The biotite appears to have been derived in part from sericite and intermediate forms of these two minerals are present. A similar occurrence of biotite, remote from any known igneous mass of a younger age, was observed in a slice of a grit associated with the Numees tillite near the type area of that formation.

In handspecimen the quartzite above the tillite appears dark grey-blue in colour and it contains grains of the blue quartz which appear to be characteristic of many of the post-Pink Gneiss quartzites in this region. Microscopic examination shows the rock to consist of grains of indented quartz showing considerable variation in size, and occasional relatively large grains of microcline. Segregations of iron-ore particles between the quartz grains may be partly responsible for the dark colour of the rock.

The inclusions in the tillite and the composition of the quartzite suggest that these rocks were derived from

the Pink Gneiss. The quartzites which occur as pebbles in the tillite may have originated from the Kaaien Series represented by quartzites on the farm Potklei approximately five miles to the north-west of the tillite occurrence.

THE NAMA SYSTEM.

Sediments of the Nama System cover a considerable portion of the area surveyed. These sediments, together with those of the Nuwerus area lying immediately to the north, constitute the most southerly known development of the Nama System, although it is possible that certain phases of the general term "Malmesbury Series" of the south-western Cape may shortly be correlated with this system.

In the southernmost part of the van Rhynsdorp Division two series of the Nama System have been mapped, viz. the Basal Limestone Series and the Nuwerus Series. The Basal Limestone Series is comprised of from 1,000 to 2,000 feet of limestones with minor dolomitic horizons, and was previously correlated with the Malmesbury Series. These limestones have been shown to underlie the Nuwerus Series conformably, and therefore represent a hitherto unrecorded basal phase of the Nama System. The Nuwerus Series, represented by arkoses, quartzites, phyllites and sericitic schists, is recognised, but the succeeding Schwarzkalk Series of the Nuwerus area is not present.

In this region the Nama is the only system at present known which is younger than the Kaigas Series, but of pre-Cape System age. It has been shown to rest with a sedimentary contact on the Pink Gneiss in the Nuwerus area (Rogers and Brink), and at Windhoek, south of van Rhynsdorp, the Table Mountain Sandstone overlies the Basal Limestone Series unconformably.

The Basal Limestones would appear to have been deposited in a marine trough lying to the south of the Nuwerus area. Deposition of the Nuwerus Series commenced with a marine transgression across the landmass bordering the marine trough; and the lithology of the Nuwerus sediments strongly suggests that they were derived from an essentially

granitic terrain, and that they were deposited under relatively shallow conditions.

The Nama System in the region has been folded on a comparatively small scale, but tectonic movements are represented by two phases of faulting, essentially of a tensional nature. There is evidence that this faulting is of a pre-Cape age.

### The Basal Limestone Series

The name Basal Limestone Series is assigned to an extensive development of dark coloured limestones with minor dolomitic horizons, occurring at the base of the Nama System in the southern part of the van Rhynsdorp Division. These rocks had previously been correlated by Rogers with the Malmesbury Series, including the Aties group. The dark coloured limestones of the Aties group are now recognised as the Basal Limestone Series, while the lighter coloured, cream to brownish dolomites of the Aties area, are correlated with the Hilda Series of the Gariep System.

Basal Limestones, previously mapped as part of the Malmesbury Series on Sheet 19, Nieuwerust, occur at the following localities in the present area: along the course of the Groot Graafwater on the farms Luiperskop, Wolwernest and Rooiberg, on the farm Klipdrift they are exposed in the Moedverloor stream just above its influence with the Hol River, and also at Vlermuisklip. The blue, grey and white limestones and dolomites in the Tree Tree and Widow Rivers, between the farm Aties and van Rhynsdorp, are now considered to belong to the Basal Limestone Series. The blue and white limestones mentioned by Rogers (22p.16) as outcropping between Vlermuisklip and Kokenaap would also seem to belong to the Basal Limestone Series.

During April of 1947, the author assisted in prelimin-

ary prospecting operations in the van Rhynsdorp area for high grade limestone suitable for the manufacture of Portland cement. A traverse up the Widouw river was made and the limestone outcrops were sampled at approximate intervals of 500 yards. The localities at which samples were taken, together with the localities on the farm Sandkraal are shown on Map No. 3. The Widouw River was selected for sampling because it runs roughly at right angles to the strike of the limestones, and because of the continuous series of outcrops available. The analyses of these samples, together with two from a marble quarry in the Basal Limestones just south of the farm Sandkraal, and one from the Basal Limestones on Moedverloor south-west of the Luiperskop Trigonometrical beacon, are given in the following table.

Sample No.	1	2	3	4	5	6
Silica and acid-insolubles	2.24	0.24	1.36	1.08	0.44	0.24
(Fe,Al) <sub>2</sub> O <sub>3</sub>	2.16	0.68	1.72	1.20	0.52	0.60
CaCO <sub>3</sub>	94.90	62.15	62.09	88.86	63.47	62.09
MgCO <sub>3</sub>	1.57	36.98	35.54	9.27	35.44	37.00
	100.96	100.05	100.71	100.23	99.87	99.93

1-16. Widouw River and Sandkraal. Analyst; McLachlan and Lazar, Johannesburg.

17-18. Widouw Marble Quarry. Analyst; J. Muller, Cape Town.

19. Moedverloor. Analyst; G.T. Lamont.

The general trends of the limestone and dolomite horizons in the Basal Limestone Series, based on the above table of analyses, are indicated on Map No. 3. There is a general dip to the south-west in the area traversed, and evidence of some strike-faulting suggests that the sequence has been repeated. The investigation proved, however, that

high grade limestone predominates in the series. A large number of samples, collected from all the larger outcrops in the area mapped, were tested in the field with cold dilute hydrochloric acid and the majority indicated high calcium carbonate contents.

An intensive diamond drilling programme at the Hol River quarries of the National Portland Cement Company proved high grade limestones to depths of approximately 200 feet. Several thin dolomitic horizons were struck near the bottoms of the deeper bore-holes.

In the light of the above information it may be concluded that the Basal Limestone Series is composed essentially of limestones with high calcium carbonate contents, and subordinate dolomitic horizons.

The Basal Limestones invariably give off a smell of  $H_2S$  when hammered, and this is particularly noticeable in the case of the darker coloured horizons. This smell is also noticeable in the neighbourhood of the trucks loaded with the quarried stone at the Holrivier quarries. Rogers (22 p.15) mentioned this characteristic when describing the blue limestones of Aties. He wrote "The darker coloured rocks give out a strong smell when broken, just as the dark beds in the carboniferous limestone of England do when crushed".

Associated with the Basal Limestones at Aties, there occurs a group of phyllitic rocks. On account of the rather severe faulting in this area, the exact relationship between these phyllites and the Basal Limestones could not be established and the phyllites are tentatively correlated with the Hilda Series. They may however constitute a lower phase of the Basal Limestones being partly interbedded with them. Since they were not seen at the base of the limestones at Gembokberg, and since they are strongly veined with the quartz breccias characteristic of the

Hilda Series, they are considered as being older than the Basal Limestone Series. The phyllites range in colour from blue to black due to the presence of graphite. Rogers (22 p.17) mentions a weathered specimen of these phyllites, described as a plastic clay, as having a carbon content of 46.42%.

If these carbonaceous phyllites prove to be contemporaneous with the Basal Limestones, an interesting point arises concerning the possible origin of these calcareous rocks. The carbonaceous nature of both the phyllites and the limestones, and the presence of  $H_2S$  in the latter, suggest that organic matter may have been present in the original calcareous sediments, and therefore that these limestones may be partly of algal origin. A careful search of the limestones in the whole region however, revealed no trace of fossils since these, if originally present, must have been destroyed by the recrystallisation the limestones have undergone. A slab of limestone collected at Gembokberg showed some peculiar surface markings, roughly half an inch in diameter, some of which were semi-circular and some horse-shoe shaped. The slab was etched with dilute acid and polished in the laboratory, but these markings proved to be due to a differential surface weathering effect.

The recrystallisation of the Basal Limestones is particularly noticeable in the lighter coloured horizons, and individual grains attain sizes up to 3 mm. Since there are no known igneous masses in the region of post-limestone age, with the exception of minor dolerite intrusions, the recrystallisation of the Nama limestones is ascribed to dynamic metamorphism induced by the load of overlying sediments and earth movements.

Solution and reposition of carbonates by liquids no doubt also played a part. The Basal Limestones in the

region must have been overlain by a considerable thickness of sediments, including the Cape System and possibly part of the Karroo System (the Dwyka Series of the latter being present on the escarpment to the north-west). This view is supported by the theory of Continental Drift ( p.113) since, according to this theory, the Cape and Karroo Systems must have extended west of the van Rhynsdorp region in pre-Cretaceous times. The view that the Cape System extended over the region is further supported by the occurrence of Table Mountain Sandstone north of the mouth of the Olifants River. The other Nama series, namely the Nuverus and Schwarzkalk, may not be included in the overlying load of sediments, because the Table Mountain Sandstone is seen to overlie the Basal Limestones unconformably at Windhoek south of van Rhynsdorp, and therefore the Nuverus and Schwarzkalk Series, if originally present, must have been eroded away before the younger Cape and Karroo sediments were deposited.

Extensive quarrying in the Basal Limestones at Holrivier has revealed some interesting sections that were examined in some detail. The rock varies from medium- to coarse-grained, and in colour from light grey to pale blue. Mineralised veins of calcite occur at several places in the quarries and would appear to be connected with a flat-lying system of joints. These veins are not consistent in thickness and tend to swell and pinch out over distances of 10 to 20 feet. They consist essentially of coarsely crystallised calcite with occasional patches of clear glassy quartz. A peculiar feature of the calcite is the strong smell of  $H_2S$  it gives off when hammered, similar to that of the surrounding limestone. Purple fluorite, in the form of cubes and distorted octahedra up to 2 inches in size, occurs in the calcite. One large piece of this fluorite gave off a very strong smell of  $H_2S$  when fractured.

Pyrite and white mica also occur in the calcite veins.

The occurrence of these minerals in the limestone suggested the proximity of a mass of igneous rock of post-limestone age. The nearest known outcrop of Pink Gneiss is approximately 4 miles away, but the limestones are known to be of post-Pink Gneiss age. During a discussion of this point with Drs. Truter and de Villiers, of the Geological Survey, they suggested to the author that the occurrence of these minerals did not necessarily indicate the presence of post-limestone igneous intrusion. They quoted the following instances of the occurrence of fluorite and pyrite unassociated with any known igneous activity.

1. On Tooykraal (36 p.22) fluorite occurs in a definitely post-Karoo fault.
2. In the Leeupoort area (3 p.09) the post-Karoo fault trending just N. of E. is filled with fluorite at present being worked by Iscor.

No post-Karoo igneous activity is known in the Bushveld where these two localities occur.

Dr. de Villiers also informed the author that galena occurs in the Schwarzkalk Series near Modderdrif, and that he and Dr. Söhne have adduced proof in a paper to be published shortly on the Kuboos, to show that the Kuboos granite is older than the Nama. Therefore this galena appears to be unconnected with any known igneous activity. Dr. de Villiers also mentioned the following occurrences of pyrite unconnected with igneous activity; pyrite cubes in the Ecca and Beaufort south of the dolerites, pyrite cubes in the Kuibis, and pyrite in coal seams. The author has also observed limonite after pyrite in the basal arkoses of the Nuverus Series and in the Bokkeveld Series.

From these instances of fluorite, pyrite and galena occurring in formations remote from any known igneous

activity, it seems permissible to assume that the mineralisation of the Holrivier limestone need not necessarily be connected with an igneous phase.

Mineralisation of the Basal Limestones was not observed at any other locality, and no traces were revealed by a careful examination of two diamond drill cores obtained during prospecting operations in the limestones on the northern boundary of the farm Moedverloer.

An estimate of the thickness of the Basal Limestones was made in the poort out through these rocks by the Sout River at Gamsbokberg. These limestones are illustrated by Photograph No. 8 which was taken looking downstream from the north-eastern end of the poort.



No. 8. The Basal Limestones in the Sout River poort, Gamsbokberg.

At this point the limestones overlie grey phyllites and a pale green phyllitic schist containing small octahedra of magnetite. Both these rocks are highly cleaved and are veined by quartz carrying cavities filled with epidote; these rocks are tentatively correlated with the Hilda Series. It is noticeable that the limestones are not out by these quartz veins. The older rocks appear to occupy the core of an anticline in the limestones, the south-

western limb of which forms the Gamsbokberg ridge. The limestones extend for 600 yards through the poort, and have an average dip of approximately  $30^{\circ}$  to the south-west, which gives a true thickness of 900 feet for the series. During the traverse up the Widow River mentioned previously, an estimate of over 2,000 feet was made for the thickness of the Basal Limestones in that area. No reliable estimate of the thickness could be made along the course of the Groot Graafwater because of sand cover, but it would appear to be similar to that measured at Gamsbokberg. Sand cover and faulting similarly prevented measurements at Holrivier and Vlermuisklip. From the Gamsbokberg and Widow River estimates however, it may be stated that the Basal Limestones increase in thickness when followed towards the south, from nearly 1,000 feet at Gamsbokberg to between 2,000 and 3,000 feet south of van Rhynsdorp. This thickening in a southerly direction is a characteristic of both the Basal Limestone and Nuwerus Series, and was also observed by Brink in the latter series further north.

The longest outcrop of Basal Limestones in the area surveyed, extends from a point north-north-west of Luiperskop, all along the course of the Groot Graafwater to a point where that river turns to the south at Rooiberg, a distance of almost 10 miles. Exposures of limestone in small streams, and the extensive development of gypsum in the sand-covered area between Rooiberg and the beginning of the Gamsbokberg ridge, strongly suggest that this gap is underlain by limestones, so that from the point mentioned north-north-west of Luiperskop to the end of Gamsbokberg, the Basal Limestones extend for about 15 miles. All along the south-west side of this extensive belt the basal arkoses and quartzites of the Nuwerus Series occur. The nature of the conformable contact between the two series is described

on page 59.

South and south-east of Gamsbokberg the limestones occur but are frequently sand-covered, especially to the south-east in which direction they extend to link up with the limestones at van Rhynsdorp. Photograph No. 9 illustrates the limestones along the Scout River about 2 miles south-west of the Gamsbokberg poort. In this area the limestones are gently folded along N.W.-S.E. axes.



No. 9. Basal Limestone cliffs along the Scout River below Gamsbokberg.

An extensive belt of the Basal Limestones, brought to the surface partly by an anticlinal structure, extends from the northern portion of Moedverloor in a south-easterly direction towards Bergplaas. These limestones have several thin phyllitic phases near the top of the sequence and pass into the quartzites, phyllites and sericitic quartz schists of the Nuwerus Series with only a minor development of the arkoses characteristic of the basal Nuwerus Series at Gamsbokberg. While carrying out a diamond-drilling programme in connection with marble prospecting operations, the author was able to examine two cores from the top of these limestones on Moedverloor. The following is a description of one of these cores recovered from practically

horizontal beds.

Bore-hole core in upper Basal Limestone Series, Moedverloor.

<u>Depth below surface.</u>	<u>Core description.</u>
<u>0-10 feet</u>	7 feet coarse-grained, dark blue limestone. 3 feet of mixed clay and dark grey phyllite, being in part a solution cavity.
<u>10-20 feet</u>	3 feet phyllite. 3 feet medium-grained blue limestone. 1 foot of calcite, probably a vein. 3 feet alternating dark blue limestone and grey phyllite.
<u>20-30 feet</u>	2 feet medium-grained dark blue limestone with thin phyllitic bands. 8 feet medium-grained, mottled, dark blue limestone.
<u>30-40 feet</u>	1 foot similar to previous 8 feet. 3 feet of mixed phyllite, calcite and gypsum, probably in a zone of movement. 6 feet of medium-grained, dark blue limestone.
<u>40-50 feet</u>	1 foot similar to previous 8 feet. 1 foot of coarse-grained, dark blue limestone. 1 foot of blue limestone with thin phyllitic bands. 7 feet coarse-grained, dark blue limestone.
<u>50-60 feet</u>	8 feet similar to previous 7 feet. 2 feet of alternating phyllite and limestone.
<u>60-70 feet</u>	3 feet similar to previous 2 feet. Hole stopped at 63 feet.

The core described above shows the presence of frequent thin phyllitic horizons in the upper portions of the Basal Limestones. It is of interest to note the presence of gypsum in a shattered zone in the limestone, and this supports the view that some of the gypsum deposits in this region have resulted from the reaction between the limestone and  $H_2SO_4$  produced by the oxidation of the  $H_2S$  which is universally present in these limestones.

Several outcrops of the limestones surrounded by Basal Nuwerus beds, were mapped between the Groot Graafwater north of Bergplaas and Beeswater on the Sout River. These upper-

most limestones are almost invariably fine-grained and dark in colour. The limestones are extensively developed along the north-eastern side of the Olifants River from a point about 2 miles south-east of the mouth of the Hol River, as far as Vlermuisklip; rocks of a similar nature are reported by Rogers (22p.16) to occur beyond the latter place in the direction of Kokenaap. The relationship between these limestones and the Hilda Series of the area is obscured by extensive faulting and sand cover. The occurrence of limestone beneath the red sand is occasionally indicated by thick deposits of calcrete, as for example below Vlermuisklip station, and along the railway line between Liebendal and Lossand.

A pale blue quartzite associated with arkoses occurs in the railway cutting near the bridge over the Hol River. These rocks probably represent basal beds of the Nuwerus Series overlying the limestones of the Hol River.



