THE GEOLOGY OF THE MANGANESE AND IRON DEPOSITS NORTH OF POSTMASBURG C.P.

BY

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Table of Contents:

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THE GEOLOGY OF THE MANGANESE AND IRON DEPOSITS NORTH OF POSTMASBURG, CAPE PROVINCE.

Abstract.

This thesis is based on nearly three years work on the manganese fields of Postmasburg. During this period the writer was able to study in detail every corner of the fields, and make detailed maps of every manganiferous portion, barring a small area at Aucampsrust, which was later visited, and formed the subject of a paper read before the Geological Society of South Africa. Small portions bearing little manganese in the immediate vicinity of Postmasburg itself were mapped on a smaller scale by two of my colleagues.

Because of the lengthy and detailed field work, the subject matter of this thesis is largely based on field observations, supplemented by the study of some mineralogical details in the laboratory.

The field study therefore embodies the results of the detailed mapping and observations. The complex geology, dominated by the two major factors in the shape of the unconformity between the Matsap and Transvaal systems, and the post-Matsap thrusting, is described. From the nature and distribution of the basal member of the Gamagara sediments, conclusions are drawn with regard to the distribution of the members of the Transvaal system in the area in pre-Matsap times. In the light of such a distribution, the evolution and effect of the post-Matsap tectonics is discussed.

Particular attention is paid to the nature of the manganese and iron deposits, and the relation of the one type of deposit to the other, as well as their relations

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to the enclosing geological formations. The probable time and mode of the periods of haematitisation and manganisation is discussed, and the possible effect of the active constituents in the accessory minerals on the mineralisation is alluded to. The interesting assemblage of accessory minerals are also described.

CHAPTER I.

Introduction.

(A) Resume of Past Work.

Early accounts of the structure of some of the rocks of the area were given by the travellers W.J. Burchell and H. Lichtenstein about the year 1805. (28.p.6.) R. Moffat travelled extensively in the area, and added many interesting geological notes in papers printed in the "Journal of the Royal Geographical Society" for 1858. (28.pp.64-65.)

Stow (28.pp.68-77.) was the first geologist to describe the general geological succession of the area. Many of his observations were remarkably astute. For instance, he ascribed the crumpling of the banded ironstones on a hill called Ramajes kop south of Kuruman, to horizontal pressure from the west, and it was his opinion that the rounded outlines of many of the ranges was the result of glacial erosion.

In 1904-5 A.W. Rogers (25, 26 and 27.) surveyed the Hay and Kuruman divisions in which the manganese belt falls. He largely upheld Stows classifications, but correctly placed the Ongeluk Lavas in the Pretoria (Griquatown) series. He did not uphold Stows opinion that the Blinkklip breccia was a detrital rock. Rogers maintained that it was formed by slumping of the lower Griquatown beds under the influence of gravity, and perhaps, earth movements, into hollows dissolved out of the underlying limestone. The peculier structures west of the Gamagara rand led Rogers to assume normal, and at a later date, reverse faulting, along the same plane. (His "Paling" fault.)

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After the discovery of the manganese deposits by Captain T.L.H. Shone in 1922, there is a spate of publications. Hall (16) describes the local geology, but was mostly interested in the nature and economic possibilities of the manganese deposits. Wagner (36) embodied his investigations on the rich haematite ores of the region in his memoir on South African iron ores.

During this period there were naturally numerous private reports, mainly of an economic nature, drawn up for the various companies interested. There were naturally many contradictory opinions, for the local geological structures present unusual structural problems, and the origin and structure of the manganese ore bodies gave rise to much divergent discussion.

In order to get to the root of these problems and so aid mining engineers in locating exploitable ore bodies, Nel (21) undertook a more detailed geological survey of the manganese deposits and surrounding country in 1927-28. In the main the opinions of Rogers were upheld. Owing to its isolation from the main masses of Matsap sediment by faulting, Nel gave the name Gamagara series to the group of ferruginous conglomerates, aluminous shales and quartzites building the manganiferous range of hills of that name.

Their correlation with the Matsap sediments to the west by Rogers, was upheld. Nel was, however, was forced to modify Rogers "Paling" fault by a thrust fault acting from the west. His detailed mapping on a scale of over 1 inch to the mile had shown Gamagara quartzites dipping westwards beneath older Griquatown beds, a fact

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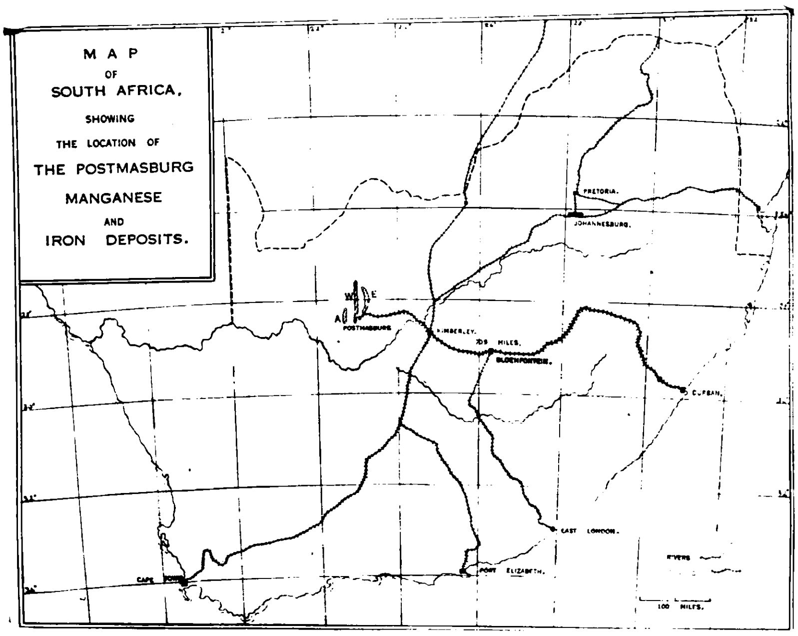
which Rogers "Paling" fault could not explain. Furthermore, Nel realised the important fact that manganese was formed by the metasomatic replacement of the permeable Gamagara conglomerates and shales and the siliceous breccias, only where these rocks directly overlie the dolomite.

In 1933 du Toit contributed an excellent paper on the manganese deposits, in which he drew attention to the generality that the manganiferous zone usually underlies the ferruginous zone; his paper contains a searching discussion on the origin and deposition of the manganese ores. (13)

In 1936 the writer re-mapped the northern half of the fields, lying north of Lat. 28° S., paying special attention to the haematite ores. (34. Map and portion of publication.) During 1937 and 1938 the very large scale maps (approximately 5 inches to the mile), were prepared, covering the most valuable portions of the mineralised area, as well as the most complex and instructive geology. This portion of the work and the maps form the basis of this thesis.

(B) Location of Area, Communications, and Physical Features.

Situated in the north Cape Province bordering on the Kalahari desert, the area is unfortunately well away from the beaten tracks of South African commerce and the main centres of population.



Access to the ocean is moreover a great difficulty, since Postmasburg lies near the centre of the sub-continent. Actually it is somewhat nearer the Atlantic than the Indian ocean, but the nearest parts of the Atlantic coast has no well-equipped ports, nor is there direct rail communication across this semi-desert part of the country. Kimberley, the nearest large centre, lies 108 miles east-south-east (in a direct line) of Postmasburg, to which it is connected by rail. From Kimberley the nearest and best equipped port is Durban.

As a result of the discovery of the manganese deposits, the railway was extended to Postmasburg from the then railhead at Koopmansfontein, 62 miles distant. After the economic depression of the early 1930's, the line was extended northwards from Postmasburg along the strike of the fields for 25 miles to the present railhead of Lohathla, 154 rail miles from Kimberley. In addition a branch line was built eastwards from Driehoekspan (Map G.) to Kapstewel the terminus of this line being named Manganore. (Map K.)

Along//.....

Along the main roads, which are gravelled, as well as along many secondary roads, an efficient Road Motor Bus service is maintained by the railways, carrying ingoing commerce to the farms, and outgoing produce to the railway and towns from the pastoral community. No main roads occur within the confines of the present maps, barring the short stretch in the extreme south op map G, running through the mining village of Beeshoek, and connecting Postmasburg to Oliphantshoek. Within the area covered by the maps the road communications are poor, being sandy or gravelly, and where the karst of the dolomite plateau is traversed, extremely rough.

Forming portion of the inland plateau of South Africa, with heights varying about 4,400 feet above sea level, the relief is in general low. The landscape, however, is not monotonous, for the general level of the plateau is broken by hills of moderate relief, trending in a northerly direction parallel to the conspicuous Langeberg range in the west. This range forms the local boundary of the Kalahari proper, which extends as a vast sandy plain west of these mountains to the border of South West Africa.

Some of the crests of the Klipfontein hills immediately north of Postmasburg approach 5,000 feet in altitude. (On map K.) The Gamagara ridge is generally lower, and forms a small escarpment, for the general level of the sand plains west of these hills is from about 50 to more than 300 feet lower than the level dolomite country to the east.

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The continuous line of the Gamagara rand is in strong contrast to the disconnected line of the Klipfontein hills. Outliers of the latter often form conspicuous landmarks of such curious shape that they carry distinctive names such as Tigerkop, Koppie Alleen etc.

All the valleys are filled with detritus and pink Kalahari sand, which the sluggish drainage is unable to move. The deeper and lower lying valleys west of the Gamagara rand are naturally more deeply filled.

(C) Climate, Drainage and Vegetation.

The climate is pleasant and healthful, and during the cooler months, invigorating. Being a semi-arid region, the summer heat is dry, and not unpleasant, tempered by frequent breezes and cool nights. Rainfall is mainly in the summer months, falling in sudden sharp showers during thunderstorms, and averages about 14 inches per annum. However, it is variable, ranging from about 7 inches to over 20 inches. Autumn is the most pleasant season of the year, while the winters are a succession of bright sunny days following frosty nights. This is broken by occasional bursts of cold damp south-west winds, bringing with them sleet showers.

Lying on a local watershed, the drainage is in two main directions, north-westwards to the Gamagara river, and southwards to the Postmasburg and Matsap valleys and so to the Orange river. Practically all the drainage within the confines of the accompanying maps falls within the latter system. An important system of local drainage is that running westwards from the Klipfontein hills over the dolomite plain, and thence across the tilted edges of the Gamagara beds to the low lying sandy flats beyond. (See map G.) This drainage is important since it seems that the dolomite supplies the manganese by its chemical weathering.

In spite of the semi-aridity of the climate, the country is well-clothed by a pretty, if xerophilous vegetation. Where the soil is deep in the sandy stretches, large umbrella shaped camelthorn trees (Acacia giraffae), are found dotting the flats. Where waters are shallow along dolerite dykes or drainage hollows, the soetdoring tree (Acacia karroo) is found. As a result of the dry climate, the grasses grow in clumps, but are nutritious, mainly belonging to the sweetveld types. The most common are the drought resisting Bushman grass (Aristida ciliata and Aristida obtusa) and the white steekgras (Aristida burkei).

Most of the vegetation is of the bushy type. Level stony country and the lower slopes of the hills are thickly dotted with the pretty silvery thornless scrub, the vaalbos. (Tarchonanthus camphoratus). Rocky hillsides, and especially the rubble covered slopes, often harbour a dense growth of the thorny swarthaak bush. (Acacia detinens). Many other types of hardy plants are represented, among them interesting varieties of succulents.

(D) Compilation and Accuracy of the Maps.

Owing to insuffient data being available, key points were plotted on the scale of 100 Cape roods = 1 inch, or approx. 5 inches = one mile. This scale was sufficient to plot well exposed contacts to an accuracy

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of 10 feet or the thickness of a pencil line on the map. The areas to be done were flagged at close intervals and in the process thoroughly reconnoitered. The positions of the flags were accurately located by means of a telescopic alidade, and checked by back-sighting. No points were accepted until perfect agreement was obtained.

The plane table mapping was then proceeded with, special attention being paid to the areas occupied by the manganese and iron ores, which owing to their habitual situation on high ground and resistance to erosion, afforded excellent outcrops and contacts. During the mapping of the complex manganese outcrops use was made of the ferruginous band lying between the manganese ores and the overlying aluminous shales, and the continuity of this band was somewhat exaggerated.

To ensure accuracy and an extra check, map G. was commenced in the north and completed halfway. This area was then tackled in the south, working northwards. An excellent fit was obtained, indicating negligible error.

CHAPTER II.

General Geology.

(A) Table of Formations.

Tertiary and Recent Deposits...		Sand, Surface limestones and Gravels.
Karroo System..................		Unrepresented.
Post-Waterberg Cataclastic series...		Blinkklip and Siliceous breccias.
Waterberg System.....	Matsap series ...	Not represented.
	Gamagara Series..	Quartzites Shales Conglomerates.
Transvaal system......	Pretoria Series.	Upper Griquatown Stage...not represented. Ongeluk or middle Griquatown stage...Andesitic laves. Lower Griquatown stage...Banded ironstones, chert, jaspers, and tillite.
	Dolomite Series.	Dolomitic limestone, chert and shales.
Igneous Intrusions......		Dolerites, Kimberlites.

(B) Lithology, and General Geological Relationships.

(1) The Dolomite Series.

This rock, which crops out widely but inconspicuously in the area, forms a solid basement on which all the other formations rest. It is the oldest rock exposed in the area, being pre-Cambrian in age. Its aggregate thickness is computed at several thousands of feet. (26). It is seen to outcrop mainly east of the Gamagara rand, where it occupies the wide flats extending to the Klipfontein hills and beyond. The bases of these hills are built of dolomite. They

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are in the nature of erosion relics, their cappings being composed of various resistant rocks, mainly breccias, resting on the dolomite. (See K. series of sections.)