No.10. The Basal Limestones at Vlermuisklip.

On the southern side of the limestone ridge at Vlermuisklip, shown in Photograph No.10, there occur some thin purple phyllites, arkoses and bluish quartzites, the latter carrying grains of blue quartz. This suggests that the Vlermuisklip limestones occur at the top of the Basal Limestone Series. Across the Olifants River from

Vlermuisklip, i.e. on the left bank, there are exposures of rocks of the Hilda Series, and this supports the view that at this point the Nama System has been faulted down on the north side against the Hilda Series.

Several outcrops of dark limestone were observed on the south-west side of the Olifants River, between Vlermuisklip and a point opposite the mouth of the Hol River. These outcrops may represent outliers of Basal Limestone, but extensive faulting and sand-cover prevent a definite correlation between them and the limestones at Vlermuisklip and Holrivier.

THE NUWERUS SERIES.

The Nuwerus Series forms the base of the Nama System in the northern part of the van Rhynsdorp Division, where it has been described in detail by Brink (4 p.153 et seq.). In the latter area the series is represented by arkoses, arkosic grits, felspathic sandstones, felspathic quartzites and practically pure quartzites with a few instances of thin chloritic shaly layers near the base. Brink noticed a general tendency in the Nuwerus Series to become less felspathic from the base upwards, and this feature was also observed in the present area.

Lateral and vertical variation in the series is a marked feature, especially in the lower portions, and this prevents the recognition of definite horizons at widely separated points and adds to the difficulties in the mapping of the series in sand-covered areas. This variability suggests rapidly changing conditions of deposition and is more fully discussed elsewhere.

The great majority of the quartzites of the Nuwerus Series are characterised by the presence of grains of blue quartz in addition to the more normal colourless and white grains. This feature is of great help in distinguishing between the Nama quartzites and those of the Hilde Series in which blue grains, if present, are of a much paler colour and occur in much smaller amounts. The typical blue quartz of the Nama quartzites was derived, in all probability, from the Pink and Grey Gneisses of the southern portion of Namaqualand, in which rocks it frequently occurs as quartz veins and as the constituent grains of the gneiss itself. This blue quartz is markedly developed in the gneiss immediately to the south of Garies where it occurs in the gneiss itself and in the associated quartz veins and pegmatites.

During two visits to the Steinkopf area, the author

was able to examine the quartzites from several horizons in the Steinkopf Beds and found it impossible to distinguish between these rocks and the Nuwerus quartzites of the van Rhynsdorp region. It is of interest that grains of blue quartz were observed in the quartzites at Steinkopf, though not in the same quantity usually present in the Nuwerus. A very characteristic weathering phenomenon was observed in the quartzites from both these localities. It is most frequently observed when a boulder about 6 inches in diameter is split open to reveal a core of whitish to pale blue, glassy quartzite surrounded by a weathered ring having a pale purple colour which grades into an outermost shell of an amber colour. This effect is responsible for the purple and brownish colours so typical of many of the outcrops of Nuwerus quartzites.

The continuity of the Nuwerus Series in the area mapped with that of the Nuwerus area mapped by Brink, was established by following the quartzites occurring in the neighbourhood of Luiperskop to the north-west where they are cut off against the Pink Gneiss by the Potklei-Moedverloor fault, and then northwards via Mostertskop to the Witputs area south of Nuwerus. These typical blue and purple quartzites were also observed to the south of the Flaminkberg area, where, in the author's opinion, they overlie phyllites and schists tentatively correlated with the Hilda Series, but mapped on Sheet 19, Nieuweraast as Ibiqus Series.

The conformable nature of the contact between the Nuwerus and Basal Limestone Series can be observed at Gembokberg just below the Sout River poort. Extensive erosion has exposed the contact and the following sequence was determined.

Pale blue quartzite		10	feet
Arkose		20	"
Dark, fine-grained limestone		15	"
Blue quartzite		10	"
Basal Limestones	approx.	900	"

The occurrence of 15 feet of limestone following upon the first blue quartzite of the Nuwerus Series is an important feature which strongly suggests that the deposition of the Nuwerus Series commenced immediately after the formation of the main limestones had ceased.

Above the base of the Nuwerus Series given in the above table, there follow rapid alterations of arkoses and quartzites with occasional shaly to phyllitic horizons. The quartzites and arkoses vary in thickness of individual beds from 1 foot to about 20 feet. Photograph No. 11 shows these alternating quartzites and arkoses.



No. 11. Alternating arkoses and quartzites  
in the lower Nuwerus Series at Gembokberg.  
(Dip slopes of the Basal Limestone Series  
form the ridge on the skyline.)

The figure in the photograph is standing on an arkose horizon which has been weathered away to a greater extent than the more resistant quartzite just to the left. The dip slopes of the Basal Limestones forming the

Gemsbokberg ridge can be seen on the skyline on the left and in the middle of the photograph.

Approximately 500 feet above the base of the Nuwurus Series some 150 feet of pale blue quartzites form a small ridge rising above the sand parallel to the main limestone ridge. A similar parallel ridge lies a considerable distance to the south-west, and suggests that a synclinal structure is present. The limestones come to the surface again to the south-west of this second quartzite ridge and must therefore form the south-west limit of the syncline.

The structure of the Nuwurus Series in the synclinal trough is complicated by a series of minor strike faults which repeat the succession on a small scale. The following general succession for the series was however established.

Alternating quartzites, phyllites and arkoses	650 feet
Pale blue quartzites	150 "
Alternating quartzites, arkoses and occasional shales	450 "
Quartzite	10 "
Arkose	20 "
Limestone	15 "
Quartzite	<u>10</u> "
Approximate total thickness	<u>1300</u> "

The arkoses vary in colour through the following range: light yellow, buff, brown and brick red. Felspathic grits occasionally occur in the sequence. Blue, purple, mauve, yellow and greenish clay bands probably represent weathered shale horizons. Cubes of limonite, pseudomorphic after pyrite, occur in several of the arkosic beds, especially the finer grained ones.

The quartzites of the Nuwurus Series can be followed, projecting above the intervening sand, from the Gemsbokberg area in a north-westerly direction to the Groot Graafwater

hills formed by the arkoses and quartzites of the lower Nuwerus Series rise above the plain on the east. The occurrence of these basal members on the west, and quartzites characteristic of the middle portion of the Nuwerus Series on the east, supports the view that a north-south trending fault, with a downthrow on the east side, exists parallel to the Groot Graafwater in this area. This view is further strengthened by the extensive sheets of white quartz pebbles derived from veins marking a fault-plane which cover parts of the flats to the east. Such a fault would cause the Gembokberg synclinal structure to pitch towards the north-west and lineation measurements in the area confirm this.

The beds of the Rooiberg area are similar to those of the lower Nuwerus at Gembokberg. Photograph No.12 shows the alternating quartzites, arkoses and phyllitic phases exposed in a tributary of the Groot Graafwater. The distant hills near Luiperskop are capped by blue quartzites of the upper Nuwerus.



No.12. Quartzites, arkoses and phyllitic phases of the lower and middle Nuwerus Series near Rooiberg.

Photograph No.13 illustrates the mode of weathering of the arkoses near Rooiberg, several horizons of which

carry limonite pseudomorphs after pyrite.



No. 13. Arkoses of the Nuwerus Series near Rooiberg.

From Rooiberg towards Luiperskop the rocks rise in the succession until the upper blue quartzites, with minor horizons of mauve and pink phyllites, cap the prominent ridges. These rocks persist in a north-westerly direction across the northern portion of Moedverloor to Mostertskop where they are cut off against the Pink Gneiss by the Potklei-Moedverloor fault.

To the north-east of the Luiperskop-Rooiberg ridge along the Groot Graafwater valley, the Nuwerus beds overlie the Basal Limestones. The nature of this contact was examined by traversing across the valley from a point north of Luiperskop towards the Trigonometrical beacon. Just south of the river isolated patches of quartzites were observed, apparently overlying the limestones, but sand cover conceals the nature of the contact. An extensive development of vein quartz and limonite suggests however, a series of strike faults, and these quartzites may be a small graben of Nuwerus beds in the limestones. Nearer the beacon the arkoses and quartzites of the Nuwerus Series are seen to overlie the limestones conformably. It is noticeable at this locality that the arkoses are developed

to a lesser extent and that the lower beds of the Nuwerus Series show a definite tendency to thin out in a north-westerly direction. A similar thinning of the arkoses was also observed above the limestones south of Luiperskop on the northern portion of Moedverloor.

South of the Luiperskop ridge the Nuwerus Series is represented mainly by the middle and upper blue quartzites and their associated pink and mauve phyllites, with occasional quartz-sericite schists which may replace in part some of the arkosic horizons. In this area the series is repeated several times by strike faults which are marked by limonitic breccias. Some minor folding is present, but the dips, approaching  $30^{\circ}$  in places, are due mainly to block faulting and tilting. The competent quartzites have in some cases suffered slight shattering, while small drag folds have been induced in the softer, interbedded argillaceous horizons.

The quartzites of the upper Nuwerus are generally coarse-grained and occasionally show conglomeratic phases. About two and a half miles west of the gypsum diggings at Bergplaas several koppies lie half a mile west of the road to Bergplaas, and on one of these koppies, marked by a stone beacon erected during the survey, a conglomeratic phase was observed in the quartzites. Pebbles of blue quartz and fine grained quartzite, up to 1 inch in diameter, occur in a coarse-grained quartzitic matrix. As illustrated by the quartzites in this locality, the bedding in these massive rocks can often be discerned only by bands of grains of the characteristic blue quartz.

The ridge to the south-west of the stream just south of Bergplaas is built up of a thicker phase of the phyllites and quartz-sericite schists of the middle and upper Nuwerus Series than was observed in other parts of the area. This ridge is seen in Photograph No.32 (p.109)

types occur in the present area. It is possible that more intense earth movements in the southern area were responsible for their formation. They would appear to correspond to the chloritic shales that occur in the Nuwerus Series in the northern area.

The Probable Mode of Deposition of the Nama System in the van Rhynsdorp Division.

The Basal Limestone Series is known only from the area to the south of Nuwerus, where it shows a tendency to thicken when followed from the Groot Graafwater area in a south-easterly direction towards van Rhynsdorp. Brink (4 p.183 et seq.) has shown that the Nuwerus beds at the base of the Nama in the area mapped by him, rest upon the Pink Gneiss or on the rocks of the Kheis System, and he has suggested that they represent, in part, deposits of a terrestrial origin. As evidence he mentions the lens-like habit of the basal conglomerate bands and the inconsistency of successive layers. He says further, "Sometimes the deposits were formed on dry land on the granite surface as indicated by the 'insitu' arkoses. Higher up in the succession around Nuwerus the sediments are less felspathic and the thin purplish Nuwerus quartzites of the northern area, in the vicinity of Draaihoek and Groot Riet are almost felspar-free; and the conditions of deposition may have been shallow marine". Brink also considers that the Schwarzkalk which follows the Nuwerus Series conformably, is of shallow marine origin.

The above observations by Brink, together with observations made in the area to the south, have led the author to submit the following generalised scheme for the mode of deposition of the Nama System in the van Rhynsdorp Division.

behind the mission church and huts. These argillaceous rocks must attain a thickness of several hundred feet and contain some quartzite horizons. The phyllites and schists are almost invariably in a highly weathered state that renders difficult a description of their original composition.

The Zoutfontein Trigonometrical beacon is situated on a koppie composed of Nuwerus quartzites surrounded by an extensive area of red sand. This outcrop is useful in mapping the continuation of the Nuwerus quartzites which lie to the north of the horst of Hilda rocks on Moedverloor. Beyond the sand cover to the east of the Zoutfontein beacon, arkoses and quartzites of the lower Nuwerus Series occur overlying the Basal Limestones in the vicinity of the confluence of the Varsche and Sout Rivers.

Blue quartzites, pink phyllites, a grey felspathic sandstone and quartz-sericite schists occur on the south-west side of the fault bounding the horst of the Hilda Series on the southern part of Moedverloor. These rocks are correlated with similar ones of the upper Nuwerus Series on the northern portion of Moedverloor. A quartzite carrying grains of blue quartz was observed at a point just south-west of the fault crossed by the road from Holrivier siding to Beeswater, to the south-west of the Zoutfontein beacon. This quartzite would appear to correspond to the quartzites mentioned above on Moedverloor to the south-west of the Hilda Series horst fault, and is correlated with the Nuwerus Series.

The blue quartzites of the Nuwerus Series associated with the Basal Limestones at Holrivier and Vlermuisklip have been mentioned in connection with the Basal Limestones at these places.

Although phyllites and sericitic quartz schists were not recorded in the Nuwerus Series by Brink, rocks of these

The Basal Limestones were deposited in a marine trough that lay to the south of a landmass composed in the main of gneiss and also of other rocks of pre-Nama age. The old shore-line of this trough would appear to have extended from the neighbourhood of Mostertskop (north-north-west of Luiperskop) in a general south-easterly direction towards van Rhynsdorp. The floor of this trough probably consisted of Pink Gneiss and sediments of the Hilda Series.

The rising level of the Nama Sea flooded the trough and the deposition of the calcareous Basal Limestones commenced. A rise in sea-level, rather than a general sinking of the landmass, seems more probable when it is remembered that about 300 miles to the north a similar calcareous, basal Nama phase was in the process of formation under somewhat similar conditions in the Nabas area.

In connection with the formation of these basal calcareous phases of the Nama, it is of much interest to quote du Toit (8 p.491) on the Transvaal-Nama marine submergence; "That the whole of this huge area then subsided beneath the waters of the ocean cannot be doubted, it being furthermore not unlikely that the great and extensive limestone formations in Katanga and along the Lower Congo were contemporaneously formed".

Following the filling up of the trough with limestones, the sea-level continued to rise with the resultant flooding of the low-lying coastal portions of the pre-Nama continent. Rapid oscillations of sea-level during those times are indicated by the numerous sudden changes in the lithology of the basal Nuwerus beds from predominantly quartzitic to arkosic and argillaceous phases, and also by the occurrence of deposits characteristic of the littoral conditions which have been observed by Brink in the Nuwerus area. The similarity between the basal Nama phases in both the van Rhynsdorp and Steinkopf regions strongly suggests that this

marine transgression across the pre-Nama continent occurred over a wide-spread area, extending at least from the van Rhynsdorp region in the south, as far north possibly as the Naukluft Mountains region in South West Africa, a distance of approximately 600 miles. It is of interest to note here that Dr. Martin has found evidence in the Naukluft Mountains of the slumping of Nama sediments into a marine trough.

There is evidence that the present elevated mountain region of the Kamiesberg also constituted an elevated region in Nama times. The Nama shows a marked tendency to become thinner when followed towards the north in the van Rhynsdorp Division, that is towards the Kamiesberg. At Gamsbokberg the Nuwerus Series is at least 1,300 feet thick, at Nuwerus it is in the neighbourhood of 500 feet, while further to the north at Graafwater, north-east of Bitterfontein, Brink records a thickness of less than 100 feet of Nuwerus beds between the underlying Primitive Rocks and the Schwarzkalk shales above. Still further to the north the Nama rocks occur as thin, isolated outliers resting on the gneiss near Garies.

Brink has suggested that the Schwarzkalk Series was also deposited under shallow marine conditions, and cites the following evidence (4 p.184): "The discoidal form of their pebbles, and the poorly sorted nature of the conglomerates and grits of the Byzondermeid sector (the so-called Ibiqus conglomerates) have already been mentioned and the conclusion that these are gravel and shingle indicating the position of an old shore-line of the shallow sea seems to be reasonable".

The deposition of the Nama System in the van Rhynsdorp Division may therefore be summarised as follows. The rising Nama Sea filled the pre-existing trough of the southern area with limestones which may possibly be of an

organic origin ( p.45). Marine transgression across the low-lying coastal regions of the pre-Nama landmass resulted in the deposition of the predominantly quartzitic and arkosic Nuwerus Series consisting of true marine sediments in the southern area, and mixed marine and littoral sediments in the northern area where the sea was advancing up the slope of a landmass of essentially gneissose rocks. This advance continued or was renewed in Schwarzkalk times, and the presence of extensive shaly horizons in the latter series may indicate that chemical weathering over the landmass was dominant in contrast to the mechanical weathering of Nuwerus times which gave rise to the arkoses and quartzites of that series. It is possible that the thin limestone horizon recorded by Brink in the Schwarzkalk of the Nuwerus area may correspond in stratigraphic position to the much thicker Schwarzkalk limestones of the Northern Cape and South-West African regions.

The Correlation of the van Rhynsdorp Nama with the Nama System of the Northern Region.

No basal Nama formation corresponding to the Basal Limestones of the van Rhynsdorp Division has been recorded from the northern region, with the possible exception of the Nabas Series described by de Villiers (7) from the Nabas-Changab River area on the Orange River. The Nabas Series, which may reach a maximum thickness of 1,500 feet, contains several limestone and limestone conglomerate horizons. It would seem that this series was deposited in a local trough prior to the deposition of the Kuibis quartzites, and thus parallels the Basal Limestone Series of van Rhynsdorp. de Villiers found no break in deposition between the Nabas Series and the overlying Kuibis quartzites. The conformable nature of the contact between the Basal Limestones and the Nuwerus Series at Gamsbokberg has

been demonstrated.