Over large areas occupied by the dolomite, soil is scanty, forming a thin covering over the rugged dolomite and chert outcrops, or filling the cavities in the frequent karst surfaces. The best outcrops are seen on the flanks of the hills, especially the Klipfontein hills and on Pensfontein. Here the bedded nature of the rock is apparent, the sides of the hills presenting a step-like appearance.

The rock weathers with a dark gray rough surface, and where free from chert, forms large flat outcrops with deep karst channels between, filled with reddish soil. Occasional large sinkholes have been dissolved in the rock, while near the eastern boundary of Paling large caves occur.

The composition of the rock shows that it is not a pure dolomite, but a dolomitic limestone. (40) Its composition varies from place to place and from horizon to horizon. Portions less dolomitic indicate their richness in lime by the appearance of lighter gray shades or even a whitish translucence. Calcite veins and nests are frequent.

Chert is a common constituent of the dolomite, occurring as irregular bands, nodules and lenses. It is mostly gray in colour and is more frequent near the top of the series. Owing to its superior resistance to weathering it outcrops conspicuously. Silicified oolites are found, while at the top of the series the passage beds

which//.....

which grade into the lower Griquatown banded ironstones take on a thinly bedded character. Red and yellow colourations become frequent while pisoliths of haematite (after pyrite) as large as peas are common.

Besides the calcium and magnesium in the rock, iron in small amounts is common, colouring the rock pink or red at some localities. Manganese occurs probably in the form of carbonate, in amounts up to over 2% of the metal. (21.p.8.) It is of interest to observe that traces of fluorine and chlorine have been observed in the dolomite. (21.p.18. and analysis below.) The following partial analysis of dolomite shows notable amounts of chlorine; the dolomite, then, seems to have been the source of these halogens and also the source of the residual aluminous slime forming much of the Gamagara shales. (39). Analysis of dolomite taken from an outcrop adjacent to the new zunyite occurrence on a knoll on north-eastern Doornfontein:

Table 1.

Sample No. L.B. 201. Lab. No. p. 13550.

	%
SiO_2	0.02
Al_2O_3	-
Fe_2O_3	-
MgO	21.44
CaO	29.08
Na_2O	-
K_2O	-
Cl	0.07
F	-
CO_2	35.51
Total H_2O	-

The ratio of Calcium carbonate to magnesium is as 52.8% to 47.2%. The rock is therefore a true dolomite.

Total//.....

Total	86.12

Analyst: C.J. v.d. Walt, Division of Chemical Services, Pretoria.

(2) The Pretoria Series.

(a) The Lower Griquatown Stage.

Nowhere in the area under consideration does this stage of the Pretoria series attain more than a portion of its true thickness. Crumpled erosion relics and overthrusted slabs, however, form prominent outcrops. They largely compose the cappings to the Klipfontein hills in the form of breccia (map K.) or form prominent dip slopes along the western side of the Gamagara rand on Japies Rust and Lomoteng (map G.)

(i) The Banded Ironstones and Jaspers.

Where preserved in normal development, this sub-stage is composed of about 1,000 feet of well laminated highly ferruginous banded ironstone, which overlies the dolomite without any break in the sedimentation. The next 1,500 feet is composed of relatively iron poor banded jaspers, mainly brown and yellow in colour, and more massively bedded than the preceding phase. The entire stage is powerfully magnetic.

The banded ironstones are so well laminated and jointed that they are split with ease into large slabs and paving stones. Cross fractures reveal alternating layers of brown and white chert interleaved with thinner layers of black glistening haematite and magnetite. The total iron locked up in these banded ironstones must be almost beyond computation, for their iron content

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is about 30%, and the reserves of rock in-exhaustible. (36) Even in the small area covered by the accompanying maps the tonnage of this rock must run into hundreds of millions. There is little doubt that the high grade iron ores of the area have derived their iron content mainly from this source.

(ii) The Griquatown Tillite.

This interesting rock is the uppermost member of the lower Griquatown stage of the Pretoria series, and abruptly terminates the thick mass of banded jaspers, on which rock it lies with apparently a slight disconformity. The tillite is thin, but is wonderfully persistent over wide areas. The thickness varies from a few feet to a rare maximum of about 50 feet.

It is a small pebble tillite, being crowded with oval and sub-rounded pebbles of black and white chert and brown jasper, almost to the exclusion of other pebbles like quartzite and banded ironstone. Grooved pebbles are plentiful locally. (25) The matrix is fine grained and calcareous, weathering into a characteristic red and brown porous mass studded with pebbles. Fresh samples are only to be found in wells etc.

In spite of the thinness of this rock formation, it is frequently found involved in the thrusting, in many places marking the site of such breaks. This may be the result of its situation sandwhiched between the incompetent banded ironstones and jaspers below, and the thick mass of andesitic lavas above.

(iii) The Ongeluk Lavas.

Computed to be about 3,000

feet//...

feet thick, (21 and 25) this massive bed of andesitic lavas composes the middle Griquatown stage of the Pretoria series in the area. The lavas are wonderfully consistent in texture and composition, and as a competent mass have played a great part in the structural composition of the area as a whole. However, in the area covered by the accompanying maps the lavas appear only on the western fringe of map G. as an irregular foreland of an overthrusted mass. (See G. Series sections).

(iv) The Upper Griquatown Stage.

Not much is known about this local phase of the Pretoria series. At one locality it appears to be very thick. It is composed of banded ironstones, shales, quartzites and limestones, and occurs along the eastern foot of the Langeberg range, not appearing within the confines of the accompanying maps.

(3) The Gamagara Series.

This small sedimentary series was named by Nel, (21,pp.16, 30.) in 1927-8, since Rogers original correlation of these beds with the lower Matsap then seemed open to some doubt. Rogers correlation, however, is upheld for reasons enumerated in section (b) below. The term "Gamagara series" is retained for reasons of convenience, and because of the economic importance of the series.

(a) Distribution.

(i) The Gamagara Rand.

Stretching from the farm

Olynfontein//....

Olynfontein, situated immediately west of Postmasburg, (south end, map G.) to beyond the northern limit of the map on the farm Bishop in the Kuruman division, is a continuous strip of Gamagara beds. These ridges represent the southern and larger half of the Gamagara rand, and include by far the strongest development of these beds. They consist of lenticular masses of ferruginous conglomerates at the base, followed by aluminous shales and quartzites respectively. These rocks, which lie on an erosion surface of the Transvaal system, strike in a north-south direction, while moderate westerly dips are the rule. The distance from Olynfontein to Bishop is nearly 25 miles. Nowhere along this length of strike does their width of outcrop exceed a mile or two, being everywhere terminated along the western dip slopes by a complex of thrust faulting.

(ii) Outliers and Inliers.

Outliers of the Gamagara beds are found chiefly along the crests of the Klipfontein range of hills. (See map K) Here these remnants have been preserved from erosion in basin shaped depressions in the harder erosion resisting Blinkklip and siliceous breccias. (See K. series sections.) Smaller patches are found lying on, or more usually folded into, the breccias. Small outliers of conglomerate and shales, often manganised, fringe the Gamagara rand to the east, and are found capping detached hills of dolomite on eastern Paling and Gloucester, thus proving the former easterly extension of the main mass of Gamagara beds, connecting up with the Klipfontein occurrences.

Small//.....

Small inliers, mainly Gamagara quartzites, are exposed by erosion beneath a cover of overthrusted rock, immediately west of the trace of the Gamagara thrust from Beeshoek to Paling. (See sections 7G, 8G and 9G.)

(b) Stratigraphical Relationships.

Along the eastern slope of the Gamagara rand, particularly in the vicinity of Paling, the Gamagara beds are seen to rest with a distinct unconformity on the Campbell Rand dolomite. South of Lace's Goat on Doornfontein this unconformity transgresses across the lowermost horizons of the Griquatown banded ironstones, which are intensely brecciated. From here this relationship persists in a north-easterly direction, curving round to the north at the Klipfontein hills, where the Gamagara beds lie with a sedimentary contact on thicknesses of nearly 100 feet of banded ironstones. In the vicinity of HH trigonometrical beacon (map K.), small patches of Gamagara shales are seen to lie on horizontally disposed banded ironstones, which are but slightly brecciated.

It is clear, from this field evidence, that the Gamagara beds were deposited on an erosion surface of the Transvaal system, which was at that time gently folded. (See reconstruction of Maremane anticline and sections.) Furthermore, a study of the detrital material composing the coarser facies of the Gamagara conglomerates and quartzites, revealed that all the fragments are traceable to the beds of the Transvaal system as exposed in the area.

That the Gamagara sediments are actually a facies

of//....

of the lower Matsap beds, is shown by exposures some miles to the south, where undoubted Gamagara rocks, complete with basal conglomerate, are seen to pass upward into the lower Matsap sequence. (Observation by Visser, 35).

Occurrences of Karroo sediments (Permo-Carboniferous), in the valley bottoms scoured subsequent to the Post-Matsap orogenic movements, and Dwyka ice pavements on Gamagara rocks, (Plate V.) indicate a vast time lag between the formation of the Gamagara beds and the Dwyka glaciation at the base of the Karroo sediments. It seems probable then, that the Gamagara beds, which are entirely unfossiliferous, are pre-Cambrian in age.

(c) Petrography of the Gamagara Rocks.

(i) The Conglomerates.

There is no doubt about the sedimentary nature of this rock, for it is often well bedded. (Plate I. Fig. 1.) Field evidence shows it to be a fan-conglomerate composed of locally derived material, all the fragments having been derived, it seems, from locally exposed members of the Transvaal system. In fact, much of the material, especially the predominant banded ironstone fragments, lie on or adjacent to the outcrops from which they came. Naturally, near the source of the material the conglomerate is often prominently developed, on Beeshoek and Olynfontein attaining thicknesses of 40 to 50 feet.

The beds are subject to rapid variations in thickness, and were probably deposited on an uneven and potholed land surface. The thicker the deposits become, the less distinct the bedding becomes, while the//....

the constituent fragments are larger and show little or no attrition. In fact, some of the deposits lying on or adjacent to the parent banded ironstone are composed of an agglomeration of platy and angular fragments six inches or more across.

This facies of the Gamagara beds is in all superficial respects similar to present-day scree and fan-conglomerate deposits filling gullies along the foot of the banded ironstone hills. There are, however the following significant differences. In the recent deposits pebbles and fragments of the banded jaspers and even of the Ongeluk lavas are not infrequent, whereas in the Gamagara deposits jaspers are rarely encountered and lavas never. On the other hand the latter deposits contain quartz and chert pebbles from the dolomite, which the former do not have. These facts are interpreted to indicate that the relief during pre-Matsap times was much less than that ruling to-day. The relatively prominent hills of Griquatown beds existing today enable material to be rapidly transported from the interior of the hills, i.e. the jaspers and lavas, to be debouched on the fringing dolomite flats.

In addition it has been noticed that in the young deposits the plates and slabs of banded ironstone preserve their laminae unbent and unbroken, while in the Gamagara beds slabs of comparable shape and size are commonly twisted, bent and sometimes broken across. This effect is ascribed to the deformation resulting from the consolidation of the material under the enormous weight of thousands of feet of subsequently de-

posited//....

posited Gamagara (Matsap) beds. A large amount of settling and adjustment must have occurred, judging by the compactness of the Gamagara conglomerate as compared to the loose nature of the young screes and gravels. In the Gamagara conglomerate no Blinkklip or siliceous breccia has been observed. The significance of this is discussed at a later stage.

Lateral facies changes in the Gamagara basal conglomerate are rapid from point to point. On Beeshoek and Southern Doornfontein these changes give excellent clues to the origin of the conglomerate, which thickens and becomes coarse as soon as the sedimentary contact approaches and transgresses upon patches of banded ironstones or Blinkklip breccia. (See map G.) Away from these patches where the sedimentary contact lies against dolomite or its associated cherty rocks, the conglomerate is represented by thin pebble washes, grit, or merely by ferruginous shales. This arrangement clearly demonstrates the local origin of the detritus composing the basal beds, and proves the sedimentary nature of the contact with the dolomite, cherty rocks and banded ironstones.

North of Lace's Goat, right up to Bishop, no banded ironstones are found preserved between the Gamagara beds and the dolomite. Significantly, nowhere in this area are great thicknesses of conglomerate developed, and nowhere is it very coarse, except on the isolated pinnacle near the eastern boundary of Gloucester. The coarse fragments composing this hill have, however, a nearby source in the adjacent Klipfontein hills.

On//......

On northern Paling, Driehoekspan and Marthas poort persistent beds of small pebble conglomerates are developed. They are fairly uniform in thickness over great lengths of strike, the thickness being most commonly 3 to 5 feet. These facts indicate that the material was carried some distance and was deposited as a sheet along a fairly even and level surface. The pebbles are small, well worn and well graded. In general the basal conglomerate is poorly developed between Lace's Goat and Bishop, being often represented by thin pebble beds only,or occasional grit washes in the ferruginous shales. (N.B. The distribution of the banded ironstones (Blinkklip breccia) and the conglomerate derived therefrom was strong supporting evidence leading to the reconstruction of the pre-Matsap Maremane anticline, see plan.)

In composition the conglomerates are almost entirely an agglomeration of rounded and sub-rounded banded ironstone fragments. The fragments have, with rare exceptions, been completely ferruginised, the original banding being betrayed by the lighter and darker bands of haematite. Wagner (36) observed a similar banding in the Crocodile river iron ores. Pebbles of white and gray cherts, red,brown and banded jaspers, quartz, and unaltered banded ironstones, have been observed. These are usually crowded into a local and siliceous facies of the conglomerate. The usual conglomerate is as a rule more or less free of such siliceous rocks, apart from ordinary banded ironstone pebbles, which are more widespread.

No pebbles of siliceous breccia, Blinkklip breccia

or//.....

or manganese ore have been found. This fact is regarded as having great significance, since it indicates that these rocks, which are so widespread to-day both as large masses and as scattered detritus and surface drift, were not in existence when the Matsap sedimentation was initiated. This fact is of great importance when considering the origin of the breccias and the manganese ore. No pebbles of dolomite or of Ongeluk lavas were found, but this is probably due to the fact that these rocks cannot withstand prolonged weathering.

In the coarser conglomerates, the matrix is very subordinate in amount and consists of films and fillings of ferruginous clayey matter, mostly terra-cotta or purplish in colour, in the interstices between the pebbles. It is occasionally sandy or gritty, and has more often than not undergone secondary haematitisation, with some crystallisation of specularite. The smaller and more rounded the constituent fragments become, the more abundant the shaly matrix becomes until the rock grades into a ferruginous shale often containing some gritty bands of haematite. This transition has been observed both laterally and vertically. Owing to the widespread ferruginisation, in a former period, of the pebbles, and later of the matrix as well, by far the greater part of the conglomerate constitutes an excellent iron ore. (Plate I. Fig. 1. Plate IV. Fig. 1. and Plate VI. Figs. 1 and 2.)

An unusual type of conglomerate is found on the high hills on northern Marthas Poort. It is composed almost entirely of siliceous rocks -- brittle banded and massive yellow jaspers and banded ironstones from the upper zone of the lower Griquatown beds, as well as red jaspers from the Ongeluk lavas, overlying the jaspers. The beds are not ferruginised. They lie as usual below shales and quartzites of the Gamagara series, and in part lie on much disturbed ferruginous jaspers belonging to the lower Griquatown series. Detailed mapping and cumulative field evidence show that the whole mass has been thrust over the autochthonous Gamagara quartzites lying below and to the east.

The thrust plane runs along the base of the conglomerate, and below the associated remnants of banded jaspers. (See centre, section 3G.) Signs of disturbance were observed in the conglomerate, pebbles being sliced in a step-like or sometimes rotational fashion. The matrix is much slickensided around the pebbles, indicating differential movement within the body. However, taken as a whole, the conglomerate seems to have offered remarkable resistance to deformation, in strong contrast to the ferruginous jaspers and banded ironstones.

From the pebbles in this conglomerate, it is clear that the material was mainly derived from the upper jaspery horizon of the lower Griquatown beds, and the overlying lavas. Owing to the nature of the thrust movement, the allochthonous mass must have migrated some miles from its original position in the west, bearing these conglomerates along. It can be inferred therefore that the unconformity at the base of the Gamagara beds transgressed over higher horizons of the Griquatown beds in a westerly direction. This conforms to the reconstruction of the pre-Matsap Maremane anticline. (See plan.)

(ii)//.......

(ii) The Shales.

This horizon, which follows the conglomerate conformably, is thinner but more persistent than the latter along most of the Gamagara rand. It seems to have been deposited in deeper water on a levelled surface owing to the infilling of depressions by conglomerate. The thickest and most prominent development of shales encountered occur on Beeshoek and southern Doornfontein, but even here they seldom exceed about 30 feet in thickness. In the long stretch northward to Bishop the thickness varies from about 5 feet to 15 feet. These figures relate to localities relatively free from tectonic complications.

In the highly folded belt on Marthas Poort, rather anomalous outcrops of shale are encountered. The intense folding has resulted in the incompetent shales being squeezed away from the more or less vertically disposed limbs of the folds, leaving the conglomerates and grits abutting against quartzites. In consequence large masses of shales, crumpled and phyllitic from the pressure, are bunched up to form abnormal thicknesses in synclinal portions of the folds.

A wide range of colours characterises the Gamagara shales. Predominantly pink, terra-cotta or mauve, all tints from pale pink to cream and pure white are encountered. The pale colours are the result of the leaching of the colouring matter, mainly in the form of finely divided haematite. Some peculiar mottled effects are produced by patchy leaching. Local ornamental stone workers utilise pretty pink and cream striped varieties for gravestones.

The//.....

The shales are almost always of a fine texture, being soft and sectile, giving the appearance of being hardened impalpably fine muds. Gritty intercalations are found. On the low hill east of Lace's Goat, on Beeshoek, and in the outliers found on Klipfontein and Kapstewel, a gritty quartzite band 3 to 5 feet thick lies interbedded in the shales. A fine exposure is found on the hill slope to the left as one enters the kloof behind Klipfontein homestead. Numerous chert, quartz, and brown, yellow and red jasper pebbles characterise this bed. Very fine pisolitic structures are found in the shales at some localities, for instance on Gloucester immediately north of the mine houses, and on the north-eastern corner of Lomoteng. (See analysis 3. Table 12.) The pisolitic facies are as a rule red to maroon in colour owing to their haematite content, which is often sufficient to render the shale a useful iron ore.

The addition of fine quartz particles to the shale heralds the facies change to the overlying quartzites. As a rule the transition beds between the shales and the quartzites consists of a thickness of about 20 feet of red fissile and rather friable quartzite. At some localities a hard pale fine grained quartzite occupies this horizon, for instance on the Paling-Doornfontein boundary.

The pale leached varieties of shale are of great interest owing to their unusual composition. (Table 2.) Their unusually cohesive and yet sectile nature combined with resistance to weathering may make them of value in the economic field. The frequent presence

of//......

of laths and stubby crystals of diaspore in the severely leached varieties, indicates their unusual composition. (Table 16.) Their richness in alumina may make them of value as a source of this metal.

The following analyses of these highly aluminous shales are given by Nel; (21, p. 35.)

Table 2.

	(1)	(2)	(3)
SiO_2	46.5	44.05	46.55
TiO_2	1.65	1.75	2.15
Al_2O_3	42.2	41.35	42.6
Fe_2O_3	0.7	4.8	0.5
FeO	0.2	0.3	0.15
MnO_2	tr	tr	tr
Cr_2O_3	0.05	0.05	0.05
CaO	tr	tr	0.35
MgO	nil	nil	nil
K_2O Na_2O	0.35	0.4	0.35
P_2O_5	0.05	0.1	0.1
H_2O-	0.1	0.1	0.1
H_2O	8.35	7.15	7.15
Total	100.25	100.05	100.05

(i) White or gray shale, from Beeshoek.
(ii) Red shale, from Beeshoek.
(iii) Pale gray shale, from Beeshoek.

Analyst: H.G. Weall, F.I.C. Govt. Chem. Laboratories,
Johannesburg.

In these samples, which are unusually rich in titania, this element is seen to be present in the form of minute rutile needles. (21.p.35

Diaspore is prevalent in all the shaly rocks,

especially//......

especially where secondary leaching processes have been active. As a rule, the crystals are fine and invisible to the unaided eye. At many localities alteration and crystallisation has been so intense that tabular crystals as much as a centimetre across are found. The presence of coarse diaspore in the shale is revealed on the weathered crust of outcrops and loose fragments as little lumps and rods standing out in bas-relief. In the kloof behind Klipfontein homestead, the central of the three hills on south-western Klipfontein, on Beeshoek and Olynfontein are the best localities for such samples.

The shaly matrix in which the diaspore crystals are embedded is seen to be a dense aggregate of some flaky minerals. When observed under the microscope under crossed nicols, this aggregate resolves itself into a predominant strongly double refracting mineral, and a subordinate weakly double refracting mineral. The proportions naturally vary in different sections and even in the same section.

The aluminous minerals found in these highly altered shales are described in chapter VII. In addition to the leaching and crystallising processes which have resulted in the assemblage of aluminous minerals, the shales have been widely impregnated with manganese, producing an ore with shaly laminations. Less frequently, silica has been the replacing material, resulting in brittle cherty variations. These have been involved in the brecciation, as observed on Kapstewel, (Map K.) while the ordinary shales into which the siliceous varieties grade are intensely puckered.

This//.....

This shows that the silicification occurred previous to the brecciation.

(iii) The Quartzites.

Quartzites are found all along the western side of the Gamagara rand, where wide dip slopes are found at some localities, e.g. at Paling poort and at Lomoteng where prevailing dips of 12° to 25° to the west are seen. From southern Paling to Lace's Goat, and south of Beeshoek village, the thrust faulting has cut away most of the quartzites. On northern Doornfontein and at Lace's Goat they are entirely missing for short distances. North of Paling poort thicknesses up to several hundred feet have been preserved, either as folded masses as on Driehoekspan and Marthas Poort, or as simple dip slopes as on Lomoteng. Outcrops over a mile wide and hills several hundred feet high are composed of quartzite along this stretch. They build the main bulk of the Gamagara rand.

Smaller patches of quartzite are found on the outliers of Gamagara beds to the east, while west of the Gamagara thrust (T.I.) a few small inliers appear. The predominant colouring of the quartzites is pink to brown, but hard glassy white varieties and coarse gritty gray to mauvish types are encountered higher up in the sequence. The latter compose the quartzite hills on Vlakfontein and Marthas Poort, and are indistinguishable from the characteristic Matsap quartzite.

Near the base, just above the shales, a red sandy thinly bedded quartzite occurs to a thickness of about

20//.....

20 feet. White fine grained compact varieties, with the same thin bedding, are also found along this horizon. On Klipfontein and Doornfontein a thin gritty quartzite occurs in the shales. Pebbles of chert and jaspers are characteristic of this bed.

The quartzites are mainly composed of rounded and sub-rounded fragments of gray, white and smoky quartz, the frequent pink colouring being due to films of haematite or pink clayey matter. Lenses of grits are frequent in the quartzites. These contain pebbles and grits of bright red jaspers, such as are yielded by weathering from the Ongeluk lavas. Pebbles and flattish slabs of banded ironstone, jasper, haematite and chert are also frequent. These originate from the much older Transvaal system.

(4) The Cataclastic Series.

This is a general term including all the breccias which are so well represented in the Postmasburg area. They are grouped in a separate series because they form an important and widely spread group of rocks, and, according to the interpretation here laid forth of the evidence, were formed contemporaneously, mainly as the result of tectonic movements. (See Chap. IV.B.3.) The terms "cataclastic series" and "siliceous breccia" were proposed by my senior colleague Dr. F.C. Truter.

(a) The Siliceous Breccias.

This term is proposed to cover all the breccias called by Nel (21) "chert breccias".

The//.....

The breccias are indeed mainly composed of chert fragments, but it has been found that locally other siliceous material, mainly brecciated Gamagara quartzite, forms part of the breccia. For this reason the term "siliceous breccia" is more accurate. Later infiltration by manganese oxides has resulted in the formation of manganiferous breccias, highly siliceous "sausage" ore, (Plate III. Fig. 2.) and various grades of siliceous manganese ore.

It is remarkable, and significant from a genetic viewpoint, that the breccias always occur together within the same belt of country. This is true of the siliceous and the "Blinkklip" or shattered banded ironstone varieties. The main belt where these brecciated rocks occur stretches from south and west of Postmasburg, past the Townlands, to Doornfontein. From this farm masses and isolated outcrops are found capping the irregular hills and ridges distributed in a great arc north-eastwards and northwards through Klipfontein and Kapstewel. (See Key map and Reconstruction of Maremane Anticline.)

Along the Gamagara rand north of Doornfontein little or no breccia is encountered, the Gamagara beds lying directly on the dolomite.

Since the breccias are more resistant to weathering than either the Gamagara beds, where these overlie them, or the underlying dolomite, erosion has left masses of breccia standing out as prominent hills to form a typical relict landscape, which is characteristic of the dolomite country east of the Gamagara rand. The largest known masses of breccia cap the Klipfontein

range//.....

range of hills, (map K.) and the prominent hills east and north of Beeshoek village. (Map G.)

The siliceous breccia is always found lying on the dolomite. The junction with the dolomite is invariably highly irregular. (See K. sections.) This contact always cuts across the gently dipping bedding planes of the dolomite, into which huge masses of breccia usually extend, often to a depth as great as 100 feet, in great pothole-like depressions. A difference in level in the dolomite-breccia contact of 200 to 300 feet has been observed within a lateral distance of half a mile, and that in areas where the bedding planes of the dolomite are seen to vary little from the horizontal.

There is little doubt that this effect is due to subsurface solution of the dolomite, shattered portions of which are still locally preserved. That much, if not all this slumping, occurred after the formation of the breccia, is shown by the nature of the tumbled-in masses, where large quantities of dislodged breccia, residual soil and dislodged fragments of loose chert lie intermixed beneath the main mass of breccia. (See Chapter IV.B.3.)

Above the siliceous breccia a covering either of Blinkklip breccia or less brecciated banded ironstones occurs. Transgressing Gamagara beds occasionally cap the breccias, (see K. Sections) in which case the sediments are themselves highly contorted and disturbed, the more so where the underlying rocks, the siliceous and/or Blinkklip breccias are more intensely brecciated.

The//....

The siliceous breccia varies enormously in thickness from place to place within short distances. Localities where it is absent bring the Blinkklip breccia down against the dolomite. Within half a mile from such localities a development of up to 150 feet thickness of siliceous breccia may be attained, separating the dolomite from the Blinkklip breccia by this distance. (See K. sections.)

The composition of the siliceous breccia is variable. The fragments composing it are in the main chert from the dolomite. Locally, on the other hand, fragments of other siliceous or silicified rocks make up a large proportion of the breccia. The amounts and proportions vary much from place to place. At some localities the breccia is composed predominantly of brecciated and contorted Gamagara shales, which had previously become in part silicified, and thereby rendered brittle. Much of this sort of breccia can be found flanking the hill a few hundred yards south-west of Klipfontein homestead. (See evolutionary diagram of the breccias.) In the main, however, the siliceous breccia can be termed truthfully a chert breccia.

At other places reddish and brownish Gamagara quartzite bulk largely in the composition of the breccia. Such types frequently exhibit crush conglomerate structure; rounded quartzite cobbles being embedded in a sandy silicified gouge, or cemented by haematite or manganese oxides. This type was found in the deep kloof about half a mile east-south-east of Manganore siding. (Map K.) In the northernmost quarries

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on Klipfontein, situated in an embayment on the eastern flank of the hills, cherty crush conglomerates were found. Rounded and irregular fragments of gray chert, ranging in size from that of a walnut down to a pea or smaller, are heterogeneously packed in a gouge of fine chert fragments and clayey haematite and manganese.