There can be little doubt that the Nuwerus Series of van Rhynsdorp can be correlated with the remarkably similar Steinkopf Beds which have been discussed on page 55. Both these formations show but a small degree of folding and have been affected by faults of a tensional nature. Folding on a more intense scale has affected the pre-Nama formations of both the van Rhynsdorp and the northern regions. The Steinkopf Beds rest unconformably on gneiss which is in all probability of the same general age as the Pink Gneiss which underlies the Nuwerus Series in the northern van Rhynsdorp region. If therefore the Steinkopf Beds are accepted as being of undoubted Nama age, the Basal Limestone and Nuwerus Series of the van Rhynsdorp region can be confidently correlated with the Nama System of the Northern Cape and South-West Africa.

According to Brink (4 p.189) there is no necessity for the introduction of a new name for the upper arenaceous portion of the Schwarzkalk Series mapped by him in the Nuwerus area. He considers that this arenaceous phase is of local importance only, and that it would be undesirable to group it as a separate series corresponding to the Fish River Series of South-West Africa.

The following table shows the three members of the Nama System recognised in the van Rhynsdorp Division, together with those of the northern region with which they would appear to agree most closely.

<u>van Rhynsdorp</u>	<u>Northern Region</u>
Schwarzkalk Series	Schwarzkalk Series
Nuwerus "	Steinkopf Beds
Basal Limestone "	Nabas Series

The following table gives the succession of the Nama System in South-West Africa from the northern Naukluft Mountains area, southwards via the Bethanie area to Warmbad. The author is indebted to Dr. H. Martin of Windhoek for this information.

<u>NAUKLUFT (folded)</u>	
	?
	Dolomites
	Tillite with Nama Dolomite and Schwarzkalk
Upper Nama	2000 to 3000 ft.
	Dolomites with brown and blue shales
	Dolomites interbedded with quartzites and purple shales
	Green and brown indurated shales
Lower Nama	150 to 1000 ft.
(Schwarzkalk)	100 ft.
	30 to 100 ft.
	Black limestones with dolomite reefs partly passing into Kuibis quartzite in the Zavis Mountains.
	Dark shales with thin quartzites and dolomite bands.
	Conglomerate

It is of interest to note the occurrences of basal conglomerates in the Naukluft and Bethanie areas which are succeeded by dark shales and dolomite bands in the former area. It is possible that these shales and dolomites may correspond to the Basal Limestone Series of the Van Rhynsdorp region. The organic origin of part at least of the Naukluft Schwarzkalk limestones and dolomites is indicated by the algal reefs. Two tillites are recorded associated with limestones, one in the Upper Nama in the Naukluft Mountains and one in the Warmbad area.

BETHANIE (unfolded)

about 3000 ft.

Purple indurated shales  
Argillaceous quartzites inter-  
bedded with purple shales  
Quartzites

Greenish and blue indurated  
shales

200 to  
500 ft.

Black limestone and indurated  
blue shales

White quartzite (Kuibis)

Thin conglomerate

WARMHEAD (unfolded)

Argillaceous quartzites inter-  
bedded with purple shales  
quartzites

Grey and green indurated  
shales

Black limestone with tillite

700 ft. White quartzite

THE PINK GNEISS.

The present investigation has shown that there are not two distinct phases of gneiss in the southern part of the van Rhynsdorp Division, and that the younger mass of the Moedverloor Hills area, mapped by Rogers on Sheet 19, Nieuwerust, is a southern extension of the Pink Gneiss of the Nuwerus area.

In the southern part of Namaqualand it is possible to distinguish two main types of gneiss that may conveniently be called the Grey Gneiss and the Pink Gneiss. The Pink Gneiss extends southwards from a line between Garies and Bitterfontein towards van Rhynsdorp, while to the north of Garies the Grey Gneiss continues towards Springbok and forms the major part of the Namaqualand batholith in this region. It is hoped that the recognition of these two distinct types of the general terms "Namaqualand Granite" and "Namaqualand Granite-Gneiss" will help to minimise the confusion sometimes caused by the use of the latter terms in describing the crystallines of southern Namaqualand. The use of the terms Grey Gneiss and Pink Gneiss conforms with the distinction that is made in the Orange River region to the north.

There is considerable evidence that the Pink Gneiss of the van Rhynsdorp region is the result of extensive granitisation of the Kheis System, and that it is essentially a marginal phase of the Grey Gneiss and occurs between the latter and the original hood-zone of Kheis sediments.

There are grounds for suggesting that the Pink Gneiss of the van Rhynsdorp Division corresponds to the Pink Gneiss of the Kakamas area, and it is possible that the aplogranites described by Coetzee ( 5 p.181) from the Goodhouse-Pella area can be correlated with the Pink Gneiss. The Hoogoor granite, which Coetzee included in

the aplogranites, has several features in common with the Pink Gneiss of van Rhynsdorp. Söhnge and de Villiers give the following description of the Hoogoor occurrence, (27 p.266) "It appears to have been confined to the contact between the gray gneiss and the meta-sediments and -lavas to the south, in which it appears as lit-par-lit injections on a grand scale. It is generally of a reddish colour, and mafic minerals are not common. It is possible that this granite may be a later phase of the main period of intrusion of the gray gneiss, and its origin may also be due in part to granitisation and palingenesis accompanying the earlier magma".

The Pink Gneiss of the van Rhynsdorp area tends to weather into large rounded boulders which are gradually reduced in size by exfoliation. It does not form the great dome-structures so common in the Grey Gneiss further to the north. Photograph No.14 shows the weathering typical of the Pink Gneiss of van Rhynsdorp.



No.14 . The mode of weathering of the Pink Gneiss on Moedverloor in the van Rhynsdorp region.

There are two occurrences of the gneiss worthy of note in the area surveyed. The first occurs in the small stream-bed about a mile east of the old farmhouse on

Moedverloor. A patch of gneiss, about 450 feet long by 150 feet wide, is exposed in the stream-bed and is surrounded by sediments of the Hilda Series. Practically all the contacts of the gneiss are concealed, but at the northern end in the stream-bed a pegmatite about 2 feet wide runs from the gneiss for about 6 feet into an adjacent weathered felspathic grit. The pegmatite consists solely of white feldspar and a bluish quartz with occasional flakes of muscovite. The second occurrence is seen at the head of a small kloof next to the road from Vredendal to Vlermuisklip and is shown on Map No. 2. At this locality a patch of gneiss is closely associated with grey phyllites and dolomite of the Hilda Series. While the gneiss appears to lie adjacent to the phyllites, the contact with the dolomite seems to be a faulted one. This gneiss is sheared and somewhat weathered but can be correlated with the Pink Gneiss of the Moedverloor Hills to the north.

The Petrography and Mineralogy of the Pink Gneiss.

The texture of the Pink Gneiss is typically allotriomorphic granular and is illustrated by Microphotograph No. 15. In most of the localities visited the gneiss is medium- to fine-grained, but some porphyritic varieties have been recorded by Brink from the Nuwerus area.



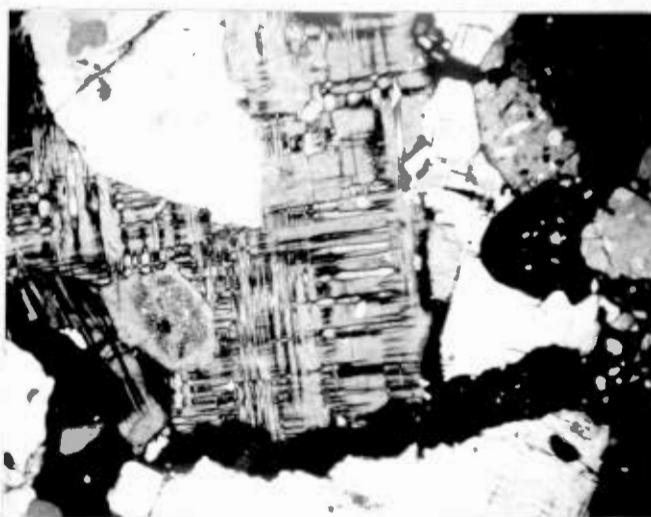
No. 15. The typical texture of the Pink Gneiss. Crossed Nicols. x20.

The average of 14 modes of the gneiss in the van Rhynsdorp Division shows roughly 45% potash felspar, 40% quartz, 12% plagioclase and 2% biotite, the latter being the most abundant dark mineral. Hornblende is rarely present. The accessory minerals include iron ore, titanite, zircon, apatite and muscovite.

#### Potash felspar.

Potash felspar is represented almost entirely by microcline, a feature common in rocks rich in  $K_2O$ . Small amounts of orthoclase were observed in several specimens collected on Houtkraal near the Klein Goerap River.

The microcline shows the characteristic "gridiron" structure and forms the largest grains, frequently enclosing other constituents as illustrated by Microphotograph No. 16. Measurements of  $2V$  showed a range of between  $82^\circ$  and  $85^\circ$ . While the plagioclase frequently shows some degree of clouding, the microcline is always clear in fresh specimens.



No. 16. Microcline enclosing plagioclase. Crossed Nicols. x45.

#### Plagioclase.

Plagioclase occurs as small grains, often subhedral, and occasionally enclosed in the larger plates of microcline. Compositions were determined on the Universal

Stage by means of the Rittmann zonal method (10 p.15) and showed a range from  $Ab_{93}An_7$  to  $Ab_{73}An_{27}$ . The plagioclases vary therefore from basic albite to oligoclase with the latter predominating; the average of 14 specimens, including 4 from the Nuverus area, had a composition of  $Ab_{84}An_{16}$ .

Practically all the plagioclase shows signs of sericitisation and in several instances this process prevented determinations of composition. Reaction rims between sericitised plagioclase inclusions and the enclosing microcline were observed in several cases. These rims are in general more acid than the plagioclase and twinning is usually absent. This suggests reaction between the earlier plagioclase and the later microcline during which addition of soda to the plagioclase increased its Ab content in the rim. The absence of sericitisation in the rim would seem to indicate that the clouding of the plagioclase was induced prior to the formation of the microcline which was responsible for the clear reaction rim. The frequent occurrence of myrmekite in laths of plagioclase may be related to a similar reaction process with the microcline. Microphotograph No.16 shows an inclusion of plagioclase in a plate of microcline, and illustrates the clouding of the plagioclase core and the clear rim. Microphotograph No.17 shows the development of myrmekitic structure in plagioclase. It is of interest to note that the twin lamellae often cross through the myrmekitic structures.



No. 17. Myrmekitic structure in plagioclase. Crossed Nicols. x45.

Two opposed explanations have been offered to explain the reaction between potash felspar and plagioclase. Tilley (29) and Anderson (2) suggest that potash felspar has been replaced by plagioclase, while Nockolds (19) inclines to the view that microcline replaces the plagioclase. Spencer (28) expresses the opinion that myrmekite results from the segregation and coalescence of albite held in solution in the potash felspar.

In the Nuwerus area, Brink also observed the formation of albitic rims around plagioclase and myrmekitic structures. He considers it likely that the myrmekite and the albitic rims are deuteric reaction products.

The author prefers the explanation given by Nockolds regarding the albitic rims, i.e. that they represent a replacement of plagioclase by microcline.

### Biotite.

Biotite constitutes the most important dark mineral in the gneiss. It shows a pleochroism of greenish-brown to a dark, almost opaque, greenish-brown. The green tinge may possibly be due to initial alteration of the biotite to chlorite. The relatively high refractive indices of the biotite ( $n_m = 1.650 \pm 0.003$ ) suggests a high iron content, and was also observed by Coetzee (5 p.181) in the

1. Pink Gneiss, Moedverloor. PG 1.
2. " " " PG 2.
3. " " " PG 3.
4. " " Houtkraal, Klein Goerap River.
5. " " Moedverloor.
6. " " "
7. " " "
8. " " Potklei.
9. " " Zonderwater, N.-W. of Potklei.
10. " " Elandsfontein, N.-W. of Potklei.
11. " " Gannabos Trig. beacon (W.C. Brink).
12. " " near 11. " "
13. " " Hoedkop-Hartseer sector " "
14. Granite at Geelputs associated with metamorphic gneiss (W.C. Brink).
15. Average of 14 samples of Pink Gneiss from the van Rhynsdorp Division.
16. Average of the Aplogranites (Coetzee).
17. Aplogranite associated with Kheis biotite-felspar gneiss, Pella. (Coetzee 6).
18. Pink Gneiss, Kakamas.
19. " " "

1. Pink Gneiss, Moedverloor. PG 1.
2. " " " PG 2.
3. " " " PG 3.
4. " " Houtkraal, Klein Goerap River.
5. " " Moedverloor.
6. " " "
7. " " "
8. " " Potklei.
9. " " Zonderwater, N.-W. of Potklei.
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gneiss, Pella. (Coetzee 6).
18. Pink Gneiss, Kakamas.
19. " " " "

Modes of the Pink Gneisses etc.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Quartz	40.6	37.8	36.4	41.9	47.2	39.1	43.8	53.3	43.2	49.2	38.1	35.5	29.7	22.7	39.2	40.3	40.2	41.3	38.6
Potash felspar	43.5	48.2	42.1	44.5	41.5	37.5	43.8	26.4	43.4	34.7	53.2	49.9	49.2	68.8	44.8	36.6	33.0	39.9	40.2
Plagioclase	7.4	11.1	21.2	12.4	10.1	15.2	9.7	16.0	12.8	12.8	8.8	11.8	16.3	7.7	12.2	20.8	18.5	16.5	19.3
Biotite	8.5	2.9	0.2	0.7	1.2	5.1	2.4	1.7	0.6	2.2	+	-	3.9	0.8	2.2	+	2.7	1.6	1.6
Muscovite	-	-	-	+	+	-	+	1	+	-					+	+	+	-	+
Hornblende	+	-	-	-	-	-	-	-	-	-	-	2.0	-	+	+	-	-	-	-
Apatite	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Zircon	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+
Iron ore	+	+	+	0.3	+	+	+	} 1.3	+	} 1.0	+	0.7	0.9	+	0.3	0.5	0.5	0.5	+
Titanite	+	+	+	0.2	+	3.1	+		+								+	+	+
% An in Plag.	7	15	7	13	11	n.d.	14	14	17	15	20	22	27	20	16	17	10	12	16
Pot. fels/Plag.	5.9	4.3	2.0	3.8	4.1	2.5	4.5	1.7	3.4	2.7	6.0	4.2	3.0	9.1	3.7	1.5	2.3	2.4	2.1

aplogranites of the Goodhouse-Palla area.

While sagenitic webs were observed in the biotite of several specimens, this feature is not general.

Accessory minerals.

Iron ore occurs in practically all the sections examined, and titanite, with associated leucocrene, is of common occurrence. Apatite and zircon were observed in all the specimens. Green hornblende, probably associated with biotite, was observed in a few sections including P.G.1 on Moedverloor.

The Modes of the Pink Gneiss.

The modes of 14 specimens of Pink Gneiss from the van Rhynsdorp Division are given in the following table, together with 2 from the Kakamas area, and the average of the aplogranites of the Goodhouse-Palla area given by Coetzee (5 p.182) including the Aggenys granite given by Mathias (17 p.194).

Modes of the Pink Gneisses etc.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Quartz	40.6	37.8	36.4	41.9	47.2	39.1	43.8	53.3	43.2	49.2	38.1	35.5	29.7	22.7	39.2	40.3	40.2	41.3	38.6
Potash felspar	43.5	48.2	42.1	44.5	41.5	37.5	43.8	38.4	43.4	34.7	53.2	49.9	49.2	68.8	44.8	36.6	38.0	39.9	40.2
Plagioclase	7.4	11.1	21.2	12.4	10.1	15.2	9.7	16.0	12.8	12.8	8.8	11.8	16.3	7.7	12.2	20.8	18.5	16.5	19.3
Biotite	8.5	2.9	0.2	0.7	1.2	5.1	2.4	1.7	0.6	2.2	+	-	3.9	0.8	2.2	+	2.7	1.6	1.6
Muscovite	-	-	-	+	+	-	+	1.	+	-					+	+	+	-	+
Hornblende	+	-	-	-	-	-	-	-	-	-	-	2.0	-	+	+	-	-	-	-
Apatite	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Zircon	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+
Iron ore	+	+	+	0.3	+	+	+	1.3	+	1.0	+	0.7	0.9	+	0.3	0.5	0.5	0.5	+
Titanite	+	+	+	0.2	+	3.1	+	+	+						+	+	+	+	+
% An in Plag.	7	15	7	13	11	n.d.	14	14	17	15	20	22	27	20	16	17	10	12	16
Pot. fels/Plag.	5.9	4.3	2.0	3.6	4.1	2.5	4.5	1.7	3.4	2.7	6.0	4.2	3.0	9.1	3.7	1.5	2.3	2.4	2.1

Analyses of Pink Gn

	1	2	3	4	
SiO <sub>2</sub>	70.4	74.7	71.5	77.1	
Al <sub>2</sub> O <sub>3</sub>	13.6	12.7	13.0	11.7	
Fe <sub>2</sub> O <sub>3</sub>	1.3	1.0	1.9	1.1	
FeO	2.6	1.0	1.9	0.6	
MgO	1.1	0.3	0.7	0.3	
CaO	0.8	1.0	1.7	0.5	
Na <sub>2</sub> O	3.3	3.5	3.3	3.1	
K <sub>2</sub> O	5.7	5.0	4.7	5.2	
MnO	0.07	0.02	0.09	0.02	
P <sub>2</sub> O <sub>5</sub>	0.13	0.09	0.13	0.03	
TiO <sub>2</sub>	0.4	0.2	0.3	0.2	
H <sub>2</sub> O	0.6	0.3	0.7	0.3	
H <sub>2</sub> O	0.07	0.04	0.06	0.05	
	100.07	99.85	99.98	100.20	1

Norms.