At many localities chips and fragments of banded ironstones have found their way into the siliceous breccia, especially in the vicinity of the contact with the Blinkklip breccia. In fact in this zone of contact, complete gradations between the siliceous and Blinkklip breccias have been observed. This is especially true of localities where brecciation has been most intense, with small patches of banded ironstones being involved.

The siliceous breccia is, of course, always more or less impregnated with manganese oxides, forming vast quantities of low grade ore. Peculiar mottled rocks result, (Plate III, Fig. 2.) which are used in the outcrop by miners to locate payable bodies of ore. Such outcrops are then termed "marker," or where shaly and cherty gouge has been impregnated with manganese and the leached silica forms white patches of quartz and hyalite as on Beeshoek, the rock is termed "sausage ore." The nearer completion the process of leaching and manganisation has progressed, the higher the grade of the resulting ore. In practice ore with inclusions of chert or ferruginous matter easily visible to the eye, does not fall within the present economic grades.

The//....

The "marker" type of siliceous ore is commoner than the "sausage ore" type. In much of the manganised siliceous rock, especially on Doornfontein and Beeshoek, white inclusions which are mistakenly thought to be chert are in reality secondary growths and concentrations of siliceous matter chemically deposited. Irregular blebs and nodules of white or glassy chalcedony, and sometimes even botryoidal lumps of clear hyalite are very frequent. These represent leached silica precipitated almost in situ. Close study, especially of gradational types, has shown that much of this mottled rock, notably in the workings near Beeshoek village, is not a true breccia at all. Here it is seen that great thicknesses of shaly gouge, representing crushed and contorted Gamagara beds, have undergone intense metasomatic alteration to their present form.

The chalcedonic growths show cracks and displacements which indicate small movements, probably resulting from the widespread slumping into the dolomite, and volume changes in the rock itself consequent on the intense metasomatic changes.

The origin of the peculiar "sausage ore" can thus be traced back to a Gamagara shale at favoured localities. In the Beeshoek quarries all gradations from shale with the bedding preserved, to shaly manganised gouge, "sausage ore" and manganese ore itself, can be traced. This leaves no doubt as to the sequence of the changes. On Beeshoek this rock series can be traced downward into true siliceous breccia of the cherty type, lying traditionally against the dolomite.

The//.......

The exact boundary between the various gradations of siliceous breccia is impossible to determine, owing to their similarity and intimate relationship. It can thus be seen that the term "siliceous breccia" covers a great variety of rock types. It is, to put it shortly, a brecciated or disturbed siliceous rock which has often undergone more or less intense metasomatic alteration.

(b) The Blinkklip Breccia.

The Blinkklip breccia is distributed throughout the same area as the siliceous breccias, with which it is always associated, and which it normally overlies. In many cases it is absent owing to erosion, firstly of the parent banded ironstone in pre-Matsap times, and latterly to post-Karroo erosion. In the first instance, overlapping sedimentation of the Gamagara rocks transgressed across the Blinkklip breccia,thought still to be in pre-Matsap times banded ironstones,to the underlying dolomite-chert assemblage from which the siliceous breccia has mainly been derived. This overlapping of the Gamagara rocks is well illustrated between Beeshoek and Paling. On the former farm the Gamagara rocks lie on Blinkklip breccia, (at the time of sedimentation banded ironstones,) and on the latter farm they lie on bare dolomite, without any intervening cherty rock.

In some isolated cases siliceous breccia has been brought to overlie Blinkklip breccia as a result of inversion by tectonic movements, e.g. about 2 miles north of Klipfontein homestead. (Map K.)

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The Blinkklip breccia is named after the small hill with a prominent bouldery peak passed by the railway a few miles north-east of Postmasburg village. This hill is called locally "Gatkoppie" because of the cave on its eastern slope. This cave has been enlarged by ancient workings for specularite. It is also known as "Blinkklip Kop," referring to the glitter produced by the specularite rich breccia in the sun. This hill was visited by Burchell about 1805, (28, p.6.) and marked "Sensavan" by him on his map. From the structures exhibited in this hill Rogers obtained the idea that the breccia was a slump breccia. (25)

In composition the Blinkklip breccia is far simpler than the siliceous breccias. It is merely the brecciated equivalent of the basal portion of the lower Griquatown beds, which are iron rich banded ironstones. The extent of the brecciation varies from place to place, ranging from the mere fracturing and puckering of the banded ironstone, e.g. around H.H. beacon on Klipfontein, down to a true mylonite so fine that it has the appearance of a compact burnt brick. This however, is rare and very local.

The usual Blinkklip breccia consists of a heterogeneous conglomeration of all sizes of angular fragments and chips, as well as occasional slabs of banded ironstone solidly cemented together by silica and specular iron. There is a strong tendency for the average fragment size to vary between a half inch to two inches across. The average fragment size of the siliceous breccia is much smaller. (Compare Plate 1.

Fig.3.//...

Fig.3. and Plate II. Fig. 1.) Near the contact with the siliceous breccia a certain amount of gradation often occurs, resulting in an admixture of cherty fragments in the Blinkklip.

Cliff sections of the Blinkklip breccia, for instance the prominent cliff immediately north-west of Klipfontein homestead, clearly show the most intense brecciation at the base near the contact with the siliceous breccia. From this point upwards the brecciation decreases, becoming a jumble of large displaced blocks separated by brecciation zones. The disturbance dies away within 100 feet or so into puckerings and a few lines of shatter. This gradation from true Blinkklip breccia to banded ironstones, somewhat disturbed, is illustrated in the series of sections depicting the evolution of the breccias.

Where Gamagara beds are preserved on the Blinkklip breccia (and banded ironstone) they show intense puckering when found lying on the former, but lie with mere gentle undulations on the less disturbed banded ironstones, where their contact is clearly an undisturbed unconformity. On the other hand, where the plane of this unconformity transgresses across the intensely shattered siliceous breccia, the Gamagara beds are almost unrecognisable. Fragments thereof are inextricably mixed into the breccia, and it is of great interest that at such localities have been found the richest concentrations of the siliceous type of ore.

The great difference in the weathering forms

between//.....

between the Blinkklip breccia and the constitutionally identical banded ironstone is noteworthy. The former weathers into great "tors" like granite, (Plate I. Fig. 2.) while the latter weathers into low rounded hills like shales. This difference can probably be ascribed to the changed structure in the Blinkklip as compared to the parent banded ironstone. Owing to the heterogeneous distribution of individual chips and slabs in all azimuths in the Blinkklip breccia, a structure similar to the distribution of quartz and felspars in granite is obtained, and the rock weathers in the same way. Exfoliation of large slabs cutting across the individual fragments is common, thus producing the large boulders. Such exfoliated slabs are wonderfully rigid, ringing like a bell when struck by a hammer, thus bearing testimony to the completeness of the re-cementation process by which the individual fragments have been welded together.

Magnetometer tests over Blinkklip breccia reveal little or no anomaly, while the original banded ironstones produce intense anomalies. (34) Since no clear signs of oxidation of the magnetite content could be observed, it is possible that this phenomenon is due to the heterogeneous distribution of the chips in the rock nullifying each others polarity, and thus producing a practically neutral rock. In table 13, however, very little FeO was observed in the rock.

Cementation of the fragments in the Blinkklip has been efficient and complete. Practically all the cavities have been filled by silicified fragmental

matter//.....

matter, silica, haematite or specular iron. The latter two cementing media are the most common. For this reason the breccia is more or less enriched in iron, some portions more so of course than others. The average composition is fairly constant, assays showing about 50% silica and 50% iron oxides, mainly haematite, with negligible amounts of other radicles present.

Because of a fair iron content and the negligible amount of injurious constituents, the Blinkklip breccia must be regarded as a potential low grade iron ore. The silica content is in the form of cherty silica, which should flux far easier than crystalline quartz. In the area stretching from Olynfontein north-eastwards to Kapstewel, there are hundreds of millions of tons of this rock. All of it is in addition well placed on the tops of moderately steep hills which would make for cheap and easy quarrying and gravity transportation to loading plants. The grade of the rock, however, makes it an asset belonging to the future. It may, however, be mined as an accessory to the very pure haematite ores which cap these hills at several localities. (See Chapter VI. B.)

(5) Tertiary and Recent Deposits.

These cover a wide area but are shallow and of small importance.

(a) Surface Limestones, or Calcareous Tufa.

In the higher lying area to the east of the scarp formed by the//....

the Gamagara rand, the run-off is fairly steep, and erosion comparatively active. In consequence very little surface limestone has been formed. Small patches of calcareous tufa have collected where dykes have interfered with underground drainage, e.g. on the north-east corner of Gloucester, on Paling, and east of Lace's Goat on Doornfontein.

West of the Gamagara rand are wide areas of impure surface limestone, cementing gravel and sand, and largely obscured by sandy drift. None of these impure deposits are of any economic importance at present.

(b) Sands and Gravels.

Because of the general altitude of the manganese area, over which passes the watershed between the Gamagara and Matsap drainage systems, large accumulations of sands and gravels have not been able to gather.

Surrounding the Klipfontein hills, and filling the valley bottoms between them, are shallow grass-grown accumulations of pink Kalahari sand. (Map K.) On the hill slopes shallow alluvial and eluvial deposits of gravel have accumulated, filling irregular cavities and solution hollows in the dolomite, obscuring the karst topography. These gravels are manganese bearing, containing a varying percentage of pebbles, cobbles and boulders of manganese ore. The manganiferous gravels are restricted to the western slopes of the Klipfontein hills, and the eastern slopes of the Gamagara rand.

The//.....

The mass of the fragments in the Eastern belt gravels are sub-rounded and irregular pieces of siliceous and Blinkklip breccias, chert and haematite. In the vicinity of haematite outcrops on the hills, these gravels contain an increasing quantity of haematite cobbles, in many cases outnumbering the fragments of other rock types. Since these gravels are often 15 or more feet thick, and occur over wide areas, the quantity of high-grade haematite contained in them must be considerable, and mining will be very cheap and easy. The grade of ore produced would be a hard crystalline haematite of 65% Fe., with a probable average of 68% to 69% Fe. (See Chapter VI. B.5.)

Along the western foot of the Gamagara rand are large accumulations of pink windblown sand, especially on the sheltered flats on Marthas Poort. Some of this sand may possibly be useful for castings, owing to its even texture resulting from wind sorting.
The manganiferous gravels on the eastern slopes are composed of pebbles of manganese and haematite with more or less soil filling the karst hollows in the dolomite.

(6) Igneous Intrusions.

In the area covered by the accompanying maps, intrusive igneous rocks are very sparsely represented, being restricted to a few thin dykes of basic composition, and Kimberlitic pipes. There seems to be no doubt that igneous rock has had no part in the formation or crystallisation of the manganese ores. (21.p.82.)

(a) Dykes.//.....

(a) Dykes.

Numerous thin dykes are found to criss cross the dolomite area east of the Gamagara rand, which forms part of the core of the Maremane anticline. (See Chapter III. A.) This anticlinal core is formed of well jointed dolomite, and seemed to yield a relatively easy passage for the emplacement of igneous material.

By far the greater number of dykes trend in a direction a few degrees east of north, while several branching dykes follow an east-west direction, for instance on the eastern portion of Gloucester. Locally, a direction north-east by south-west is followed. The main dykes falling within the confines of the maps are the composite one running parallel with, and east of, the Gamagara rand, and the powerful dyke running north-north-east through Klipfontein. This dyke has been followed from the Postmasburg Dopper Church, northwards for a distance exceeding 30 miles.

The composite dyke east of the Gamagara rand is interesting from the point of view of its mode of emplacement, since it repeatedly divides and re-unites. The outcrops can be easily followed, and are for the most part covered by an outstanding ridge of accumulated calcareous tufa, which has resulted by transpiration of ground water from the weathered water-bearing dyke material beneath. These ridges of calcareous tufa are utilised as the sites for local roads in order to avoid the rough dolomite karst,

and//.....

and to connect the various farms, which are nearly always situated on such dykes, whence the local water supplies are drawn, for the most part from wells.

It is possible that the composite dyke east of the Gamagara rand, and the Klipfontein dyke, follow the sites of relaxation faults of the normal type, subsequent to the relief of the intense pressure accompanying the thrust faulting. No definite evidence could be obtained. If such be the case, the triangular blocks of dolomite between dykes following different directions, between parallel dykes, and the lens-shaped masses surrounded by branches of the composite Gamagara dyke, are downfaulted blocks or small "graben" of dolomite.

It seems that the dykes are all contemporaneous, since, though no definite contacts were observed, they seem to flow into each other where two or more converge. The dykes are important from the point of view of underground water supplies, since, especially where weathering has been deep, weak to moderate but constant supplies are obtainable at relatively shallow depths, of from 40 to 50 feet. In the dolomite away from the dykes search for water is a risky procedure. So strongly do the dykes interfere with the circulation of underground water that at many localities springs are brought into being, as for instance on Doornfontein east of Lace's Goat. Such shallow accumulations of water are well shown in the area by the accumulation of calcareous tufa on the surface.

The//....

The dykes are all doloritic in character, but have a fair variation in composition from place to place. For instance varieties fairly rich in olivine and orthorhobbic pyroxene can be contrasted with syenitic variations, the latter segregating near the centres of unusually broad dykes, i.e. where they exceed about 100 feet across the outcrop. The average width of the dykes varies from 10 feet or less to 50 feet.