Q .. ..	24.90	32.88	28.08	37.74	
or .. ..	33.92	29.47	27.80	30.58	
ab .. ..	27.77	29.34	27.77	26.20	
an .. ..	3.06	4.17	6.67	2.50	
c .. ..	0.82	0.10	-	0.10	
di	wo ..	-	0.35	-	
	en ..	-	0.20	-	
	fs ..	-	0.13	-	
hy	en ..	2.80	0.80	1.80	0.80
	fs ..	3.17	0.66	1.19	-
mt .. ..	1.86	1.39	2.78	1.16	
il .. ..	0.76	0.46	0.61	0.46	
hem .. ..	-	-	-	0.32	
ap .. ..	0.34	0.34	0.34	-	
H <sub>2</sub> O .. ..	0.67	0.34	0.86	0.35	
	100.07	99.95	98.46	100.21	1

The table of analyses includes four new analyses of Pink Gneiss, three from Moedverloor and one from Houtkraal on the Klein Goerap River. The latter locality is near the group of Kheis rocks mentioned on page 21.

It is noteworthy that Nos. 1 and 6, which have the lowest  $\text{SiO}_2$  contents, carry hornblende. No. 6 shows 2.0% hornblende in the mode (p. 74) and may possibly be an occurrence of Grey Gneiss.

An attempt was made to plot the eight analyses on an  $\text{SiO}_2$  variation diagram but no definite trends were recognised. This is to be expected if the Pink Gneiss is the result of granitisation since the original sediments would have controlled the chemical compositions of the rocks to a large extent: also the analysed samples were collected from widely separated localities.

7	8	9	10	11	12	13	14	15	16	17	18	19
0.20	0.16	0.40	0.44	0.36	0.28	0.36	7.80	1.84	0.32	0.89	0.44	1.17
0.04	0.68	1.08	0.96	0.80	1.00	0.28	1.20	0.44	0.28	0.50	0.70	0.32
97.75	97.16	96.31	96.36	92.38	95.81	94.74	54.83	85.87	97.88	96.60	97.93	98.26
0.05	1.63	2.72	2.24	5.81	2.78	4.18	35.33	12.73	0.90	2.15	1.50	0.60
99.90	99.63	100.51	100.00	99.35	99.87	99.56	99.16	100.93	99.38	100.14	100.57	100.35

7	8	9	10	11	12	13	14	15	16	17	18	19
0.20	0.16	0.40	0.44	0.36	0.28	0.36	7.80	1.84	0.32	0.89	0.44	1.17
0.64	0.68	1.08	0.96	0.80	1.00	0.28	1.20	0.44	0.28	0.50	0.70	0.32
77.83	97.18	96.31	96.36	92.38	95.81	94.74	54.83	85.87	97.88	96.60	97.93	98.26
21.23	1.63	2.72	2.24	5.81	2.78	4.18	35.33	12.78	0.90	2.15	1.50	0.60
99.90	99.63	100.51	100.00	99.35	99.67	99.56	99.16	100.93	99.38	100.14	100.57	100.35

The Classification of the Pink Gneiss.

Coetzee used Johannsen's method of quantitative mineralogical classification of the granitic rocks (14 p.140) in classifying the various rock-types of the Goodhouse-Pella area and his results are shown in Diagram No. 18. This method gave an excellent separation, and the Older Basement Granites, the Younger Namaqualand Granite-Gneisses and Alogranites fall into distinct fields. In this diagram 16 Pink Gneisses from the van Rhynsdorp Division and 2 from the Kakamas area have been plotted.

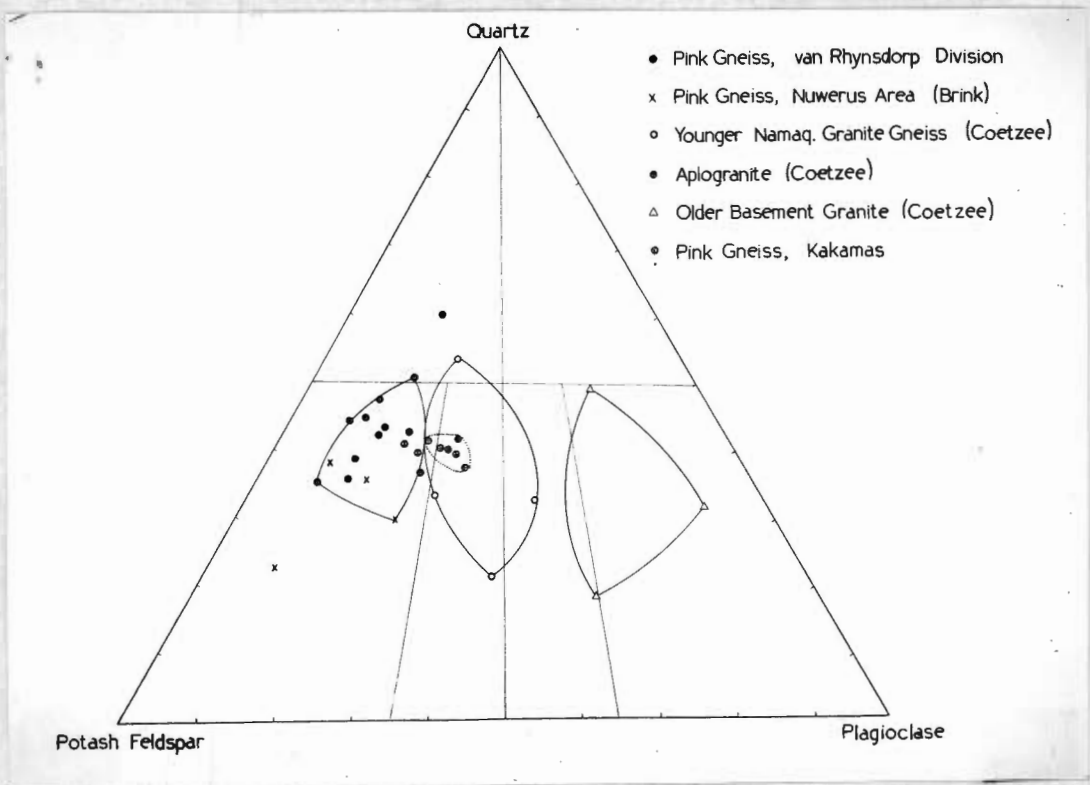


Diagram No. 18.

The Older Basement Granites fall mainly in the monzonalite family of the granodiorites with a slight transgression into the adamellites. The Younger Namaqualand Granite-Gneisses (i.e. the Grey Gneiss) are confined mainly to the adamellites, while the Alogranites fall on the border between the adamellites and monzogranites. The Pink Gneisses form a distinct field in the monzogranites and lie adjacent to Coetzee's Alogranite field.

Elongation ratios of the zircons of the Pink Gneiss.

In an investigation of a suspected product of granitisation occurring near Springbok, Coetzee (5 p.192) used the method described by Smithson (26) to distinguish between sedimentary zircons and zircons of igneous origin. Briefly, the procedure is to plot the lengths and breadths of the zircons on a diagram as shown below. Sedimentary zircons flood the field bounded by the ratios 1:1 and 1:2, while igneous zircons tend to be confined to the field bounded by the ratios 1:2 and 1:5.

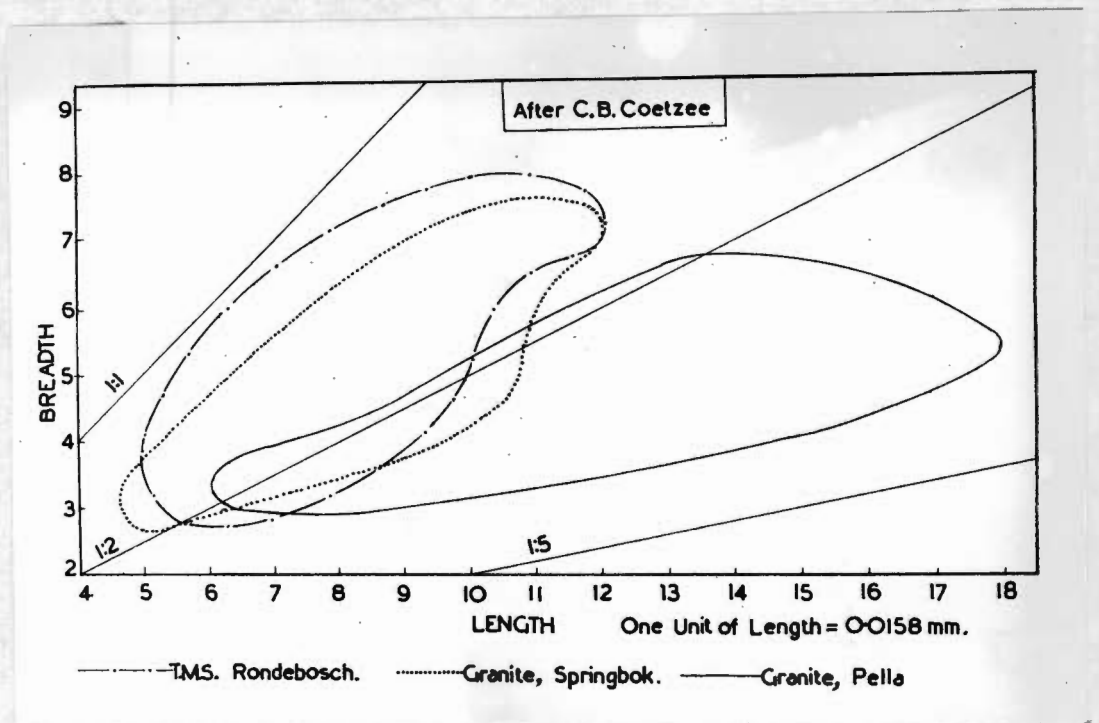


Diagram No. 19.

Diagram No.19 was obtained by Coetzee for a sedimentary rock, a magmatic granite from Pella and the granitised xenolith from Springbok. The separation into the sedimentary and igneous fields is evident. Similar diagrams were plotted for three samples of Pink Gneiss from the localities on Moedverloer shown on Map No.2, and these plots are given in Diagrams 20,21 and 22.

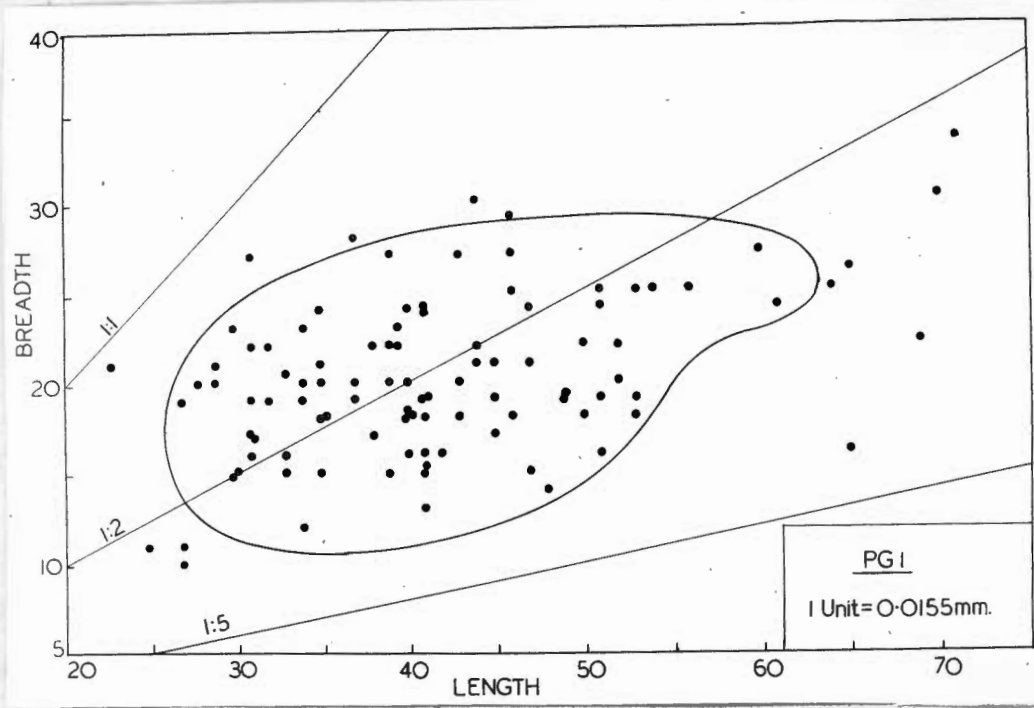


Diagram No. 20.

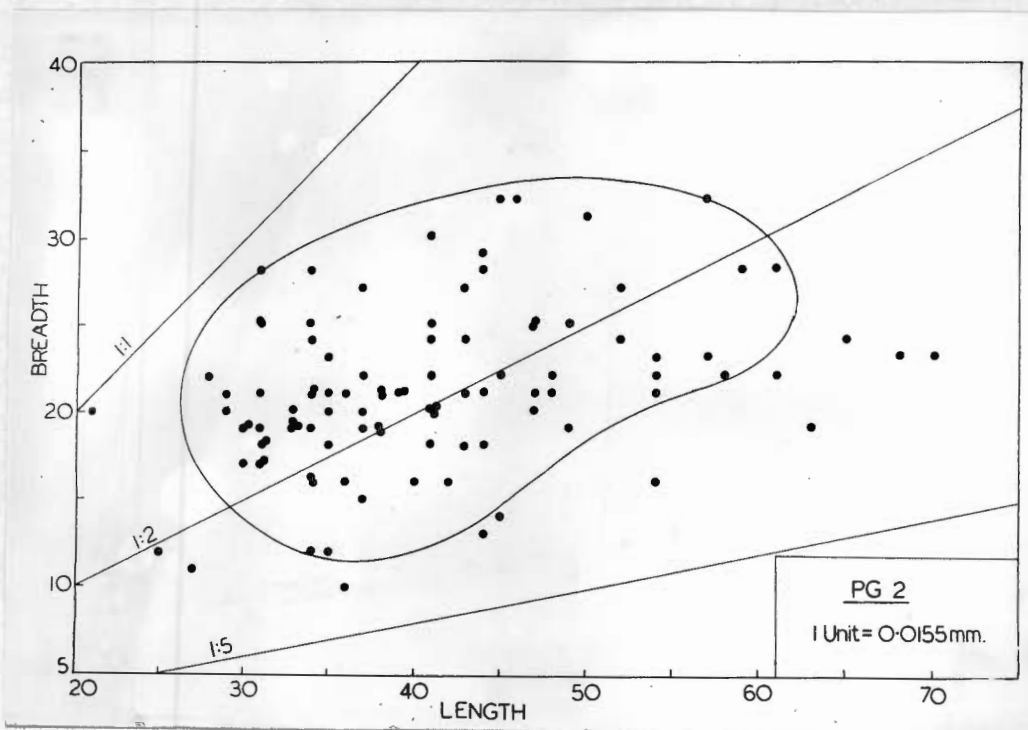


Diagram No. 21.

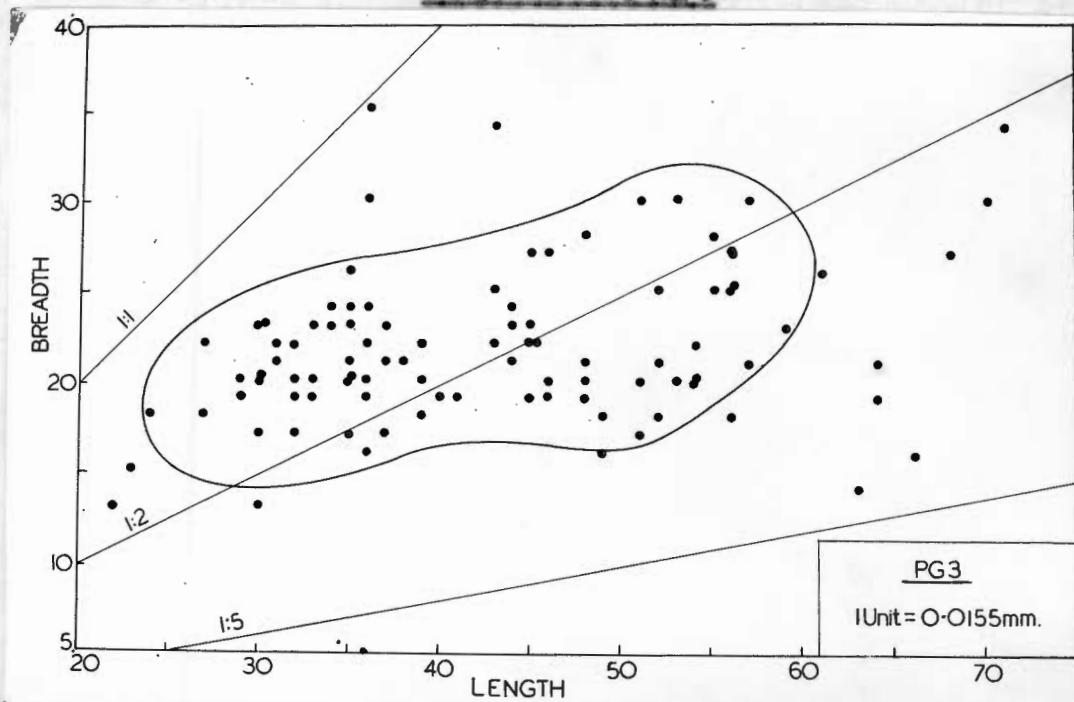


Diagram No. 22.