At one locality a thin vein, 6 inches across, of a finegrained leucocratic soda granite was observed. The texture is a fine mosaic of quartz and albite-oligoclase, with a few scatterd augite individuals. The latter exhibit reaction rims consisting of sheafs of amphibole, which was determined to be a hornblende weakly pleochroic in pale yellow and green. Granophyric quartzfelspar textures are found in subordinate amount. At another locality a highly altered dolerite from a thin dyke was seen to be shot with fine cubes of pyrite. No other evidences of mineralisation were observed, while metamorphic effects on the surrounding rock are very weak.

Near the north-eastern corner of the farm Gloucester a well was sunk on a dyke, which proved to be too solid to be water bearing. A thin section revealed it to be composed of an intergrowth of labradorite felspar with monoclinic and some orthorhombic pyroxene, in a sub-ophitic manner. Many small rounded and resorbed crystals of a mediumly iron olivine were scattered about in the rock.

The//.......

The optical properties reveal that the clino-pyroxene has pigeonitic affinities, with 2 V gamma = 49° and gamma / C = 40°.

The ortho-pyroxene is a hypersthene with 2 V alpha = 62°, i.e. with about 56% $MgSiO_3$. The plagioclase is normally zoned andesine to oligoclase, with 45% down to 20% An. The olivines were too small to determine accurately.

The following analysis bears out the basic nature of this rock, which is seen in addition to contain small amounts of chrome, phosphate and titania:

Table 3.

Radicles.	Lab. No. P.8508. %
SiO_2	48.73
Al_2O_3	9.58
Fe_2O_3	3.83
FeO	9.05
MnO	0.40
MgO	13.77
CaO	8.05
Na_2O	1.81
K_2O	0.46
TiO_2	1.08
ZrO_2	0.00
P_2O_5	0.12
Cr_2O_3	0.23
H_2O	2.90
H_2O-	0.15
Total	100.16

Norm values calculated from this analysis:

Orthoclase		2.78
Albite		15.20
Anorthite		16.69
Diopside	fs	2.24
	en	6.42
	wo	9.41
Hypersthene	fs	8.31
	en	23.49
Olivine	fg	1.22
	fo	3.10
Magnetite		5.56
Chromite		0.45
Ilmenite		2.12
Apatite		0.34
H_2O		3.05
Total		100.38

Analyst: C.J. v.d. Walt, Division of Chemical Services//.

Services, Pretoria.

(b) Kimberlite Pipes.

A small pipe was found about half a mile to the south-west of the prominent Tigerkop, immediately north of Kapstewel on the farm Thaakwaneng. The Kimberlite is very weathered, and is rich in micaceous elements of a phlogopitic type. A few small garnets and ilmenites were observed.

Near the northern boundary of the farm Doornput, which adjoins Klipfontein to the south, a small Kimberlite pipe was found during mining operations for manganese, which was proceeding in the siliceous breccia on the southern slopes of the hill across which the boundary fence passes. As usual the Kimberlitic material is deeply weathered into a friable greenish-yellow mass in which are scattered numerous mica flakes. It is reported that on being washed, a few small diamonds were found. Apart from small limestone inclusions derived from the dolomite, some inclusions of a very fine-grained greenish quartzite were found. This is totally unlike any of the Gamagara or Matsap quartzites found in the area, and it is surmised that it may have come from the Black reef quartzites which underlie the dolomite.

Diamonds have been reported from Paling as well. Less than half a mile to the north-west of Paling poort lies a low rounded outcrop of dolomite, which belongs to the allochthonous thrust block, heaved along the Gamagara thrust fault, (T.1.) over the Gamagara quartzites adjacent. Boreholes sunk

for//....

sunk for water in this dolomite mass are reported to have encountered Kimberlitic material which is stated to have yielded a few tiny diamonds.

It is probable that many Kimberlite pipes, possibly large ones, remain to be discovered in the area, for the large areas of sand would obscure the easily weathered Kimberlite, which is discovered only in favourably exposed areas.

CHAPTER III.

Probable pre-Matsap Topography and Conditions of Matsap Sedimentation.

This section deals with the probable distribution and disposition of the older rocks, which provided the debris now composing the Gamagara beds in pre-Matsap times; the distribution of the Gamagara rocks, and the probable conditions under which the basal members of these beds were deposited. These deductions are based on the facts to hand, embodied in the previous chapter, and in turn inferences are drawn with regard to the heave of the thrust faults, described in the subsequent section.

(A) Distribution and Disposition of the Older Rocks.

There seems to be no doubt about the existence in pre-Matsap times of Rogers' Maremane anticline, affecting the rocks of the Transvaal system. (25) This anticline seems to have been very gentle, with a major north-south axis approximately along the present site of the Gamagara rand, with a second minor anticline to the southwest from Wolhaarkop to Aucampsrust, joined to the main anticline by intervening saddle syncline, and with a major axis parallel to that of the main anticline. This minor area does not concern us here. (See key plan of maps.) In considering the problem, only the main anticline is taken account of, according to the reconstruction of this, the Maremane anticline, as illustrated in the accompanying diagram.

About the time sedimentation of the Gamagara rocks was initiated, erosion of the Transvaal system had progressed so far as to lay bare the upper horizons of the dolomite in the cores of the anticlines. This dolomite seems to//...

to have formed a somewhat potholed plain fringed in concentric fashion by low hills of the Pretoria series, (c.f. 34. p. 52.) the higher members forming the outer rings. The innermost eminences of this concentric hill system were without doubt composed of the resistant rocks of the lowermost portion of the lower Griquatown stage -- the highly ferruginous banded ironstones. The low dip of these rocks undoubtedly resulted in the formation of outliers of this rock on the dolomite adjacent to the main body of banded ironstones. These outliers would be disposed sub-horizontally, and being resistant cappings lying on a relatively soluble rock like dolomite, it is quite probable that a certain amount of sub-surface solution of the underlying dolomite took place, resulting in the sagging in of the banded ironstones into the hollows, as shown in the diagram illustrating the first stage of the evolution of the breccias.

To the east of this central outlier-dotted, or probably more correctly, outlier-fringed plain, the banded ironstones and higher members of the Pretoria series dipped away at a low angle to the east, composing the eastern limb of the Maremane anticline, much as it is exposed today, except that by erosion the edge of the banded ironstones have retreated about 5 miles further east. The western limb of the Maremane anticline, subsequently so distorted by the thrust faulting, probably reproduced the same arrangement, with the rocks dipping at low angles to the west. (C.F. evidence of conglomerate on Japies Rust.)

(B) Distribution and Disposition of the Younger Rocks.

The hills of older rock described above yielded much debris composed of the more ferruginous part of the banded ironstones, owing to their superior resistance to weathering. This debris would have collected about the lower hill slopes and adjacent dolomite flats as irregular beds of conglomerate, while further afield on the dolomite plain, grit washes, and finally, ferruginous muds were deposited. On a small scale, it seems that this is a parallel

with//....

with the well known fact elucidated in the Alps and mentioned by Jas. Geikie (15) that the coarser detritus was deposited near the source of the material, i.e. near the land remnants bordering the plain of sedimentation. In the Postmasburg area the resistant banded ironstones would compose such land remnants, while the plain of sedimentation was mainly underlain by the easily weathered dolomite core.

With the levelling effect on the topography resulting from this deposition, a more continuous blanket of muds was deposited and finally sands and siliceous grits brought from further afield. This was the sequence of sedimentation of the Gamagara rocks as revealed by their distribution, composition and texture.

The present arc-like distribution of the coarser ferruginous conglomerate forming the base of the Gamagara series, and the masses and remnants of banded ironstones, now mostly brecciated, so closely associated with the conglomerates, indicate the situation of the banded ironstones composing the eastern limb of the Maremane anticline, as it was in pre-Matsap times. From this it is clear that the hills of banded ironstones then bordering the dolomite plain stretched from the northern end of the Gamagara rand, via Klipfontein and Pensfontein, to Beeshoek at the southern end of the Gamagara rand, forming a symmetrical arc. (See reconstruction of the Maremane anticline). The Gamagara rand joins the ends of this arc in a straight northsouth line. An east-west line joining Klipfontein to Marthas Poort is the symmetry axis of this bow-like arrangement.

To summarise the above, it may be said that the arc of the bow, coinciding with the distribution of the Gamagara

basal//........

basal conglomerate and parent banded ironstones, marks the former edge of the banded ironstone hills on the eastern limb of the Maremane anticline, while the north-south line occupied by the Gamagara rand, the string of the bow, apparently coincides roughly with the axis of the old Maremane anticline.

When studied in detail, the conglomerates are seen to fill embayments and hollows in the banded ironstone masses, and to dip at gentle angles away from these. At many places the conglomerates and shales appear to have a disconformable relation with the underlying banded ironstones and dolomite, indicating that these rocks were then disposed in positions not far from horizontal.

A study of the size distribution of the pebbles in the conglomerates on Bishop, indicated that the material was deposited in "runs" trending north-west by south-east. The tailing off in size of the pebbles towards the north-west shows that the material was derived from the south-east, i.e. from the direction of the Klipfontein hills. This conforms to the idea that the banded ironstones capping these hills were in pre-Matsap times eminences bordering the dolomite plain, and that from these hills the conglomerates were derived. (34.p.28.)

From this we may infer that the detritus which went to form the Gamagara rocks was in general carried from regions to the east, in a westerly direction. The beds thus laid down must then have posessed a small sedimentary dip to the west, according to Twenhofel. (Sedimentary Petrography). This westerly dip of the Gamagara rocks has been accentuated by the post-Matsap earth movements, but even to-day the dip is often low.

(C)//.......

(C) Conditions of Sedimentation.

It is clear from the distribution of the material that it was for the most part locally derived, a fact attested to by the small amount of attrition suffered by the fragments., by the close association between the conglomerates and the parent banded ironstones., and by the rapid thinning of the conglomerate beds and concomitant rounding and decrease in size of the pebbles, as one proceeds away from banded ironstone remnants towards the centre of the dolomite peneplain.

The material was apparently moved into a broad shallow basin by local streams. At the commencement of deposition at any rate, it seems that large streams with great carrying power were absent. Weak local drainages seemed to have debouched into quiet shallow waters. That the waters were quiet and shallow, or agitated by weak conflicting currents, is shown by the occurence of coarse pisolitic structures in the shales. These are encountered at intervals along the whole length of the Gamagara rand.

The prevailing red colour of the unaltered shales, and the pink, red or purple colour of the quartzites, leads to the belief that the climate at the time was warm and relatively dry, resulting in thorough oxidation of the iron. The absence of anything resembling a tillite in these rocks confirms this view.

Much speculation has been caused by the unusual composition of the shales. Their abnormal richness in alumina must have originated partly during this period of deposition. Prolonged weathering of dolomite leaves highly

aluminous//.......

aluminous residues, (39) while aluminous muds probably impregnated with sulphates, could have come from the Ongeluk lavas, which bear sulphides. The dolomite has locally been proved to contain chlorine and fluorine, (Chapter II, B.1.) as also have the Gamagara shales. This is another reason for considering that weathered dolomite provided the bulk of the material to form the shales.

CHAPTER IV.

Tectonics.

(A) The Structures.

(1) General.

The main tectonic features of the area are the great thrust faults running parallel with the strike of the Gamagara rand, and to the west of it. These are low angle thrusts, evidenced by their sinuous trace as revealed by erosion in transverse gullies and valleys, especially on Marthas Poort and Japies Rust. On these farms occur isolated allochthonous blocks left by erosion, which has exposed a sinuous thrust plane running around the periphery of the loose masses. (See Map G.)

Sections exposed in gullies show that the fault planes are now undulose, (Plate II, Fig. 2.) no doubt as a result of continued pressure subsequent to the formation of the breaks. In general the average dip of the fault planes along the Gamagara rand is about 12° to the west.

Associated with the faults are numerous structures such as folds of many types, breccias, shear planes, slickensides and minor faults. By far the most intricate folding is to be seen on southern Marthas Poort.(Plate II. Fig.3.)

(2)//......

(2) The Faulting.

This is best followed by referring to the sections accompanying the maps. These sections are largely self-explanatory. Two main thrust faults can be traced within the confines of map G, where they are clearly marked and designated T.1. and T.2. or the older and younger Gamagara thrusts respectively. To differentiate, the younger or upper break has been named the Vlakfontein thrust, since it traverses the farm Vlakfontein north-west of Paling, and the older or lower break has been named the Gamagara thrust, since it so closely follows the western edge of the Gamagara rand. They will be referred to for brevity as T.1. (the Gamagara thrust) and T.2. (the Vlakfontein thrust.)

T.1. was definitely traced along the northern half of the Gamagara rand, where it is in places complex, dividing into at least two separate breaks. In this area, which is to the north of the accompanying map G. the trace of T.1. has been clearly marked on the maps accompanying the latest Geological Survey publication on the area.(34). Here and there traces of T.2. appeared in this northern sector but this break could only be definitely followed within map G., on account of the better exposures encountered along the southern half of the Gamagara rand.

The sections accompanying the maps will now be referred to. Section I.G. portrays the trace of T.1. where beautifully exposed in the south-western corner of the farm Lohathla, and the adjoining south-eastern corner of the farm Lomoteng. This section appears on Plate II. Fig.2. where it is exposed in a transverse valley. Here the

upper//.......

upper jaspery portions of the lower Griquatown series rest apparently conformably on the Gamagara quartzites. The former rocks, which are ferruginous and show up black in the field, are greatly disturbed, being throughout slickensided and fractured. On the other hand the underlying quartzites bear little evidence of disturbance. This fact conforms to the observations of Cooper (8) who found that the autochthonous beds underlying the thrust planes are relatively little disturbed when compared to the alochthonous masses above. Dake (9) also found the zone of crush breccia to be notably thin at most points, and sometimes absent, along a thrust plane involving a heave of about 22 miles. It might be stressed here that the extensive siliceous and Blinkklip breccias in the area are not regarded as lying along a thrust plane, but are a subsidiary effect of the mighty earth movements owing to a special combination of circumstances. (See Chapter IV.B.3.)

Near the thrust plane depicted on Plate II. Fig. 2., the quartzites (autochthonous beds) are somewhat slickensided and contorted close to the thrust plane, while pebbles in conglomerate bands are sliced across as if with a knife. A small distance to the south however, at Bos beacon, which is common to the farms Lomoteng, Lohathla, Japies Rust and Gloucester, the quartzites are intensely fractured in the same manner as the Griquatown beds. At this point in the thrust plane a twist in the plane caused a certain amount of bunching in the quartzites, hence the disturbance.

About a mile north of section I.G. it is seen that the plane of T.I. transgresses to higher horizons across the

lower//......

lower Griquatown series, and transgresses deeper through the Gamagara sequence, thus bringing remnants of tillite to lie across the basal beds of the Gamagara series, coming in places to lie on the dolomite itself. This fact gives some clue as to the heave of the thrust. Referring to the plan portraying the pre-Matsap Maremane anticline as reconstructed, it is seen that to bring the tillite to lie on the dolomite on Lohathla, near the middle of the Gamagara rand, T.I. must necessarily have a heave at this locality of a minimum of 8 to 10 miles. Moreover, 2,500 feet of the lower Griquatown series has been eliminated by the fault, presumably by the progressive forward movement of the higher horizons over the lower, which remained behind as a result of friction.

Section 2.G. portrays how the trace of T.I. appears immediately to the west of the Gloucester manganese mines, at the base of conspicuous red cliffs of shattered banded ironstones and jaspers. These cliffs and bouldery masses are striking landmarks when viewed from the vicinity of the manganese quarries.

On the upper dip slopes of the mountain are infolded masses of Gamagara rocks resting with a sedimentary contact on the lower Griquatown beds, which are above the trace of T.I. and therefore alochthonous. The Gamagara rocks are complete, even to a basal conglomerate composed mainly of ferruginous jasper pebbles. (c.f. Chapter II. B.3.i.) Having been heaved many miles from the west, this relationship is additional evidence as to the essential correctness of the reconstruction of the Maremane anticline, before mentioned, where Gamagara sediments are shown to have had a sedimentary transgression across successively//.....

successively higher members of the Griquatown series which completed the western limb of the Maremane anticline.

On this same section, the plane of T.2. appears at the foot of the mountain to the west, where tillite and Ongeluk lavas have been thrust over alochthonous Gamagara beds. These have themselves been heaved several miles from the west, riding along on a sheet of jaspers.

Section 3.G. depicts what is by far the most interesting and instructive portion of the Gamagara rand from a tectonic point of view. During mapping neither head nor tail could be made of the jumble of rock masses. However, on plotting the extent of each rock mass carefully, and drawing them in faithfully according to the contours of the section, it was seen that the younger T.2. thrust had actually interfered with the plane of the older T.I. thrust. Apparently after the relief of pressure afforded by the formation of T.1., renewed pressure threw the plane of T.1. into folds, and when the accumulating pressure reached breaking point, a new break, T.2., formed above T.1., truncating an anticlinal arch formed by the plane of T.1.

Continued pressure subesquent on the formation of T.2. caused numbers of small high angle reverse faults of small throw to branch from the plane of T.2., as well as throwing the plane of T.2., into undulations. Whether these small breaks were actually formed subsequent to the formation of the T.2., break, or previous to it, it is not possible to tell. Cadell (4) made interesting observations in this connection. In his experiments he found that small reverse faults pile up material in the form of imbricate structure, thus increasing the resistance, and that the mass then broke more or less horizontally in a low angle thrust//...

thrust or "sole" across or below the imbricate pile.

The crushed and slickensided banded ironstones along the planes of these small reverse faults have been heavily ferruginised, resulting in the formation of small lenses of high grade haematite ore.

Chamberlin and Miller (5) say that the common reverse fault is defined by displacement along planes neighbouring 45° or a little less, and is confined to more limited movement along the planes. These small breaks fall under this class. They state in addition that the great overthrusts in contrast slide along planes that approach horizontality, and involve displacements of astonishing magnitude. This is in conformity with the nature of the T.1. and T.2. breaks. Visser (35) has evidence to the west of map G. that the plane of T.2. there exposed, often approaches horizontality.

It should be mentioned that in section 3.G., as in section 2.G., it was found that the jaspers which moved forward along the plane of T.1., are overlain by Gamagara rocks which rest on the jaspers with a sedimentary contact. The Gamagara basal conglomerate, here very well developed, is composed of predominantly siliceous pebbles of banded jasper, again showing that to the west Gamagara beds were deposited on higher and more siliceous horizons of the Griquatown series, as portrayed in the plan and sections of the reconstructed Maremane anticline.

In consequence of their siliceous nature, these conglomerates do not constitute iron ore. However, lying adjacent to a major thrust plane, an interesting study is

afforded//.....

afforded of the tectonic effects on the conglomerate. The conglomerate as a whole seems but slightly disturbed, but individual pebbles are sliced in step-like and rotational fashion, while the surrounding clayey matrix is scored and slickensided.

On sections 4.G., 5.G. and 6.G. the thrust faults T.1. and T.2. can clearly be traced by means of the surrounding rock formations, there being a sufficiency of outcrops, although the actual traces of the faults are obscured by the sand and scree fillings in the valleys. The traces of the faults usually follow the valleys, apparently because such disturbed zones were more easily eroded.

The plane of T.1. seems to steepen considerably along the western flank of the Gamagara rand, which here forms a definite escarpment, the foundation of which is a solid massif of dolomite. Much of the pressure was dissipated by the creeping, crumpling and intense folding of the less competent Gamagara beds on and over this solid dolomite foreland. (See Chapter IV. A.3.) The resistance of this block has apparently caused the local steepening in the dip of the fault plane, which can at these places be more accurately termed a reverse fault, since the fault plane dips in the neighbourhood of 45° westwards. To the west and east of this restricted area the fault plane again flattens out to its usual 10° to 12° dip westwards, or even approaches horizontality.

Chamberlin and Miller (5) give numerous examples of thrust faults in which the plane of the fracture varies from 5° to 25° in dip, steeper angles being ascribed to

later//.....

later warping.

This may be the case here. Many of the thrust faults mentioned by Chamberlin and Miller have been traced for distances of up to 270 miles laterally, while the rock displacements are always large, being measurable in miles. These Postmasburg thrust faults have not been completely traced, and in any case their northern extension has been covered up by Kalahari sand. In this direction however, there is evidence that they extend at least as far as Black rock, west of Kuruman, and about 90 miles north of Lohathla. To the south they have been traced by Visser (35) for approximately an equal distance, thus the horizontal trace of these faults can be traced for a distance of between 150 and 200 miles, and the heave of only the lower and oldest plane is about 10 miles at least. This series of thrust faults must therefore rank amongst the worlds greatest dislocations of this type.

It is noteworthy that from the locality across which sections 4.G., 5.G. and 6.G. have been drawn, the faulting has brought dolomite up against and over the Gamagara quartzites. It is this relationship on Paling which Rogers noted, and caused him to conclude that faulting had taken place here. This he named the "Paling fault." (25) The relationship can be well seen where Paling poort debouches on the sandy flats. A well developed mass of Gamagara quartzites is seen to dip at a low angle beneath the dolomite to the west, although the Gamagara beds are clearly seen to lie unconformably <u>on</u> the dolomite half a mile to the east at the top end of Paling poort. It should be stated that there is only one dolomite formation in the area.

Another//.....

Another feature encountered in this area, and portrayed on sections 4.G., 5.G. and 6.G., in each case to the west of the Gamagara rand, are prominent hills of highly disturbed Gamagara quartzites, resting on the fractured sheet of alochthonous dolomite west of the Gamagara rand. The relation between the quartzite and underlying dolomite is on these grounds apparently a sedimentary one, when compared to the infolded portions of Gamagara beds lying on the alochthonous jaspers of the Transvaal system seen in sections 2.G. and 3.G. However, the absence of the basal beds below the quartzites suggests the possibility of the presence of a fault plane at this place. It seems unlikely that the trace of either T.1. or T.2. passes beneath this quartzite, according to the relationship of the other rocks, and the course of the traces of T.1. and T.2. For this reason it is thought most possible that the postulated plane of disturbance beneath these loose masses of quartzite be an earlier and lower branch of T.2., as depicted in sections 4.G., 5.G. and 6.G. If this be so, then the T.2. break must later have branched and cut across a higher plane bringing Ongeluk lavas to lie against these quartzites to the west. This break is the true T.2., the lower one, if it exists, being a branch of T.2.

Section 7.G. on Paling is relatively simple. In this section only the plane of T.1. appears. However, a window of shattered Gamagara quartzites showing through the highly disturbed mass of alochthonous dolomite gives evidence of the highly undulose nature of the thrust plane. Here, as at other localities, the moving mass of rock above the thrust

plane//.......

plane is seen to have undergone far more shattering and disturbance than the underlying autochthonous mass. In this section, an outlier of siliceous breccia capped by disturbed Gamagara shales, appears to the east, heralding the approach to the top of the dolomite series as exposed in the old Maremane anticline. The appearance of siliceous breccia is the forerunner of the appearance of brecciated banded ironstones or Blinkklip breccia. This sequence is to be expected, for the banded ironstones follow the chertrich dolomite in normal sedimentary sequence.

Section 8.G. on Doornfontein heralds the close approach of the two thrust planes, T.1. and T.2., which is a feature of the southern portion of the Gamagara rand. Here again, the later T.2. has interfered to a slight degree with T.1., which has at this point an unknown amount of heave, since dolomite is thrust over Gamagara beds. T.2. on the other hand has brought tillite and Ongeluk lavas to lie on the previously moved mass of dolomite brought up along T.1. T.2. has here therefore, like T.1. on Lohathla, eliminated about 2,500 feet of lower Griquatown beds in the course of its movement, and apparently its heave is of a similar order of magnitude. It seems that on proceeding southwards T.2. gains in importance as the main break with the greatest heave, while T.1. decreases in magnitude. To the north the reverse order obtains.

On Doornfontein thick masses of siliceous breccia appear on the dolomite, overlain by small discontinuous cakes of Blinkklip breccia. Section 9.G. shows the relationship these rocks have with the underlying dolomite and overlying

Gamagara//......

Gamagara beds. On this section T.1. only appears, and the undulose nature of the thrust plane is again illustrated. T.2. appears further to the west, beyond the limits of the section.

An interesting feature in this section is provided by the tall hill to the east, where a thick mass of highly ferruginous conglomerate of the Gamagara series is partly infolded in the siliceous breccia, as a result of local overfolding from the west.

Section 10.G. is drawn across the site of Beeshoek village. The positions of the traces of T.1. and T.2. is uncertain owing to a thick cover of surface drift and calcareous tufa. It may be that the traces of T.1. and T.2. actually coalesce, for some distance to the southward, beyond the confines of map G., one large break only is found, which has been followed by Mr. D.J.L. Visser (35) almost as far as the Orange river, where it dies away.

The Gamagara beds on Beeshoek show a strong development of basal conglomerate, as a result of the great amount of banded ironstone present. The presence of thick and almost continuous masses of this rock, shows that at this locality the dolomite of the Maremane anticline had disappeared beneath the arc of banded ironstones, swinging southwestwards from Klipfontein, and composing the southern portion of the eastern limb of the anticline.

Boreholes for water south and west of Beeshoek village, pierced unusually thick beds of Gamagara shales, which are strongly developed at this locality.

Apart from the powerful thrust faulting encountered in the area, very little faulting of other types is encountered.

On//........

On the north-western corner of the farm Driehoekspan small tear faults are encountered. These have been formed subsequent to the intense folding of the beds, which are offset small distances in a south-east direction. The small reverse faults encountered on Marthas Poort have already been dealt with in describing section 3.G.

(3) Folding and Distortion.

In view of the powerful thrust faulting which has affected the area, folding and distortion seems relatively unimportant, especially to the east of the Gamagara rand. For the most part the autochthonous beds beneath the thrust planes are thrown into gentle folds. The greatest disturbances are represented by shattering and closely spaced slickensiding. However, along the central part of the map, from the farm Japies Rust down to Paling, folding almost Alpine in intensity is encountered. (See Plate II. Fig. 3.)

On Marthas Poort and northern Paling, across which sections 4.G., 5.G. and 6.G. have been drawn, much of the pressure was relieved by intense folding. This belt of folding can be seen on map G. to be arcuate in shape and concave towards the west, clearly indicating that the pressure originated from this quarter. In fact, as regards the regional tectonics, the focus of the tectonic forces seems to have been concentrated in this area. The deepest point in the wide Langeberg arc to the west (35) lies opposite this part of the Gamagara rand, while to the east on the same line, lies the central portion of the arc of breccia hills on Kapstewel and Klipfontein, exhibiting likewise the maximum amount of brecciation.

The//.....

The line connecting these points of maximum pressure and disturbance in the Langeberg, the Gamagara rand, and the Klipfontein hills is not due west to east, but is inclined a few degrees north of east. The similarity of the alignment of the Gamagara rand and the Klipfontein hills to a bow has already been drawn. This line of maximum pressure would coincide with the arrow, which, correctly placed, would coincide with the common line of maximum deformation. This fact is additional evidence that the post-Matsap deformations and the brecciation are contemporaneous, and the result of the same tectonic disturbance.

The folding in this greatly deformed sector of the Gamagara rand is portrayed in sections 4.G., 5.G. and 6.G. The folds are for the most part symmetrical closed folds. (38.pp.61,62. and Plate II. Fig.3.) Some of the folds continue with remarkable persistence, erosion exposing long narrow outcrops of squeezed ferruginous core composed of Gamagara basal beds. Most of them, however, are distinctly canoe shaped, and are arranged on echelon. Canoe shaped anticlines are connected by saddle synclines. Where an anticline dies away, another commences diagonally beyond a connecting saddle syncline in a rythmic pattern. These structures are all on a relatively small scale, as can be seen on map G., and are therefore an easy and interesting study.