In these three diagrams there is not a marked concentration of points in either field, although P.G.2 and P.G.3 show a tendency to group in the sedimentary field.

In a later paper (6), Coetsee employed a different type of diagram to study zircon elongation ratios. In this method the frequencies of the elongation ratios were plotted as shown in Diagram No. 23, and a well defined distinction is obtained between sedimentary and igneous zircons. The zircons of the three samples of Pink Gneiss from Moedverloor and a sample from the Kakamas area were plotted according to this method and are shown in Diagram No. 23.

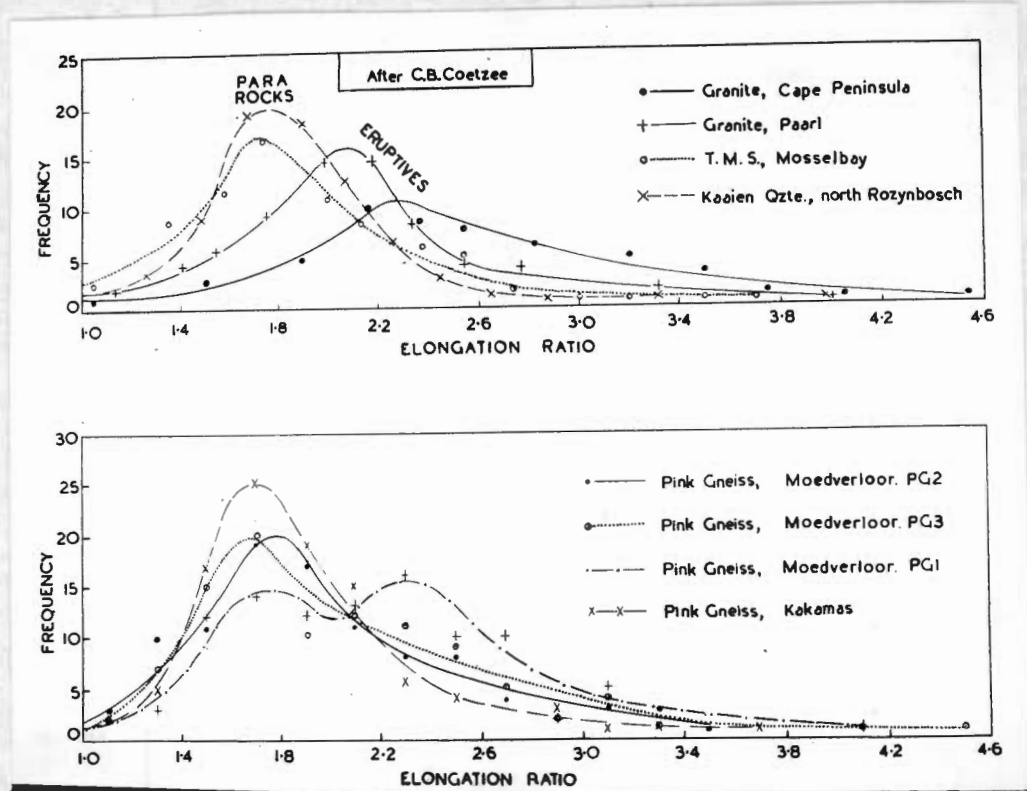


Diagram No. 23.

The grouping of the maxima about an elongation ratio of approximately 1:7 strongly suggests that the zircons of the Pink Gneiss are of sedimentary origin.

The second maximum in the igneous field shown by P.G.1 is an interesting feature for which the following explanations are offered. The zircons of this sample may be partly of igneous origin, or else, if sedimentary, they were derived originally from a near-by igneous mass and

suffered but slight rounding during transportation. On the field relations of this occurrence of gneiss, the second explanation is more acceptable.

Potash Enrichment in the Pink Gneiss.

The following table gives the average  $K_2O$  and  $Na_2O$  contents and the corresponding  $K_2O/Na_2O$  ratios of samples of Older Basement Granite (Granodiorite), Younger Namaqualand Granite (Grey Gneiss) and Aplite including Pink Gneiss.

	$K_2O$	$Na_2O$	$K_2O/Na_2O$
Granodiorites	3.76	2.63	1.43
Grey Gneisses	5.02	3.12	1.61
Pink Gneisses	5.24	2.99	1.75

Sources of analyses.

Granodiorites Coetsee (5 p.183, Table V, Nos.1,2 & 3)  
 Grey Gneisses " (" p.189, " VII, Nos.1,2,4 & 5)  
 Pink Gneisses " (" " " " " Nos.7 & 8)  
 Brink (4 p.124, Table V, No.10)  
 This thesis (p.75, Nos. 1,2,3 & 4)

The average  $K_2O/Na_2O$  ratio of the Pink Gneisses is 1.75 which is higher than that given by the Granodiorites and the Grey Gneisses, and the  $K_2O$  values increase from 3.76% for the Granodiorites, 5.02% for the Grey Gneisses, to 5.24 % for the Pink Gneisses.

In a paper on the order of crystallisation of the minerals in some Caledonian plutonic and hypabyssal rocks, Nockolds (20p.206) plotted the course of crystallisation for the feldspars on a triangular diagram with potash feldspar, albite and anorthite at the corners. The values he used were obtained from the modal values of 16 rocks ranging from pyroxene-mica -diorite, through granodiorites and adamellites to aplites, all of which are apparently of magmatic origin. The crystallisation trend of the feldspars

in these rocks is shown in Diagram No.24.

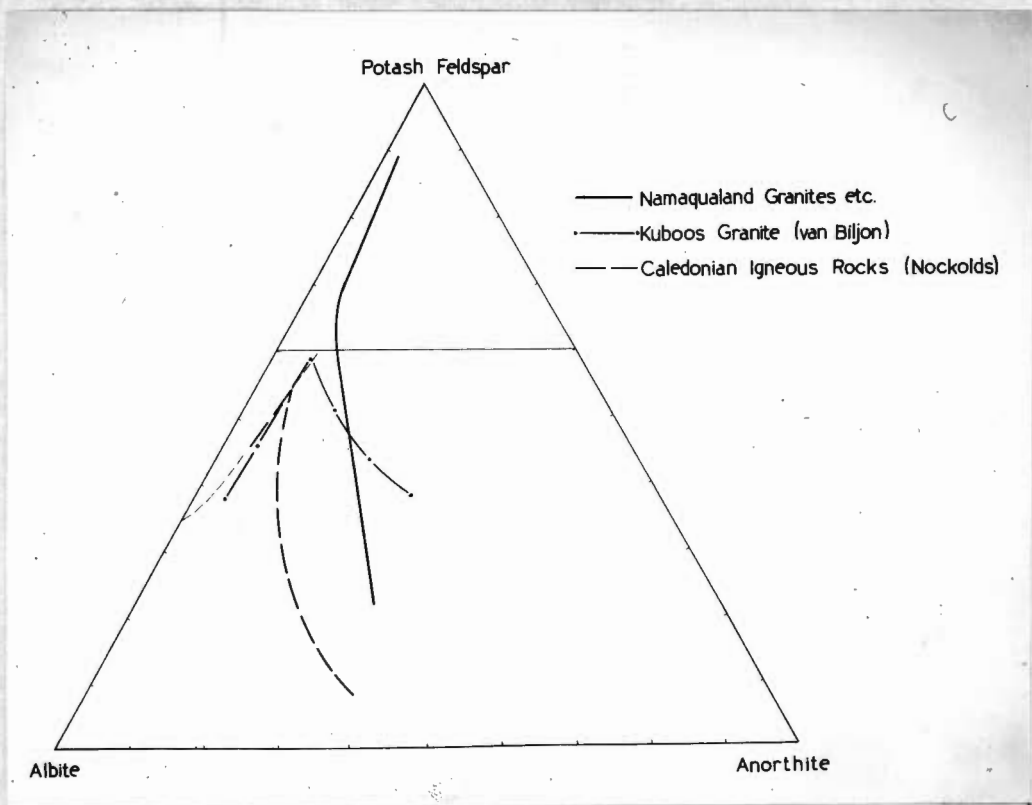


Diagram No.24

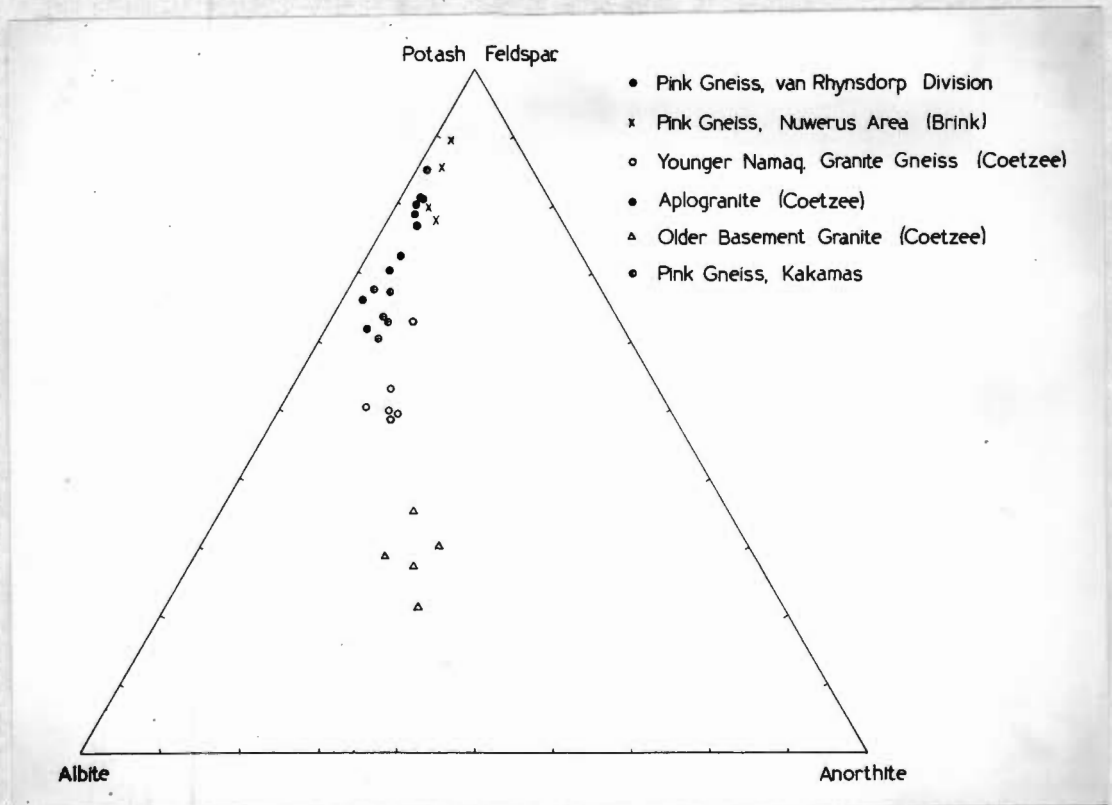


Diagram No.25

In Diagram No.25 the trend of the feldspars of a representative range of the Namaqualand granitic rocks is plotted. The trend line is shown on Diagram No.24, which

also shows the trend of the feldspars of the magmatic granite of Kuboos plotted from the norm values given by van Biljon (30p,170).

In the cases of the magmatic rocks of the Caledonian and Kuboos provinces, the trend lines show an enrichment in potash feldspar until the cotectic curve between potash feldspar and plagioclase (shown on Diagram No.24 by the thin broken line) is reached, and then the trends closely follow this curve towards the sodic feldspar corner of the diagram. The feldspars of the rocks of the Namaqualand province show the same general trend through the Granodiorites and monzonites and adamellites (Grey Gneiss), but the aplite-granites and Pink Gneisses show a marked enrichment of potash feldspar in contrast to the aplitic types plotted by Nockolds which show a final trend towards sodic feldspar.

While the significance of this trend of the Pink Gneiss is not fully understood, the following explanation is offered. The Granodiorites of the Namaqualand granitic complex probably represent the parent magma which gave rise to the Grey Gneiss by processes of magmatic differentiation during which the trend of feldspar crystallisation followed the normal direction indicated on Diagram No.24. Following the emplacement of the Grey Gneiss, the final fractions of differentiation, rich in potash, permeated the hood-zone of the complex and in doing so caused extensive granitisation of the Kheis System. This granitisation of granite-derived sediments by liquids rich in potash gave rise to the marginal Pink Gneisses of the Namaqualand complex. The Pink Gneisses are therefore not truly magmatic rocks, and their final feldspar trend does not follow the cotectic curve in the manner shown by the Caledonian aplites.

### Conclusions.

The following brief and very incomplete history of the numerous phases of the Namaqualand granitic complex suggests itself to the author.

1. The sedimentation of the Cariep System was followed by an orogenic period accompanied by the intrusion of a parent magma which gave rise to the granodioritic "Older Basement Granite", and by differentiation to the Grey Gneiss. During this period the adjacent Kheis System was metamorphosed on a regional scale and the platform on which the Kheis sediments were originally deposited was destroyed, probably by palingenic processes. The Cariep System, in the western region, overlying the Kheis, was metamorphosed on a less intense scale.

2. Palingenesis of the older sediments of the hood-zone, and an advance of a front rich in potash which caused extensive granitisation, gave rise to the marginal Pink Gneisses.

3. The closing phases of this immensely long period of igneous activity are represented by the mineralised pegmatites of the Orange River area (13).

THE DOLERITE SILL AT GEMSBOKBERG.

An occurrence of dolerite was found close to the Sout River just below the Gembokberg poort. The outcrop occurs along the base of a small spur over a distance of 350 feet and is about 20 feet thick. The field relations suggest that it is a slightly transgressive sill occurring in the lowest beds of the Nuwerus Series; an outcrop of Basal Limestone occurs about 150 feet beyond the north-eastern end of the sill.



No. 26 . The dolerite sill near Gembokberg.

This dolerite is the only post-Pink Gneiss igneous rock that was encountered in the area surveyed. Brink has recorded several dolerites in the Nuwerus area, and with the exception of the Houmoed dike, has suggested their correlation with the dolerites of the Western Province (18). The Houmoed dolerite is correlated with the Karroo dolerites and has the following properties. The plagioclase shows normal continuous zoning with cores corresponding to a composition of An<sub>60-70</sub> grading into mantles of An<sub>45-50</sub>. Orthopyroxene is absent; in the monoclinic pyroxene zoning is rather distinct with pigeonite cores (2V 10°) and outer zones of augite (2V 35° to 42°).

The mode of the Gamsbokberg dolerite is given in the following table together with a typical mode of the Blaaukrans type of Karroo dolerite given by Walker and Poldervaart (32 p.139).

	Gamsbokberg	Blaaukrans type
Plagioclase	45.0	42.5
Pyroxene	38.7	47.7
Olivine	4.5 <sup>x</sup>	3.9
Iron ore	8.3	3.4
Biotite	0.5	0.5
Micropegmatite	3.0	2.0
An content of plag.	An <sub>55</sub>	An <sub>58</sub>

<sup>x</sup> Bowlingite after olivine.

The Gamsbokberg rock is medium-grained and of subophitic texture as shown by Microphotograph No. 27. The plagioclase corresponds to a composition of An<sub>55</sub> ( $\beta = 1.561 \pm 0.003$ ). In parts of the sill clots of plagioclase up to 6 inches in size occur and have a composition of An<sub>57</sub> ( $\beta = 1.568$ ). Both pigeonite and augite occur, the latter often surrounding cores of the pigeonite. Bowlingite is present after olivine.



No. 27. The Gamsbokberg dolerite showing part of a plagioclase phenocryst. Crossed Nicols. x20.

The Gamsbokberg dolerite resembles the Blaaukrans type described by Walker and Poldervaart from the western Karroo Calvinia district, and the Houmoed occurrence also seems to be similar. These two rocks may therefore be correlated with the Karroo dolerites.

THE STRUCTURAL FEATURES OF THE AREA.Folding.

In the van Rhynsdorp region the Nama System suffered gentle folding which produced wide anticlinal and synclinal structures. These structures tend to strike in a north-north-westerly direction in the southern area, while in the Nuwerus area a more northerly strike appears to prevail. In several parts of the area surveyed, for example to the south of Luiperskop, the consistent dip of the sediments to the south-west is due more to block-faulting than to folding. This is more fully described later.

The post-Nama folding was followed by two distinct phases of tensional faulting in both the northern and southern portions of the van Rhynsdorp Division. Of the Nuwerus area, Brink states, "Associated with the major strike faulting are remnants of gentle, pitching anticlines and synclines of the Nama formation".

In the southern area the Basal Limestones frequently show small-scale folding within the larger synclinal and anticlinal structures. These smaller folds are well displayed on the polished marble slabs quarried from this series. The argillaceous phases of the Nuwerus Series, particularly in the upper portions, show drag-folding between the more competent quartzites.

The folding in the Hilda Series is present on a more intense scale than that in the Nama, and must therefore be mainly of pre-Nama age. Dips exceeding  $45^{\circ}$  were often observed on Moedverloor, and the strikes of these sediments show far greater variation in direction than do the Nama strikes. A weak lineation with a gentle pitch to the north-north-west was observed in some of the Hilda rocks, and this suggests that the gentle post-Nama folding was superimposed on the older folds of the Hilda Series.

Although the dips of the Hilda rocks along the Olifants River do not in general approach the high values measured in parts of the Moedverloor horst, the strongly sheared condition of these rocks indicates earthmovements of pre-Nama ages.

#### Faulting.

There are two major sets of post-Nama faults in the area surveyed and these would seem to correspond to the faults of the Nuwerus area ( 4 p.196 et seq.).

The older set trend in a general north-south direction and are normal tension faults with downthrows on the east sides. They are characterised by the presence in the fault-planes of large veins of quartz, a feature particularly prominent in the northern area in the vicinity of Nuwerus. The weathering of these large veins gives rise to the extensive sheets of white quartz pebbles that occur in many parts of this region.

The longest N.-S. fault in the present area is the Potklei-Moedverloor fault which extends for almost eight miles. This fault is in all probability a continuation of the one mapped by Rogers on Sheet 19, Nieuwerust, that starts on the farm Meerhofskasteel and runs over Mostertskop to Potklei, a distance of about 25 miles; in all, this fault is over 30 miles in length. Along most of this distance the Nuwerus Series is faulted down on the east against the Pink Gneiss.

A N.-S. fault, concealed by sand-cover, appears to be present along the east side of the Groot Graafwater near Rooiberg and has been discussed on page 58. The presence of smaller N.-S. faults is indicated over much of the area surveyed by extensive veins of white quartz.

The younger set of faults trend in a general N.W.-S.E. direction and are also of tensional origin. Where they

occur in the rocks of the Nama System they have determined the strike of these beds to a large extent, and they may be related to the north-north-west "grain" induced by the early phase of folding which affected these rocks.

These faults are frequently characterised by limonite-cemented fault-breccias, and their younger age relative to the N.-S. faults is demonstrated by the presence of white vein-quartz belonging to the older set in the limonite breccias of the younger set.

The origin of the large amounts of limonite in these fault-planes is rather puzzling but may possibly have been deposited in a manner similar to that which caused the concentration of iron and manganese ores in the fault-breccias in the Table Mountain Sandstone. Concerning the latter deposits du Toit (8 p.474) states, "Pyrolusite is found in the Table Mountain Sandstone at Constantia Nek near Cape Town, at du Toit's Kloof near Paarl, and at other places in the Cape, having originated through the leaching out from the sandstone of small quantities of manganiferous compounds and their deposition within lines of crushing or fracturing". The iron in the limonite breccias in the southern van Rhynsdorp area would seem to have been derived, in part, from the Nuwerus quartzites which are seen under the microscope to carry films of iron oxides between the quartz grains. These iron-cemented breccias also occur in the Hilda Series and are strongly developed in the Basal Limestones and graphitic phyllites on the farm Aties. In the latter instances original pyrite in these rocks may have contributed to the formation of the iron oxides. Where these faults pass from the sedimentary rocks into the Pink Gneiss, for example the boundary fault on the south-west side of the Hilda horst, the fault-planes are marked by quartz-veins instead of limonite zones.

Concerning these iron-filled fault-zones, Rogers wrote

(22 p.17), "In many places where the limestone occurs there are occasional layers of brown or black limonitic iron ore .... They appear to be interbedded with marble, for they have not been found cutting across the bedding planes of the enclosing strata .... On the farm Moed Verloren, at a short distance north of the Klip Drift boundary, there is an outcrop of extremely hard, yellowish-brown jasper .... It (the jasper) may be a limonite band, altered by the influence of the granite, but no minerals characteristic of contact metamorphism were found in it".

The jasper referred to above occurs in the dolomite of the Hilda Series on the left bank of the Moedverloor stream opposite the farmhouse. Erosion, subsequent to Rogers' visit, has exposed a section between the jasper and the marble and it can be observed that the marble grades into the jasper by replacement of the dolomite by silica and iron oxide. It is noticeable that, where this replacement is most complete, the marble was strongly brecciated prior to replacement.

The south-west boundary fault of the Hilda horst on Moedverloor trends in a N.W.-S.E. direction. Where the Moedverloor road crosses this fault there is a small black koppie built up largely of limonite. In a north-westerly direction this fault continues into the Pink Gneiss where it is marked by white quartz-veins. South-west of the Zoutfontein Trigonometrical beacon a continuation of this fault forms the contact between the Hilda Series and rocks assigned to the Nuwarus Series. It is possible that this fault continues in a south-easterly direction beneath the sand-cover to Aties where there are a series of limonite-filled fault-zones. Although the faults on Aties trend more nearly N.S. than N.W.-S.E., the presence of limonite suggests that they belong to the younger set of faults.

The ages of the two sets of post-Nama faults, relative to the Cape System, can be determined by the fault south of van Rhynsdorp shown on Map No.3. This fault trends in a N.W.-S.E. direction and carries deposits of limonite over much of its length and belongs in all likelihood to the younger set. It cuts the Basal Limestones at Remhoogte a mile west of van Rhynsdorp, and passes under the Table Mountain Sandstone, without affecting the latter, at the point of Matsikamma. The two sets of post-Nama faults must therefore be of pre-Cape ages.

As mentioned above, the dips of some of the Nama sediments have resulted from block-faulting rather than from folding. Examples of this were observed on the northern part of Moedverloor where the upper Numerus sequence is repeated several times by strike faults. The processes responsible for this phenomenon are described below.

1. The older set of N.-S. tension faults produced blocks of gently folded Nama rocks which pitched at low angles to the west. This induced a low-angle westerly pitch in the originally horizontal lineation which had resulted from the earlier folding.

2. The subsequent period of N.W.-S.E. faulting gave rise to a second set of blocks bounded on the east and west sides by the fault-planes of the N.-S. faults. Rotation, induced by the faulting, of these new blocks about roughly N.W.-S.E. axes resulted in the present dips observed in the sediments and also resulted in the repetition of the sequence.

THE KNERS VLAKTE - VAN RHYNSDORP PENEPLAIN  
AND ITS ASSOCIATED DEPOSITS.

An extensive peneplain, at present undergoing dissection by the drainage system, exists in the van Rhynsdorp Division north of the Olifants River. It is bounded on the east by the escarpment (Matsikamma, Kobe Mountains and the Bokveldberg), and on the west by the Moedverloor Hills, the high ground around Potklei and Mostertskop and the hilly country near Nuwerus. To the north it is terminated by the foothills of the Kamiesberg mountain-land. The greater part of the peneplain is known as the Kners Vlakte, and it slopes from an elevation of about 800 feet in the north to below 500 feet in the south.

Part of the peneplain is shown on Map No. 1 which covers an area of approximately 1,650 square miles. Of this area almost 500 square miles lie between elevations of 500 and 750 feet above sea-level. Since parts of the peneplain are above 750 feet in the northern region and below 500 feet in the south, more than one third of the area covered by the map constitutes the peneplain.

In the area surveyed the peneplain is confined almost entirely to the less resistant rocks of the Nama System, especially the Basal Limestones, and the argillaceous beds of the Hilda Series. The gneiss of the Moedverloor Hills and the quartzites of the upper Nuwerus Series rise above the plain and form features like the Luiperskop ridge and the small koppie on which the Zoutfontein Trigonometrical beacon stands.

Photograph No. 28 was taken from the Trigonometrical beacon near Liebendal siding, looking across the plain towards Matsikamma, a distance of more than 20 miles.



No. 28. Looking across the peneplain from Liebendal towards Matsikamma.

On the Kners Vlakte a group of conglomerates and quartzites, very similar to those in the Schwarzkalk Series mapped by Brink, form occasional outcrops above the plain such as those on Quaggaskop and Douse-the-Glim. In this area extensive sheets of white vein-quartz pebbles mark the north-south trending faults.

Pans are a common feature on the Kners Vlakte and a small one occurs just north of Beeswater in the area surveyed. These pans represent small areas of inland drainage and are underlain by considerable thicknesses of silty soil. On Douse-the-Glim lucerne is being successfully cultivated on one of these pans brought under irrigation from the Sout River.

The occurrence of gypsum was frequently observed over the whole of the Kners Vlakte but it is present on a much smaller scale than in the southern area.

#### The age of the peneplain.

The minimum age of the peneplain can be ascertained from the oldest known deposits which occur on its surface; these are the silcretes. On the farm Sandkraal south of van Rhynsdorp, there are extensive patches of silcrete over an area of almost ten square miles. They lie at an elevation of just under 500 feet and overlie the Basal Limestones of the area. Silcretes occur at frequent intervals along

the right bank of the Olifants River from Klaver as far at least as the mouth of the Hol River, and it is of interest to note that these outcrops maintain an almost consistent height of about 50 feet above the right-bank irrigation canal. Several other outcrops of silcrete were mapped in the area and these appear on Map No.2.

If the silcretes of the van Rhynsdorp region are assumed to be of Miocene age, the peneplain must be older, and without further evidence may be assigned to the early Tertiary, and in all likelihood corresponds in age to the Eocene peneplains of the Western Province and Saldanha Bay described by du Toit ( 8 p.509).

#### The Deposits occurring on the Peneplain.

Four types of deposits of post-peneplain ages are described below. They are the silcretes, the mud conglomerates, the calcareous capping deposits and the high-level river gravels. The gypsum deposits are described with the economic minerals of the region.

Before considering the four types of deposits mentioned above, their relative ages are discussed.

The silcretes are definitely the oldest of the group and have never been observed to overlie any of the other three, and always rest directly on Nama or pre-Nama rocks. The mud conglomerates are probably the next oldest and were observed to overlie silcrete on the left bank of the Groot Graafwater just above its confluence with the Sout River as illustrated by Photograph No.50 on page 98. The calcareous conglomerates, which form capping deposits in the Kners Vlakte, rest directly on the Nama and pre-Nama rocks of that area, but their age relative to the silcretes and mud conglomerates is uncertain since they were not observed in contact with either of the latter. Near the mouth of the Hol River some calcareous gravels

underlie the high-level river gravels, and if these calcareous gravels correspond to the Kners Vlakte calcareous conglomerates, the latter must be older than the high-level river gravels.

### The Silcretes.

The silcretes vary greatly in grain-size and show a colour range from pale yellow, through grey to brown and reddish brown. Vein-quartz pebbles occur frequently in the silcretes and a conglomeratic variety was observed about one mile south-west of Liebendal siding, just above the right-bank irrigation canal. This outcrop, illustrated in Photograph No.29, contains inclusions of vein-quartz over six inches in diameter and rests of quartzites of the Hilda Series.



No. 29. A conglomeratic variety of silcrete, south-west of Liebendal siding.

Several large quartz-veins (Photograph No.7 ) mark faults in this area and the pebbles in the silcrete were no doubt derived from these veins. The pebbles do not show much sign of rounding, and this supports the view of Frankel and Kent (11 p.29 ) that the silcretes were formed by the cementation of locally derived material. Conglomeratic horizons were observed in the silcretes near the Nuwedrif Trigonometrical beacon <sup>east</sup> west of Vredendal.

The latter siloretos overlie the dolomite and felspathic grits of the Hilda Series and are the thickest deposits seen in the region; at least 20 feet are present.

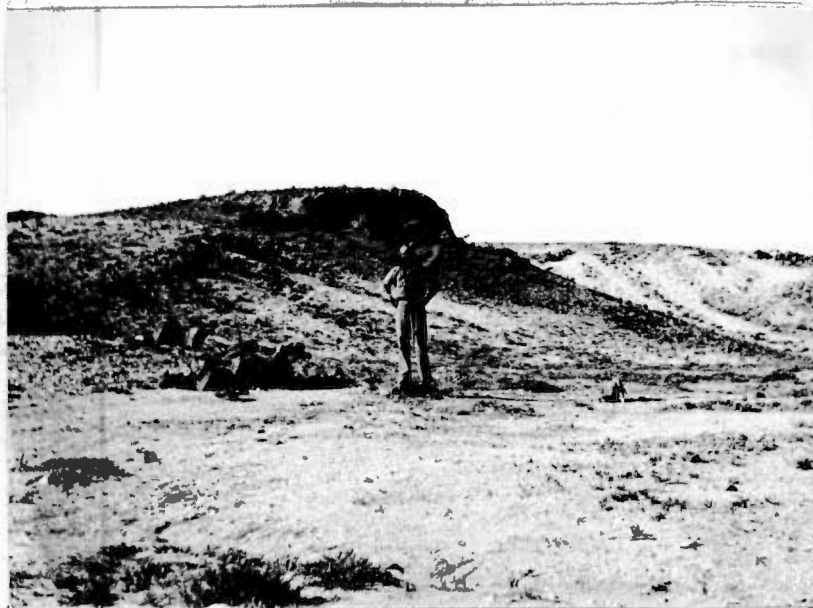
Every deposit of silcrete visited in the van Rhynsdorp region was surrounded by very numerous stone implements, especially of Middle and Later Stone Age cultures. These sites, together with the implements ranging from pre-Stellenbosch types to Wilton that overlie the high-level river gravels wherever they are exposed through the sand-cover form the richest archaeological field that the author has yet encountered. Lack of definite stratification in these occurrences is unfortunate but it is certain that this hitherto neglected region will play an important part in the future study of Archaeology in the Union.

#### The Mud Conglomerates.

These deposits form caps on the small ridges in the neighbourhood of the larger rivers, and vary in thickness from a few feet to a maximum of about twenty feet. They are characteristically developed on sloping ground above the present drainage system, and on Moedverloor occur as two patches, about one mile apart, on either side of the Moedverloor stream, strongly suggesting remnants of an old land-surface. In the author's opinion these deposits represent material washed down from the slopes of elevated ground into the streams and rivers of a choked drainage system. It is further suggested that this choked drainage system was related to a rise in sea-level, possibly during late Tertiary times. The age of the deposits remains in doubt, since a careful search failed to yield any fossils. Subsequent rejuvenation of the drainage system cut down into the silted up river valleys, and the remains of these deposits now lie above the levels of the present rivers.

Photograph No. 30 shows an outcrop of mud conglomerate

capping a small ridge on the left bank of the Groot Graafwater just above its confluence with the Sout River. The figure in the photograph stands on a small deposit of silcrete which underlies the mud conglomerate,



No. 30. A capping of mud conglomerate overlying silcrete on which the Native is standing.

Undercutting by wind erosion has formed numerous small caves on the exposed sides of these deposits, and the occurrence of wood ash, tortoise bones and ostrich egg shells shows that these caves were extensively used as shelters by the Wilton people.

In handspecimen the conglomerate is seen to consist of pebbles of vein-quartz and local rocks such as quartzite etc. set in a reddish-brown matrix of indurated clay material containing varying amounts of sand. The colour is due to hydrated oxides of iron. The inclusions show practically no signs of rounding and suggest an almost "in situ" origin for the formation. An occurrence north-west of Bergplaas contains inclusions of limonite-cemented fault breccia derived from the neighbouring strike faults in the Nuwerus Quartzites.

These deposits may correspond to the ferricretes of the Western Province with which they have several features in

common. The following descriptions by du Toit are given for comparison (8 p.412 and 413). "Most commonly there is a large proportion of clay, sand and angular fragments of quartz or other resistant material, cemented together by hydrated oxides of iron, ..... It (the ferricrete) usually appears as a rough surface crust or as a layer beneath a thin covering of sandy soil and tends to form principally on flat or gently inclined surfaces; .....".

"In the Western Province of the Cape such deposits are common on both the Malmesbury slates and on the granite, especially on the gently rising ground, while more to the east they constitute much of the materials building the high-level Tertiary terraces, .....".

During a visit to the Hardeveld region west of Bitterfontein, the author observed some deposits of a similar nature, known locally as "rooikalk". They consist of quartz pebbles and weathered felspar set in an arkosic matrix, and were derived from the gneiss of this region. Ridges of this rooikalk occur on the sloping ground above the present streams and rivers and again give one the strong impression that they represent remnants of an old land-surface. Caves, similar to those in the van Rhynsdorp deposits, also occur and were inhabited by the Wilton people.

Occasional small pans were observed in the Hardeveld near Louisfontein at a considerable elevation above the existing drainage system. This is rather an anomalous feature in the hilly country of the region, and these pans would appear to be related to the old land-surface, indicated by the rooikalk, the remnants of which occur at an elevation of roughly 1,200 feet above sea-level.

#### The Calcareous Conglomerates of the Kners Vlakte.

Dr. Rogers gave the author two photographs of capping deposits in the Kners Vlakte in which he had found marine fossils including sharks' teeth. During July 1947, the

the author made a search of the Kners Vlakke area and was able to locate the site at which these photographs were taken. It is about 150 yards to the east of the old van Rhynsdorp-Nuwerus road on the farm Quaggaskop. During this search extensive outcrops of this capping deposit were found, especially in the Quaggaskop area between the Sout and Geelbeks Rivers. Large blocks were frequently seen in the Sout River bed, having been undercut by the river. Outcrops were observed as far north in the Kners Vlakke as Douse-the-Glim and Zandkraal, often at considerable distances from the Sout River, but always overlying the much older arkoses, quartzites etc. on the tops of ridges of these rocks. Gravels containing many boulders derived from the Dwyka tillite, sometimes overlie the calcareous conglomerates and appear to be high-level river gravels.

The widely separated occurrences of these conglomerates in the Kners Vlakke strongly suggest an extensive distribution beneath the sand-cover of that region.

Thin occurrences of gravels with a calcareous matrix, similar to the conglomerates of the Kners Vlakke, were observed overlying the Nuwerus arkoses and quartzites near the dolerite sill at Gembokberg. These gravels are usually about two feet thick and may correspond to the calcareous conglomerates. Similar gravels were seen to underlie some of the high-level river gravels along the Olifants River.