Some of the squeezed folds have resulted in the elimination of the incompetent shale band between the Gamagara basal conglomerate and quartzites, while in favourable localities inordinately thick masses of puckered shales have become bunched together, as for instance in the deep longitudinal valley on south-eastern Marthas Poort.

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The shales are highly micaceous and phyllitic as a result of the dynamic metamorphism.

It is noteworthy that the most intense folding and distortion has occurred in the weak shale bands, and secondarily in the somewhat incompetent thinly bedded quartzites of the lower part of the Gamagara series. The thickly bedded quartzites higher up in the Gamagara series were more competent. This difference in the competency of the beds is well shown in Plate II.Fig.3., where a squeezed or carinate syncline has developed in the weaker lower members of the Gamagara series, while the crest of the hill is formed of the relatively competent upper quartzites of the Gamagara series. This mass has not taken part in the intense folding, but has been squeezed out, and lies in a gentle sympathetic syncline. This must necessarily have involved a large amount of differential creeping in the beds. (38.p.62. fig.24.)

This intense folding dies out to the south on Paling, and from here to the southern limit of map G., folding and distortion is represented by mere gentle undulations, with occasional complex puckerings on a minute scale, accompanied by closely spaced slickensiding. On the eastern side of section 9.G. is an example of overfolding involving the siliceous breccia as if it were a yielding mass, bulging it up and over a thick bed of basal conglomerate.

Marked folding on a small scale everywhere affects the basal beds of the Gamagara series, especially where these lie directly on the dolomite. These disturbances are ascribed mainly to slumping resulting from the subsurface solution of

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the dolomite. (Chapter V.C.)

East of the Gamagara rand folding is very little in evidence, there being instead a welter of brecciation preserved in the Klipfontein hills. Sections 1.K. and 2.K. show a certain amount of compression and folding involving largely the remnants of the Gamagara beds. Portions of the shale horizon which have been infolded beneath or bunched up against the breccia masses exhibit complex puckerings, (Plate IV. Fig.2.) or are even become schistose.

The fact that so much shattering and slickensiding has taken place along the Gamagara rand, in addition to the folding, is an indication that the disturbances took place relatively near the surface, without any considerable superincumbent weight. The structure shown on Plate II. Fig. 3. where the more massive Gamagara quartzites where squeezed out upwards from a carinate syncline, also suggests a light superincumbent burden, allowing the easy upward movement of the quartzite out of the closed fold. Clearly the horizontal pressure at this point was greater than the vertical pressure, resulting from the weight of the overlying rocks.

The extensive Blinkklip breccias are additional evidence that in this portion of the area the disturbances occurred at a level in the earths crust not so deeply buried beneath a super-incumbent mass of sediment. The Gamagara rand in fact, forms the boundary line between the zone of intense folding, which is best developed in the masses of sediment composing the Langeberg to the west, (35) and the intense brecciation, best developed in the Klipfontein hills in the east. This indicates a decrease in the sedimentary load

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east of the Gamagara rand, and an increase to the west.

From this we may conclude that the main geosyncline deeply filled with Matsap sediment lay west of the Gamagara rand. A study of the conditions of sedimentation along the Gamagara rand also points to this conclusion, for it was seen that the detrital material came from an easterly direction.

(4) Slickensiding and Brecciation.

Slickensiding is everywhere a marked feature of the rocks composing the Gamagara rand, occurring in all members of the series. Their presence indicates, as suggested above, that the lessening of the sedimentary load in this area allowed the pressure to be relieved to some extent by repeated and minute slidings within the rock mass, rather than the intense folding en masse so characteristic of the Langeberg.

The slickensides in the quartzites and shales are usually closely spaced, and movements along individual planes are small, varying from a fraction of an inch to a maximum of a few feet. In form they are concavo-convex, the planes of fracture parting for a few inches and coming together again. On Lomoteng an outcrop of ferruginous shale is so much slickensided in this manner that a hammer blow releases loose pieces of concavo-convex shale averaging the size of a mans hand or smaller. The bounding surfaces are grooved and shining. These slickensided fractures are disposed at low angles, and dip generally to the west, parallel to the main thrust planes.

In the hard haematite composing the highly ferruginised basal grits and conglomerates of the Gamagara series,

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larger slickensided surfaces disposed in more uniform westward dipping planes are encountered. (Plate IV. Fig. 1.) The example here referred to illustrates such a case, photographed on northern Lohathla. The grooving runs from west to east, as seen on the upper surface of the lower block, which although split by weathering, is lying in situ. Step-like breaks, comparable to small roches moutonnées, clearly indicate that the over-riding block moved from west to east in sympathy with the thrust movements.

Associated with the slickensiding is much brecciation and shattering of the more brittle beds. Along the Gamagara rand shattering of the quartzites is particularly marked along the stretch from Bishop to Paling, with some mylonitisation. In most cases in the quartzites intense slickensiding on a small scale, and shattering, are synonymous. The shales, owing to their incompetent nature, show extreme deformation, and only rarely, where they have been rendered brittle by silicification, are breccias encountered. The ferruginous conglomerates are wonderfully resistant rocks to both deformation and shattering. Under the extreme conditions mentioned as occurring on Marthas Poort at the base of an alochthonous sheet, individual pebbles are rotationally sliced, or the mass as a whole folded.

In places the thrust plane seems to have gouged away the relatively thin sheets of Gamagara rocks, and locally passed along a floor of dolomite, resulting in considerable brecciation and disturbance of this rock. The thinness and discontinuity of the Gamagara rocks on central Doornfontein can be ascribed to such a transgression. The dolomite here is much disturbed, brecciated masses being cemented by yellow

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and brown secondary chert. Similar structures in the dolomite occur on the west facing slopes of the conical dolomite hills on Gloucester, and on Lohathla where the tillite has been thrust across the dolomite.

On Paling an interesting effect was observed. Apparently Gamagara quartzites have been pushed across the dolomite at one spot, with the formation in that rock of irregular "sandstone dykes". (Plate III. Fig. 1.) These seem to have been tension cracks in the dolomite, into which sand has filtered. This loose sand must have been produced by the abrasion along the plane of the break of the base of the moved quartzite mass. In thin section the quartzite grains show considerable attrition. (Plate VIII.Fig. 2.) On Mount Huxley immediately east of the Klipfontein hills similar "sandstone dykes" in dolomite exhibit mylonitisation. (Plate IX. Fig. 1.

Brecciation on a vast scale is found in the brittle and incompetent banded ironstones of the lower Griquatown series, and the underlying cherts which lie at the top of the dolomite series. This amazing development of breccias nicely follows the supposed distribution of the fringe of lower Griquatown banded ironstones in pre-Matsap times, locating the eastern limb of the Maremane anticline. In my view, the formation of these breccias is to be ascribed to several factors, which are dealt with in B.3. below.

A feature of the Blinkklip breccias which is of particular significance is the presence of actual mylonite, often in distinct zones of intense crushing aligned east by west, as found on south-western Doornfontein, or roughly sheet-like elsewhere.

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The alignment of this type of mylonite, brick-like in colour and texture, definitely suggests a connection with the tectonic deformations. Norton (23. p191.) says that in his class of "founder breccias" in which he includes the Blinkklip breccias, the fragments show only small wear owing to mutual attrition. The presence of mylonite in the Blinkklip breccias suggests that it should rather fall under his "crush breccias."

It is clear that the masses of brecciated banded ironstone as seen to-day (the Blinkklip breccia), is the brecciated counterpart of more or less disconnected outliers of banded ironstones, at one time buried beneath the Gamagara sediments.

The distribution of the intensity of the brecciation in these banded ironstone masses is of prime importance from a genetic point of view. The larger thicker masses, such as encountered on the prominent hill east of Beeshoek village and on Klipfontein, are particularly instructive. This distribution in the vertical plane was noted by Nel, (21.p. 23.) who says, "There is a distinct tendency for the fragments of the breccia to increase in size towards the higher horizons of the formation. The usual breccia gives way to large tilted blocks above. These blocks, hardly displaced from their original positions, in turn are united into continous strata, where the puckered laminae, folding or slight dislocations, become smoothed out the further they are removed from the fracture zone."

To this, I could add that the chert or siliceous breccia below the Blinkklip breccia is habitually composed of much smaller fragments, and is the zone of the most intense

brecciation//.....

brecciation. A fair comparison is given between Plate I. Fig.3. and Plate II. Fig. 1. It will be hard to account for such a fact if it be supposed that the breccias were formed by gravity slumping alone. There are a number of other petrographic features of the Blinkklip breccia, which will be better described in the following section, because of their significance as to the origin of the breccias. In my explanation as to the mode of formation of the breccias given below, I think it is fair to say that the feature described above, as well as all others, find a natural explanation.

(B) Evolution of the Tectonic Structures and the Breccias.

It will not be out of place to give here a resumé of the opinions previously expressed as to the origin of the breccias, and the tectonic structures.

Owing, in the first case to the prominence and often bizarre shape of the outcrops, and their unusual nature and extent, the breccias have attracted a great deal of attention from geologists, especially in late years as a result of their close association with valuable ore deposits.

In 1870, Stow (28) expressed the opinion that it was a consolidated detrital rock. He must have confused it with some of the Gamagara conglomerate. Much later Rogers, in 1905, (25) thought that it was formed by the collapse of the lower Griquatown beds under the influence of gravity, and, perhaps, earth movements, into hollows dissolved out of the underlying lime-stone. In 1927, Nel (21) largely upheld this view, while in 1933 du Toit hinted at the larger part possibly played by earth movements. (13)

It should be noted that earlier geologists laid the

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stress on slumping as a causative agent in the formation of the breccias. However, as a result of the investigations carried out by myself, and later in conjunction with my colleagues Drs. F.C. Truter and D.J.L. Visser, we have come to the conclusion that earth movements played at least the major part in the formation of the breccias. In this connection, Dr. Truter was the first to definitely accept the breccias as tectonic breccias, and in the light of the evidence, Dr. Visser and myself have unreservedly come to the same conclusion. As regards the whole process of formation, my own views and conclusions are given below, in section (3).

(1) General.

Having, from all the evidence to hand, a fairly complete picture of the geological history of the area, it has been possible to reconstruct a credible scheme of the evolution of events.

Considering the area as a whole, a parallel can be drawn to the broad structure of the Alps, as described by Jas. Geikie, although on a much smaller scale. Geikie says, (15.pp.107-108) "There is one characteristic of the Helvetian folds of the Säntis to which brief reference may be made. They present certain features which distinguish them from the great recumbent folds occurring well within the Alpine area. The latter originated at considerable depths, and were subject, therefore, to the weight of enormous rock masses, so that when lateral compression ensued they behaved like plastic bodies, and were flexed, sharply folded, puckered and crumpled without breaking. Along the north front of the Alps, however, the strata that were thrust against the Nagelfluh, not being loaded down to//....

to nearly the same extent, did not become plastic under the folding process, and consequently were cracked, fissuerd, fractured and shattered."

In the Postmasburg region, the counterpart of the heavily loaded Alpine area is the intensely folded Langeberg, which according to the evidence of the sedimentation, rose within the heavily loaded geosyncline by subsequent compression. The folding, marked slickensiding and fracturing of the Gamagara rand corresponds to the shattered Helvetian folds of the Säntis, while the Klipfontein hills represent relief by shattering and brecciation rather than folding. The westerly dip of the thrust breaks, suggests that they approached relatively near the surface in the Klipfontein area, and had therefore a small load. The resisting Nagelfluh is represented at Postmasburg by the Maremane dolomite and the arc of the eastern bended ironstone limb of the Maremane anticline. The brunt of the brecciating forces was borne by the western flank of these banded ironstone hills, the site now being marked by the Beeshoek-Klipfontein Blinkklip breccia hills. (See reconstruction of the Maremane anticline.)

The presence of brecciated dolomite cemented by a quartzite mylonite in the form of irregular "sandstone dykes" on Mount Huxley about 3 miles east of the Klipfontein hills shows that between this point and the Gamagara rand the thrust plane approached horizontality on the average, and must therefore have passed close over the Klipfontein hills, no doubt greatly affecting them in the process. Here we have indeed a combination of circumstances and all the force

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necessary, to produce the immense brecciation observed.

(2) Evolution of the Folding and Thrusting.

Upon the filling of the geosyncline west of the Gamagara rand, compressive forces were set up, and the sediments were thrown into the intense Langeberg folds, with probably small thrusts. (35) After a certain amount of heaping up, the mass rose and rode forward bodily along major thrust planes. Such a thrust plane probably originated in a fold below, but not necessarily so, since it may have originated at once on the application of severe horizontal pressure, according to Cadell. (4)

In view of the geological structures involved, I am inclined to postulate such an early formation of at least the main and lowest thrust plane, the T.1. break exposed along the Gamagara rand. This break lies mainly in the very incompetent banded ironstone zone of the lower Griquatown series, which is sandwiched between the thick and competent masses of the Campbell Rand dolomite and the massive Ongeluk andesitic lavas. A parallel is afforded to some extent in the Appalachians, according to Hayes, (17) who explained two parallel thrusts which run for 200 miles and have displacements of 4 to 11 miles.

In this Appalachian case weak shales are interbedded with massive dolomitic beds. The strata are thought to have first flexed into a pair of gentle anticlinal bends. Between the flexures the strata remained essentially undisturbed. Finally a break occurred near the crest of one of the anticlines, and the thick competent formations sheared more or less horizontally along a slippage plane which closely followed the bedding of the weak shales.

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According to the distribution and disposition of the pre-Matsap formations as reconstructed, west of the Gamagara rand incompetent banded ironstones of the lower Griquatown series, lying on a great thickness of dolomite, and beneath a similar thickness of competent lavas, was disposed with a gentle dip westwards. During the accumulation of compressive forces acting from the west, relief was afforded in a plane parallel to the banding of the weak banded ironstones. (See Sections of Maremane anticline.) This plane was almost parallel to the direction of maximum pressure. In consequence the massive Ongeluk lavas plus the overlying Matsap beds, sheared along a slippage plane rising gently eastwards, and closely following the bedding of the weak banded ironstones. Thus was formed T.1.