The Kners Vlakke deposits vary from about two feet to over twenty feet in thickness and occasionally exhibit a sandy basal phase similar in appearance to coarse beach-sands. The latter type grades through sandy conglomerates into conglomerates practically devoid of fine-grained material, but the dirty white- to cream-coloured calcareous matrix is always present.

Photograph No. 31 shows the deposit capping arkoses on the left bank of the Sout River immediately below the bridge on the van Rhynsdorp-Nuwerus road.



No. 31. The calcareous capping deposits just below the van Rhynsdorp-Nuwerus road-bridge over the Sout River.

A large variety of rock types was observed among the pebbles which attain sizes up to four inches with occasional larger exceptions. On an average the pebbles are between a quarter of an inch and one inch in size. Vein-quartz, quartzite, shale and phyllite derived from the neighbouring rocks were observed, together with fine-grained igneous rocks. Red jasper from the Dwyka tillite was also seen. The majority of the inclusions show signs of rounding and the shale and phyllite pebbles are disc-shaped.

A thorough search of the deposit photographed by Dr. Rogers and the other deposits visited, failed to reveal any definite fossils but one specimen that may be a coral was found. The author was informed by Mr. D. Coetzee of Sandkraal, van Rhynsdorp, that a layer of thick shells was exposed in the Sout River bed on Douse-the-Glim during the building of a weir across that river. His description suggested that the shells were those of oysters, but since

none of this material was available for examination no conclusions could be reached.

In the author's opinion these calcareous deposits may be of marine origin, and this view is supported by the following points.

1. Dr. Rogers informed the author that he had found marine fossils, including sharks' teeth, in the deposits located on Quaggaskep, where the author also found a doubtful coral. A deposit of thick shells, possibly oysters, was reported in the bed of the Sout River on Douse-the-Glin.

2. The typical Kners Vlakte calcareous conglomerate is very similar to the deposits that occur on the raised beaches on the coast near Strandfontein, and can be compared with a specimen of diamondiferous gravel from Alexander Bay at present housed in the museum of the Department of Geology, University of Cape Town. The author was informed that several small diamonds were found near Vlermuisklip during the construction of the Olifants River irrigation canals. Calcareous gravels, which may correspond to capping deposits, were observed during the present survey in that area.

3. The Kners Vlakte deposits occur at elevations between 500 and 750 feet above sea-level, and the calcareous gravels near the Olifants River occur at approximately 300 feet. This suggests that if these deposits are of marine origin, they were formed during the retreat of the sea across the region concerned. It is of interest to note that Söhnge and de Villiers have recorded remnants of raised beaches in the Richtersveld area at approximately 594 feet above sea-level (27 p.269).

The possibility of a marine transgression across parts of the van Rhynsdorp region in Tertiary times is suggested by the nature of some of the gypsum deposits such as those

at Ratselfontein (p. 112).

The High-level River Gravels.

High-level river gravels occur on both sides of the Olifants River, but cover a greater area on the north-east side. Water-worn boulders were observed in the vicinity of the Liebendal Trigonometrical beacon which is over a mile from the river. This occurrence, and similar ones on this side of the river, suggest that the Olifants has migrated in a south-westerly direction; possibly down the sloping surface of the peneplain. That this lateral migration of the river may be related to crustal warping, however, is suggested by the following observation. Between the Doorn River and Klaver high-level gravels are extensively developed on the east side of the Olifants River, between its present course and the mountains. Since this area is bounded on the east by the mountains about three miles distant, and not the peneplain, it would seem that the river moved across an area that was sinking on the western side.

Extensive river gravels occur on the plain to the north-east of the Groot Graafwater opposite Luiperokop. These gravels are well above the present river bed and again suggest a lateral migration of the Groot Graafwater in a south-westerly direction.

The gravels of the Olifants River contain a large variety of rock types among which the following were observed: quartzites of the Nuwerus and the Table Mountain Sandstone Series, vein-quartz, red jasper, fine-grained igneous rocks, especially porphyries, and occasional pebbles of Dwyka tillite.

No reliable age can be assigned to these river gravels. Stellenbosch and pre-Stellenbosch implements frequently occur on top of the gravels and were no doubt made from

material selected from these deposits. Searches failed to reveal any rolled implements in the gravels and this suggests that they must be at least of a pre-Pleistocene age.

Large areas of the van Rhynedorp region are covered with deposits of aeolian origin of which two distinct types were recognised. The first is represented by the red drift-sand which forms dunes south of the Moedverloor hills, south-west of the Olifants River and over a large area to the south of the Hol and Varsche Rivers. The presence of considerable garnet and zircon in the heavy concentrates of three samples, collected between Vlermuisklip and Moedverloor, suggests that these sands may have been derived in part by the weathering and disintegration of the Pink Gneiss.

The second type of deposit occurs near the larger rivers and is typically developed near Vredendal where it exceeds a thickness of 50 feet in places, and is often overlain by the red drift-sand of the first type. It contains a high proportion of fine-grained silt and clay and may have been deposited in part by rivers, but strong cross-bedding indicates an aeolian origin. Fossil termite-nests can be observed in several railway outtings through this material, the nests having been preserved by the replacement of original organic matter with calcium carbonate.

#### The occurrence of fossil wood.

At two localities in the area pieces of fossil wood were found in the sand-cover. Both these localities lie in shallow depressions which may represent old stream courses, and occur near the bridge over the right-bank irrigation canal on the Vredendal-van Rhynedorp road, and about half way between Vredendal and Bakleiplaas.

The author submitted sections of the material to Prof. Adamson of the Department of Botany, University of Cape Town, and is indebted to him for the following description and notes.

The sample is that of a dicotyledon wood with distinct annual rings, large vessels, usually isolated, and numerous fibres. Prominent medullary rays are present which are 1 to 4 cells wide and 8 to 12 cells deep, all of which are parenchymatous. The preservation of the material is not sufficiently good to show details of vessel structure. The general construction is very much like that of some species of *Rhus*.

*Rhus* spp. occur as riverside trees throughout the dry regions, e.g. *R. lancea* and *R. viminalis* which form trees of considerable size. The latter species is general in the Western Karroo areas.

*Rhus viminalis* occurs in the present area along parts of the Sout River and therefore the occurrence of this fossil wood cannot be used in reaching any conclusions regarding the past climates of the region. It is significant however that the material between Vredendal and Bakleiplaas occurs in a sand-covered area where no water-course, capable of supporting this species, exists at the present time.

#### Rejuvenation of the Present Drainage System.

There is abundant evidence in the van Rhynsdorp region of rejuvenation of the existing drainage system. This rejuvenation would appear to be active at the present day and seems to be related to rejuvenation observed throughout Namaqualand as far away as the Richtersveld and the Viools Drift areas.

Striking evidence of this downcutting by the rivers

was observed at the following localities. In the Kners Vlakte the Sout and Geelbeks Rivers occupy steep-sided troughs rather than shallow valleys at many points, and their banks rise almost vertically to the plain above. The relatively steep banks of the Sout River in the Gamsbokberg poort afford another example. Below Holrivier siding the Hol River has cut a course with very steep banks almost twenty feet high through silt and sand which probably represent old flood-plain deposits. Both the Troe Troe and Widow Rivers show steep banks on either side of their narrow courses. An old river-bed has been exposed in the railway cutting a hundred yards on the Vredendal side of the railway bridge over the Troe Troe River. This may represent an old course of the Troe Troe River and stands about 25 feet above the present river-level.

The base-levels of the Hol and Troe Troe Rivers have always been determined by the level of the Olifants River, and the amounts of down-cutting of the Hol and Troe Troe Rivers mentioned above i.e. 20 feet and 25 feet, suggest that the Olifants River should show a corresponding drop, and there is some evidence of this. The steep cliffs of dolomite along the Olifants River from near Klaver to beyond Vredendal may be cited. Further, it is highly significant that the old Olifants River flood-plain, which constitutes the extensive irrigated lands, stands between 20 and 30 feet above the present river bed.

It seems possible that this 20 to 30 feet change in river-levels is related to the 20 feet sea-level change of relatively recent times. Krige (15 p.72) gives the following account of the dating of the related 20 feet strandline, "The age of the strandline may be vaguely deduced from the fact that a few of the species of shells are now apparently extinct, from considerable migration of species that has since taken place, and from the occurrence of some

stone implements, of the "Later Period" on a few terraces and in caves".

A phenomenon, apparently related to this rejuvenation, came to the author's notice in southern Namaqualand, in the Richtersveld and along the eastern edge of the Neint Nababeep plateau near Viools Drift. In the areas mentioned small calcareous gravel ledges are often seen along the edges of the streams at heights varying from about one foot to ten feet above the present beds. It would seem that these small ledges mark the rejuvenation of the small streams in response to the general 20 to 25 feet drops in the levels of the larger rivers of these areas.

THE MINERAL RESOURCES OF THE VAN RHYNSDORP DIVISION.

At the present moment limestone, gypsum and marble are the only minerals that are being exploited in the region, and extensive deposits of all three suggest that further development will take place. Other deposits known to occur include clays suitable for ceramic manufacture, graphite in certain phyllites of the Hilda Series at Atlas, zircon sands on the coast and silcrete which may prove suitable for the manufacture of silica bricks and other silica products. Diamonds occur in the raised beach deposits along the coast and may also be present in the calcareous capping deposits of the Kners Vlakte. All the pegmatites associated with the Pink Gneiss in the region have proved to be barren. The recently reported occurrence of gold in the Pink Gneiss north of Bitterfontein seems to be without foundation.

Limestone.

Limestone is being quarried at present by the National Portland Cement Company at Holrivier. The quarries are situated about half a mile from the railway siding and are connected with the main line by a mineral line. Present production is in the neighbourhood of 45,000 tons a month, but this figure could be raised if sufficient transport were available. It is estimated that there are sufficient reserves in sight to last for at least 50 years.

Prospecting operations along the Widouw River, south of van Rhynsdorp, have indicated the presence in the Basal Limestone Series of unlimited quantities of high grade limestone suitable for industrial purposes. The table of analyses on page 43 shows that limestones averaging about 95%  $\text{CaCO}_3$  are continuous across the strike over distances of more than half a mile in places. In this area extensive sand-cover presents exploitation difficulties in the form of excessive overburden, but cliffs occur in the gorge

of the Widow River that offer ideal conditions for the development of quarry faces. Similar conditions exist along the limestone ridge at Gamsbokberg for a distance of about 5 miles.

The present survey has shown that the limestone resources of the van Rhynsdorp region form a practically inexhaustible supply of high-grade limestone that will be able to supply the country's needs of this indispensable raw material for many years to come. The main difficulty in the development of these deposits at the present time is the lack of rail transport facilities over the greater portion of the region.

#### Gypsum.



No. 32 The gypsum diggings at Bergplaas.

Gypsum deposits are at present being worked at the following localities in the region: the deposit at Bergplaas, 12 miles from Holrivier siding has been worked for the last 15 years; on the farm Onder Aties prospecting operations are in progress and considerable quantities are being transported to the railhead at Vredendal; near Komkana siding and at a point several miles to the west of van Rhynsdorp, deposits are being worked and the raw product is concentrated by washing processes before it is railed.

There are extensive deposits of gypsum in this region but unfortunately many of these are situated at distances from the railway that render their development uneconomical under the current prices. Local experience has shown that deposits may be worked with a reasonable margin of profit at a maximum distance of between 12 and 15 miles from the railhead. This is based on an average transport cost of just under 1/- per ton-mile. Indications are that if sufficient water is available for the concentration of the raw product by washing, it may be possible to extend this range by several miles.

Mining is at present carried out by removing the overburden with pick and shovel, and sinking trenches into the underlying deposits. In some cases the overburden is removed with bull-dozers. The gypsum is partially concentrated by breaking up the clay clods and roughly sifting the lumps of gypsum with a fork. Further concentration is effected by crushing and then passing the material through a simple log-washer.

The formation and preservation of the deposits are intimately related to the arid conditions which have prevailed in this region for a very considerable period. Regarding the origin of the gypsum in the van Rhynsdorp region, Wasserstein (33 p. 33) mentions the following features. The local formations often consist of limestones and phyllites, the latter carrying pyrite. The sea, which is not far distant and has retreated in geologically recent times, may have been responsible for some of the deposits.

It is probable that the  $H_2S$ , which is almost universally present in the Basal Limestones, may have supplied much of the sulphate radical of the gypsum.

Field observations suggest the following explanations of the deposits in this region.

The arid conditions prevailing in the region are

probably one of the most important contributing factors, and the mode of the majority of the deposits suggests the concentration of gypsum near the surface by the capillary phenomena characteristic of dry climates. The richest deposits usually occur in recent sand and clay overlying limestones or at short distances from outcrops of these rocks; the deposits at Aties, Bergplaas and in the Groot Craafwater area may be cited as evidence. This would suggest that the limestones have contributed in large measure to the formation of the gypsum.

There is a belief among the local prospectors that rich deposits occur on slopes below the frequent limonite-filled fault breccias in the area, and the occasional presence of cubes of limonite, apparently after pyrite, in some of these fault breccias, suggests that these fault zones may originally have carried pyrite, the oxidation of which would have given rise to the sulphate radical of some of the gypsum.

The circulation of underground and sub-surface water has no doubt played an important part in the concentration of the deposits. All the well waters in the area are highly charged with mineral salts, including those in the essentially granitic area of Komkans and those from the shallow wells sunk in the gravels and sands of the dry river beds. An analysis of the well water from the sandy Moedverloor stream is given on page 117. This stream bed is surrounded by rocks of the Hilda Series from which the salts were derived by leaching action. It is noteworthy that both the Ca and  $SO_4$  radicals are present in relatively high concentrations, viz. Ca, 11.5 parts per 100,000 and  $SO_4$  39.9 parts per 100,000. The frequent presence of crystals of gypsum in the decomposed rocks of the Hilda Series in this neighbourhood is apparently related to the presence of these radicals in the circulating sub-surface

waters. Cubes of limonite after pyrite occur in some of the arkoses.

The majority of the gypsum deposits in the van Rhynsdorp region would appear therefore to be related to the following factors: 1. extensive limestones containing  $H_2S$ , 2. original pyrite in the arkoses and phyllites of the Nuwerus and Hilda Series, 3. concentration by underground and sub-surface waters under arid conditions.

Two other deposits deserve mention. In the neighbourhood of Komkans workings have been opened in deposits occurring in sandy clay formations of relatively recent origin. Several of these deposits, which have been opened to depths of about 15 feet, suggest that they represent areas of inland drainage partly filled by wind-blown material. Profiles reveal layers and ramifying veins of gypsum in alternating clay and sandy horizons, and the red colour of the sand indicates prevailing arid conditions. These deposits would appear to be somewhat similar to the gypsum pans of the Kimberley and Hay districts. The source of the component calcium and sulphate radicals is obscure in this area since the surrounding country is built up of Pink Gneiss and occasional patches of Kheis rocks.

Near Ratelfontein siding on the Bitterfontein line in the Clanwilliam Division, deposits of very pure gypsum are at present being developed. The surrounding country is built up of Table Mountain Sandstone with extensive areas of wind-blown sand. In this locality again the origin of the gypsum is obscure, but it may be connected with a marine transgression across this part of the country in geologically recent times. Evidence of such a transgression has already been discussed on page 102.

Three main types of gypsum occur in the deposits of this region. The commonest type may be termed "rosette gypsum" and occurs as aggregates, averaging about 3 inches

in size, of small twinned rosettes of gypsum crystals set in the usual brown to yellowish clay. This type grades into purer, semi-transparent crystals approaching selenite, which appear to represent veins of secondary gypsum purified by solution and redeposition. Associated with the rosette gypsum, and generally overlying it, layers of a dirty white "powder gypsum" frequently occur immediately beneath the sandy-gravel overburden. Recrystallisation of gypsum results in the formation of patches of the massive cream to pale brown "rock gypsum" found at several localities at Aties. The powder gypsum and rock gypsum are the purest types found in the deposits and are stated to yield over 90%  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ .

At present the bulk of the gypsum mined in the van Rhynsdorp region is consumed in the Portland cement industry, but the higher grades are finding increasing uses in the manufacture of building materials.

#### Marble.

On the farm Moedverloor, the dolomite of the Hilda Series is being quarried for marble by the Namaqualand Marble Company. Rather severe earth-movements have shattered this marble in places, but by making use of a series of joints, blocks of suitable dimension-sizes are obtained. The colours range from white, through cream to mottled blue. A description of a typical diamond-drill core from these quarries has been given on page 27.

On the farm Widouw to the south-east of van Rhynsdorp, a wavy blue-grey marble has been successfully quarried in the Basal Limestone Series. Marble from the same series was obtained at Holrivier about 20 years ago. The almost universal recrystallised state of the Basal Limestones make them very suitable for the production of marble and a wide range of colours may be expected.

Clays.

Extensive horizons of pure clays occur in many of the weathered outcrops of the Hilda Series in the region. These deposits vary greatly in colour but several localities were encountered where the white colour suggests a low iron content. Samples were collected from the decomposed rocks underlying the Table Mountain Sandstone on the road up the Giftberg Pass south-south-east of van Rhynsdorp. The samples were fused without the use of fluxes and gave a product with a high glaze and of considerable strength. If these clays can be economically transported to the railhead, a detailed investigation of their possible use in the ceramics industry may prove of value.

Graphite.

Some of the phyllites of Aties have been shown to contain over 40% of carbon, probably in the form of graphite. The phyllites, which are developed on a fairly extensive scale, may prove to contain sufficient graphite to warrant their exploitation. The deposits are situated approximately  $4\frac{1}{2}$  miles from the railway at Vredendal.

The following figures (16 p.261-263) of the percentage graphite in ores from various parts of the world are given for comparison.

Ceylon, 50% graphite in veins.

Madagascar, 10 - 60% graphite in graphitic-schists.

Germany, 10 - 20% graphite in gneisses.

Alabama, U.S.A., about  $2\frac{1}{2}$ % graphite in schists.

Silerete.

Silerete, at present obtained from the Mossel Bay and Riversdale districts, has been used successfully as a source of high grade silica for the manufacture of the silica bricks used at Iscor (35 p.354). There are two deposits near the railway; one about three miles from Vredendal on

the van Rhynsdorp road, and the other occurs 2 miles south of Holrivier siding.

#### Zircon Sands.

In 1908, Rogers (21 p.167) drew attention to a black sand on the beach at Strandfontein, some miles south of the mouth of the Olifants River. This sand contains rounded grains of magnetite, zircon and garnet. At Bamboes Bay, several miles south of Strandfontein, Rogers mentioned a heavy grey limestone on the raised beach deposits "which owes its grey colour and great density to the quantity of these minerals present". The concentration of heavy minerals in the limestone must be comparatively high if they have appreciably increased the density of this limestone, especially since these coastal limestones are usually relatively light rocks.

The occurrence of these minerals in the black sands and limestone warrants a detailed investigation in view of the recovery of valuable heavy concentrates from certain black sands in Australia. It is also possible that some diamonds would be included in the heavy concentrates of beach sands from the Strandfontein area.

The source of these minerals is obscure, but it is of interest to note that garnet, zircon and ilmenite were present in the heavy concentrates from three samples of wind-blown red sand collected between Vlermuisklip and Moedverloor.

#### Diamonds.

Desultory prospecting and mining have been carried on over a period of years along the van Rhynsdorp coast to the north of Strandfontein and above the mouth of the Olifants River. Although diamonds have been recovered, these deposits do not compare with the far richer occurrences along the northern Namaqualand coast.

The presence of marine fossils in the calcareous capping deposits on the Kners Vlakte, and the similarity of these formations to some of the diamondiferous, raised beach deposits of the coast, suggests that diamonds may be present in these calcareous capping deposits. This view is supported by the fact that certain of the rivers of the Kners Vlakte drainage system rise in the Kamiesberg region to the north where Kimberlite pipes are known to occur.

### Water.

Water supply is a vital problem over the greater part of the semi-desert region with a rainfall of approximately 5 inches per annum. Beyond the range of the Olifants River a reliable source of water necessitates the sinking of wells or bore-holes. Underground water is very scarce in this region and H.F. Frommurze (12 p.41) states that of a total of 40 bore-holes sunk in the van Rhynsdorp area, 38% proved total failures and 6% had insufficient water for practical purposes. The author knows of three bore-holes sunk in the Pink Gneiss near Komkans that all proved to be failures, and of eight failures in ten in the Hilda Series on Moedverloor.

Without the use of special instruments, the only advice that can be given is to bore on the <sup>more</sup> most likely side of the large quartz veins that mark the faults in this region. In general the most successful bore-holes would appear to be those sunk in the Pink Gneiss, while the percentage of failures in rocks of the Hilda Series is always high.

Shallow wells sunk in the sandy gravels of the river beds have proved successful at some localities, but the water is invariably highly saline. The following water analysis, which must be fairly typical of the region as a whole, is that of water obtained from the well in the dry

Moedverloor stream bed just below the farmhouse. An outcrop of jasper crosses the stream bed about fifty yards below the well and creates a natural barrier against which the underground water dams up.

Well water from Moedverloor.

	<u>parts / 100,000</u>
Ca	11.5
Mg	8.7
Alkalies (as sodium)	102.0
Fe	0.017
Silica	3.5
Sulphate (as SO <sub>4</sub> )	39.9
Carbonate (as CO <sub>3</sub> )	10.1
Total dissolved solids	340.0
Total hardness (as CaCO <sub>3</sub> )	64.7
Carbonate hardness "	16.9
Non-carbonate hardness "	47.8

Analyst; Industrial Consulting Laboratory (Pty.) Ltd.,  
Cape Town.

SOME NOTES ON THE PRE-CAPE FORMATIONS OF THE  
WESTERN AND SOUTHERN CAPE PROVINCE.

The Kheis System occurs as isolated patches associated with the Namaqualand crystallines in a broad belt along the Orange River from the Upington area to the Richtersveld, and then southwards to the van Rhynsdorp Division. In the Richtersveld, post-Kheis sedimentary rocks are represented by the Gariep System, the Stinkfontein Series, the Kaigas Series, the Numees Series and the Nama System, the latter being overlain unconformably by the Dwyka Series. In the van Rhynsdorp region there are present the Kheis System, the Hilda Series of the Gariep System, a possible Kaigas tillite and the Nama System; the latter being overlain unconformably by the Table Mountain Sandstone of the Cape System.

South of Klaver the pre-Cape rocks are overlain by Table Mountain Sandstone for about 40 miles as far as the Piquetberg region where the Malmesbury Series makes its appearance. According to Mr. L.P. Rabie of Stellenbosch University, the Malmesbury Series is capable of division into at least two distinct groups, one of which contains extensive volcanics. During 1947 Mr. Rabie visited part of the van Rhynsdorp region with the author, but no definite evidence could be found for correlating any of the van Rhynsdorp sediments with the Malmesbury Series. Subsequently the author was able to examine specimens collected by Mr. Rabie in the Verloren Vallei area and these show a certain resemblance to some of the upper arenaceous phases of the Hilda Series of van Rhynsdorp. The Verloren Vallei rocks, which are considered to be younger than the neighbouring Malmesbury Series, may therefore prove to be of value in establishing the relationship between the Hilda Series of van Rhynsdorp and the Malmesbury Series of the Western Province. Mr. Rabie informed the author that

there are some quartzites in the Piquetberg area which contain grains of blue quartz, and this feature may also prove of value in view of the occurrence of blue quartz in post-Pink Gneiss quartzites in southern Namaqualand.

In the author's opinion the correlation of the French Hoek Beds with the Nama System is incorrect. These rocks are in general more highly sheared than the Nama of van Rhynsdorp and do not show any marked resemblance in lithology or succession. It seems more probable that the younger Klipheuvel Beds may correspond to the Nuwerus Series of the Nama System. The Klipheuvel Beds (8 p.191) which contain conglomerates, grits, quartzites, sandstones and subordinate softer beds, show a greater resemblance to the basal Nuwerus Series of van Rhynsdorp than to any other group that the author has seen in the western Cape Province. The purplish colour of the Klipheuvel quartzites is similar to that of some of the Nuwerus quartzites. The beds at Honig Berg contain white quartz and reddish quartzitic rocks similar to certain beds of the neighbouring Malmesbury Series, and if these "in situ" conditions are general in the Klipheuvel and Honig Berg formations, it is possible that they may represent the basal-Nama marine transgression discussed on page 63. Recent work by Rabie has disclosed the existence of extensive sediments younger than the Malmesbury which are tentatively correlated with the Klipheuvel Beds (85 p.11).

The correlation of the Transvaal and Nama Systems is very much in doubt and the inclusion of the Malmesbury Series in the Transvaal-Nama will have to be abandoned. There are increasing difficulties in the correlation of the sediments of the western part of the Union with those of the Transvaal, and the Namaqualand crystalline complex would seem to have separated these two distinct regions where various periods of sedimentation occurred in recur-

ring geosynclines.

There is a similar difficulty in correlating the rocks of the Malmesbury Series with any of the post-Kheis groups of the western Cape Province. There is evidence that parts at least of the Malmesbury sediments were derived from soda-rich igneous rocks and Walker and Mathias (31 p.506) have recorded a very considerable proportion of sodic plagioclase ( $An_{12}$ ) in fine-grained arkoses or siltstones from the Cape Peninsula area. They consider it probable that "igneous masses of highly sodic composition (possibly trondhjemite) were being denuded during the formation of these sediments, for the felspathic nature of the psammitic Malmesbury extends far beyond the Cape Town area". The two analyses of psammitic hornfelses given by Walker and Mathias show  $Na_2O/K_2O$  ratios of 1.06 and 1.13, and Rabie has obtained similar ratios from analyses of other Malmesbury sediments. This feature suggests that the Malmesbury Series was not derived from the potash-rich granitic rocks of the Namaqualand region (if the Malmesbury sediments are younger than the latter). No igneous masses of a nature suggested by Walker and Mathias are known in the southern part of the Union, and it is possible that the Malmesbury sediments were derived in part from a basement which may have been separated from Africa by continental drift. It seems possible that the Malmesbury Series and the sediments of the Gango and Gantooes areas (25 p.11) were deposited in a geosynclinal region distinct from that of the western Cape Province in which the Cariep to Nama sedimentation occurred. It is significant that the Malmesbury geosyncline postulated above would correspond to the later Samfrau geosyncline. Scholtz (25 p.xciv) however has figured a line running approximately west from Port Elizabeth to Lainsburg and then in a north-westerly direction to the Richtersveld. This line forms the hypo-

thetical margin of the Malmesbury geosyncline and the distributive province of Malmesbury sediments lies to the north and east. Such a line apparently assumes that the Malmesbury sediments are capable of correlation with sediments of the western part of the Cape Province.

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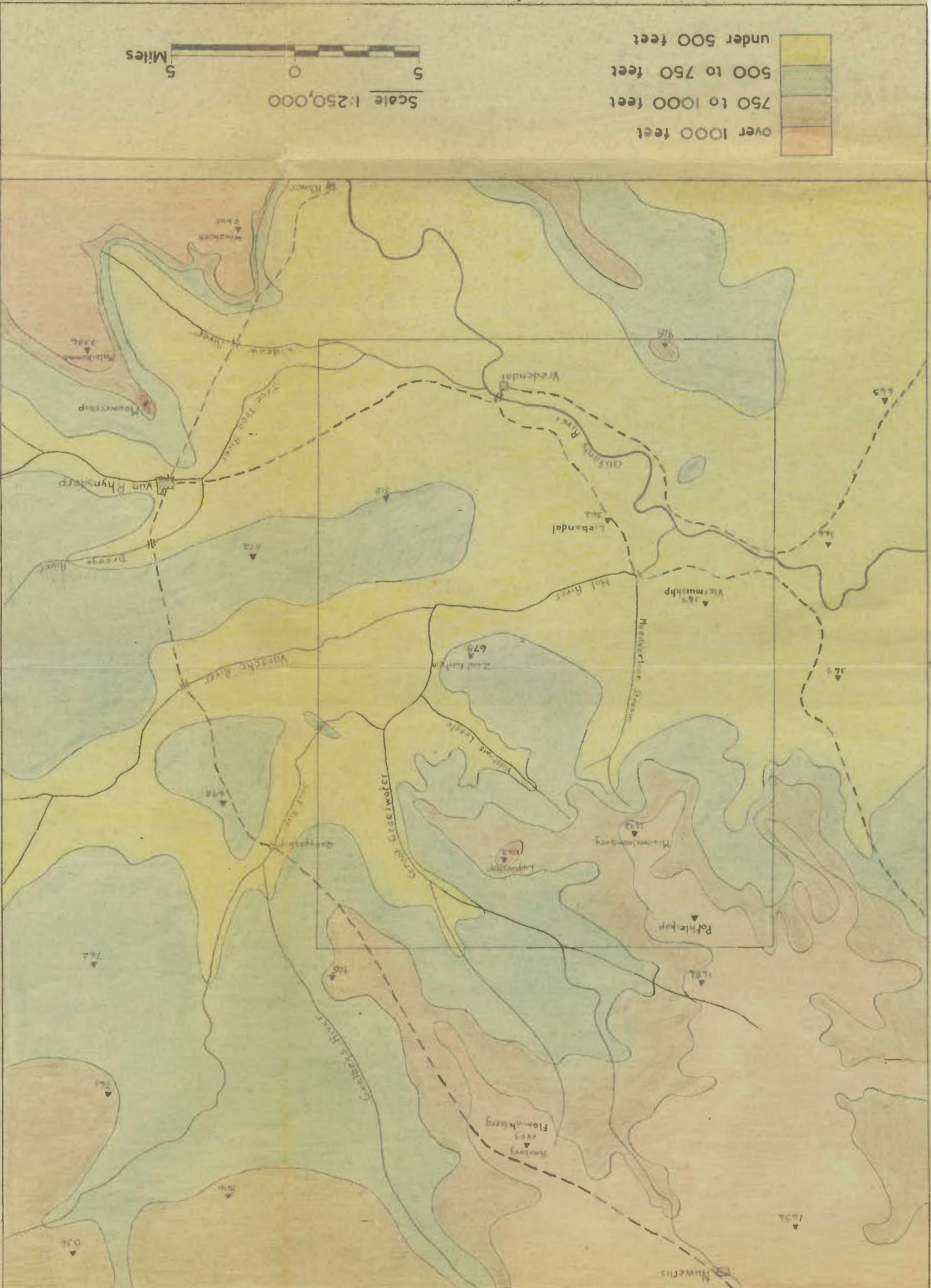
MAP No. 1

18° 51' 31" S

18° 13' 31" S

31° 47'

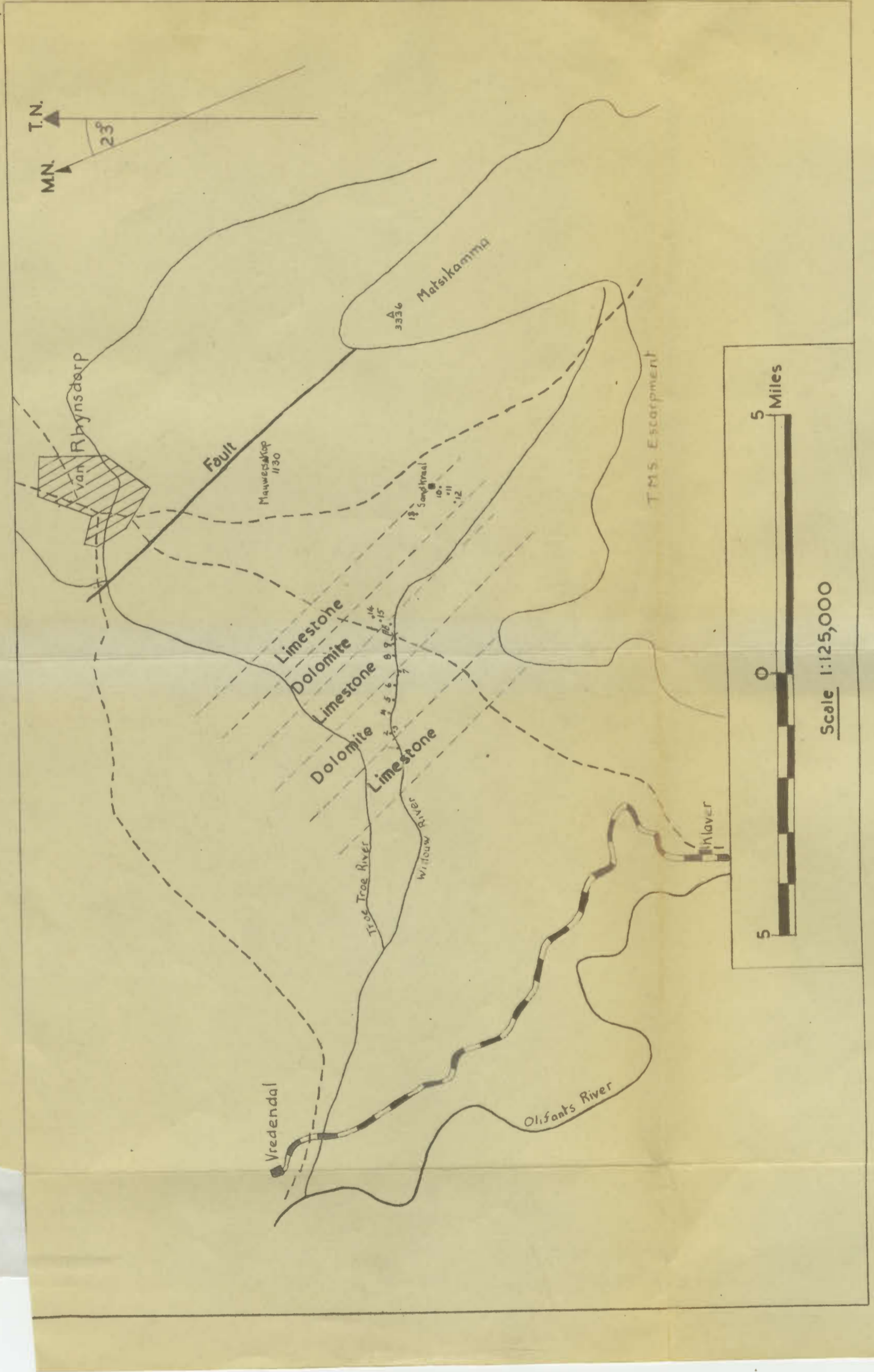
31° 47'



Scale 1:250,000  
5 0 5 Miles

over 1000 feet  
750 to 1000 feet  
500 to 750 feet  
under 500 feet

# MAP No. 3





18° 20'

**GEOLOGICAL MAP**  
OF  
PART OF THE VAN RHYNSDORP DIVISION

**LEGEND**

Recent sand

Dip of sediments