It should be mentioned that the weakest zone in the banded ironstones and jaspers lay in the lower half of the zone, namely in the fissile banded ironstones. This is probably why the more competent banded jaspers above outcrop so prominently above the trace of T.1. along the Gamagara rand.

As the competent beds moved forward and the resistance increased, movement ceased along T.1. and increased pressure now threw the plane of T.1. into folds. With further accumulation of pressure, a new slippage plane formed higher up in the sequence, but closely paralleling T.1., so that this new break, T.2., truncated some anticlinal arches of the plane of T.1. (See sections 2.G., 3.G., 8.G. and 9.G.)

Both these breaks encountered their main resistance along the Gamagara rand and the dolomite and Griquatown beds to the east, riding some distance over these resistant

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masses. Further thrusts developed later at still higher levels. These are described by Visser. (35)

Others, I am sure, will ask, as I asked myself, "Why has such a remarkably straight north-south zone of Gamagara beds been preserved beneath such powerful thrust planes? Why are not, at best, irregularly placed remnants preserved?" After much thought, I have the following explanation to offer, which I trust may be considered reasonable.

The indications are that the north-south axis of the pre-Matsap Maremane anticline ran along the present site of the Gamagara rand. It is centrally placed with regard to the arc of Griquatown hills to the east, while the thrusting has brought up similar beds from apparently an equal distance to the west. Everywhere east of the Gamagara rand the dolomite dips eastward. Along its course it is often disposed sub-horizontally, and even shows signs of low westerly dips, except in the vicinity of Paling, where fair dips eastwards are encountered.

Considering then that this was the position of the Maremane anticlinal axis, pre-Matsap erosion in all probability eroded a long low trough trending north-south along the axial plane. Erosion always attacks the crests of anticlines most vigorously. As a result, a strong development of Gamagara beds would be deposited along this trough, and during the ensuing thrust faulting, would tend to be preserved as a long straight line of Gamagara beds as we see it to-day. South of Paling where the steepest eastward dolomite dips are encountered, the Gamagara beds are most deeply cut away by the thrust faulting. This fact is also an indication of the correctness of the

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postulation. The thrusting has of course everywhere exaggerated the westerly dip of the Gamagara beds to their present position. An initial westerly dip in this direction has been suggested as a result of the course of sedimentation.

The folding along the Gamagara rand, especially the intense folding around Marthas Poort, must be ascribed to a piling up of the beds against the eastern edge of the low trough, a sort of dolomite barrier, as a result of the urge transmitted from the eastward moving masses above the planes of T.1. and T.2., but especially of T.1.

(3) Evolution of the Brecciation.

Having come to the conclusion that the prime factor in the formation of the breccias was the tectonic deformations and earth movements, I offer the following detailed scheme of their evolution as my conclusion at the present stage. Reference should be made to the evolutionary plan given in a series of sections, based on the structure of the large hill on Klipfontein.

It is not out of place to point out that the following structures noted in the Blinkklip and siliceous breccias, are additional evidence pointing to the tectonic origin of these rocks, over and above the facts already mentioned in the foregoing.

Near the north-western corner of Klipfontein I found samples of the underlying siliceous breccia, which can be more truly described as a crush conglomerate owing to the extreme attrition and rounding of the chert fragments, which are of heterogeneous size, and are included in a gouge containing fragments of Gamagara shale. Clearly then the

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date of this brecciation is post-Matsap, having affected Gamagara rocks, as are the thrust faults.

In addition, a mixed Blinkklip-chert breccia on the hillside east of Manganore siding (map K.) contains rounded cobbles of Gamagara quartzite, where this rock, which unconformably overlies a thin sheet of disturbed banded ironstones, has been infolded and involved in the brecciation. (Central part, section 1.K.) The rock containing these cobbles resembles a crush conglomerate and has clearly been formed by the post-Matsap deformation.

On the hill on the left central part of section 1.K., Gamagara shales have been seen to be infolded or rolled under the previously underlying mass of banded ironstone, now so brecciated. These shales are themselves brecciated and were evidently in part silicified previous to their brecciation. The overfold lies towards the east, and must therefore be the result of a push or thrust on the composite mass of the hill from the west. The silicification of the shales points to a considerable lapse of time subsequent to their formation, before the post-Matsap thrusting caused, as it is shown, their brecciation.

Section 2.K. provides a fine example of a mass of rock the front of which has been compressed and infolded as the result of its being urged forward in an easterly direction. Cadell, (4) in his exhaustive researches in mountain building and thrusting, finds that "the front portion of a mass of rock being pushed along tends to bow forward and roll under the back portion." The fact that this hill is compressed and infolded on the east side, proves that it was pushed along from the west to the east, and that

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the irregular zone of chert and Blinkklip breccia above the dolomite is a zone of movement, in fact a minor thrust plane, involving tremendous brecciation owing to special circumstances. This movement is no doubt a phase of post-Matsap deformations and major thrusts, and the breccia must therefore be a thrust or "crush breccia" following Nortons classification. (23)

In Missouri is found a parallel to this crush breccia. Norton says, (23.p.188.) "The sheet breccias of the Joplin district, Missouri, illustrate how terranes of brittle rock may be brecciated by lateral pressure without any further mass deformation than that exhibited in gentle warpings. Heavy ledges of chert have been thoroughly and finely crushed in places, and cemented by a chemical deposit from ground water." In the Postmasburg chert or siliceous breccias the chemically deposited cement is manganese. This fact incidentally explains the comparative rarity of large blocks of pure ore in this rock - - the ore is largely a cement! (See Plate III. Fig. 2.)

That the thin discontinuous cakes of banded ironstone which yielded the Blinkklip breccia were in all probability detached outliers lying on an erosion plain of dolomite in pre-Matsap times, is suggested by the structure of the hill on Klipfontein, shown in section 2.K. and the right hand side of section 1.K. Such outliers were covered by a blanket of Gamagara sediment (See evolutionary sections) and during the period of thrust faulting formed islands of superior resistance to any sliding movement. In consequence the less competent Gamagara shales would tend to pile up against the rear of such masses, as seen east of Manganore siding, on the left hand side of section 1.K.

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On the evidence to hand then, it seems fairly certain that the masses of banded ironstones, which were fragmented to form the Blinkklip breccia, were in pre-Matsap times erosion outliers of, and forming a fringe to, the lower Griquatown banded ironstones of the eastern limb of the Maremane anticline. (See reconstruction of anticline.) It is therefore reasonable to assume that during the cycle of pre-Matsap erosion, sub-surface solution of the dolomite beneath these thin layers of banded ironstones resulted in the formation of a structurally weak zone of tilted and cracked banded ironstone, underlain by residual soil from the dolomite, shot with loose chunks and pieces of chert. This loose material would fill the spaces between the residual pillars of dolomite, similar to structures formed today. (Plate V. Fig. 1.) (See first stage of evolutionary plan.)

There is evidence that the plane of the Gamagara thrust fault, T.1., followed a nearly horizontal course between Mount Huxley east of Klipfontein, and the Gamagara rand to the west. The plane of T.1. must therefore have passed within a hundred or so feet above the crest of the Klipfontein range as seen to-day. For this reason the relatively thin sheets of banded ironstones and some of the overlying Gamagara beds directly beneath the trace of the thrust plane, must have been urged along in sympathy, particularly in view of the weak base of loose chert and soil underlying these sheets.

One can imagine what the effect would be of a movement of only a few yards in this weak leached zone, with projecting pillar-like remnants of dolomite acting as a gigantic file, and themselves being smashed and pulverised together

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with the chert rubble and the lowermost portions of the banded ironstone mass. (See second stage of the evolutionary plan.) An extraordinary gouge of chert breccia, soil, dolomite, and remnants of infolded Gamagara conglomerate, shale and quartzite, drawn in under the front of the moving mass, would result. Just such an amazing mixture, minus the dolomite fragments at most places, and plus secondarily infiltrated manganese ore, can be observed in these siliceous breccias to-day. Hence indeed the preference for the term "siliceous breccia" in place of "chert breccia" owing to the frequent presence of fragments of the Gamagara beds. Indeed, by this process would result just such an admixture of siliceous breccia and Blinkklip breccia along the contact of these rocks, as is actually seen, as well as a diminution of the brecciation in the banded ironstones upwards away from the main zone of the disturbance, as has been referred to by Nel. (21.)

The zone of movement thus created can be regarded as in fact a secondary thrust plane, but it is purely local and subsidiary to the main break which passed above, at no great distance as can be inferred from the low angle of the thrust plane. It can also be inferred that the mass of superincumbent beds must have been relatively slight, to allow of such immense brecciation and rolling of some of the fragments, as can be judged from the formation of crush conglomerate. Such a slight load of superincumbent beds would be in keeping with the general scheme of the geological history, as sketched before.

Reverting to the distribution of the banded ironstones forming the eastern limb of the pre-Matsap Maremane

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anticline, it can be expected that where the outlying fringe of the main mass of banded ironstones was encountered, probably a small distance east of Klipfontein, (see evolutionary sections) this weak fringe would be treated in a manner similar to a detached outlier, but less severely. Further into the mass, brecciation would give way to interformational foldings and puckerings in the incompetent banded ironstones.

Incidentally, it is in these folds and puckerings in the banded ironstone hills east of Klipfontein that the valuable blue crocidolite asbestos is found, filling the lense- and saddle-like gaps or reefs so formed in these well laminated rocks. It may be then that the crocidolite asbestos owes its origin to the formation of these structures in the banded ironstones, and is post-Matsap in age. The structure of the asbestos itself conforms to this mode of origin. It is cross fibre, which would extend its growth in the direction of least pressure, i.e. across the slowly opening gaps provided by the lenses. Intermittent waves, corresponding to a change in the direction of growth of the fibres, testifies to the slow and probably intermittent opening of the cavities.

With regard to the extent of movement along this zone of brecciation in the breccia hills -- the heave-- no convincing evidence is available. However, I doubt whether it is very much, and would consider a movement of a half to a quarter of a mile to be near the mark. In fact, in many cases it would seem to be measurable in yards. Under the postulated conditions, even such a relatively small movement would cause immense brecciation.

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It should be pointed out at this stage that a breccia of the nature so produced in the chert zone, well shot with dolomite gouge and breccia, is liable to be readily attacked by circulating waters at a time when erosion of the overlying rocks allows access of meteoric waters to this region. Moreover, the porosity of the mass would allow oxygen free access, both in the form of air and oxygenated and carbonated surface waters. These waters, acting readily on the dolomite gouge and breccia as well as the shattered dolomite floor, would dissolve its manganese content, oxidise it, and precipitate it as a cement of manganese ore in the breccia.

Immediately east of Manganore siding a shallow quarry on a hillside exposed a surviving portion of the shattered dolomite floor below the breccias. This dolomite was being actively dissolved by surface waters, with concomitant crystallisation of calcite, and precipitation of veins, stringers and vughs of pyrolusite, some in beautiful dendritic fashion. Apparently this process of solution and deposition of manganese has not yet ceased.

Having come to the point where extensive solution of the dolomitic portion of the breccias has taken place, we come to the time when stage 3 of the plan of evolution comes into effect. Sub-surface solution of such undoubtedly large masses of dolomite gouge and breccia would cause the overlying mass of relatively insoluble siliceous rocks to slump inwards and fill the vacant areas created. Hence the very marked feature of slumping so noticeable in the breccia hills, especially the well eroded ones on Klipfontein and Kapstewel. (map K.) It should be pointed out that

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the above scheme explains the brecciation as well as the slumping, instead of calling in unexplained slumping to explain the brecciation. Stage 4 of the evolutionary plan shows Klipfontein hill as it is to-day. (c.f. Section 2.K.)

In conclusion, it should be noted that in my opinion the breccias could have been formed during three periods of geological time, namely:

(a) During pre-Matsap times by sub-surface solution of the dolomite, resulting in sagging of the cherts and lowermost banded ironstones, with, possibly, some formation of "gravity" breccia. This is speculative, for no breccia fragments have been found in the Gamagara basal conglomerates, in spite of the hardness of the breccias. This suggests the non-existence of such breccias in pre-Matsap times.

(b) Intense post-Matsap brecciation as a result of lateral pressure and movement, forming masses of "crush" breccia. The field evidence, as outlined above, is strongly in favour of at least the main mass of brecciation having taken place in this period by tectonic agencies.

(c) Pre- and post-Karroo sub-surface solution of the dolomite, resulting in widespread slumping, and probable formation of a new generation of "gravity" breccia. (See chapter V.)

In truth then, it can be said that the extensive and remarkable Blinkklip and siliceous breccias of the Postmasburg area are genetically both "gravity" breccias and "crush" breccias, but the latter term is the more applicable

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since the most potent causative agent seems without doubt to have been the earth movements in the shape of the powerful thrust faults.

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CHAPTER V.

Traces of Karroo (Permo-Carboniferous) Glaciation, and its Value in Dating Slumping and the Time of Manganese Mineralisation.

(A) General.

The relics of ancient ice action in the area have only recently been discovered. However as early as 1870 Stow (28.pp.68-77.) gave it as his opinion that the rounded outlines of many of the ranges were the result of glacial erosion. Later it had been surmised that the prominent north-south valleys of the area were the result of glacial scouring during the period of Permo-Carboniferous glaciation which has left such widespread traces in the sub-continent, especially since Rogers had, in 1906 (25) found the southern extension of these valleys were floored with Dwyka (Permo-Carboniferous) tillite, with shales and other remnants of the overlying Karroo beds. In his "Geology of South Africa." du Toit has surmised that the rounded forms of the Langeberg range is the result of glacial action, although no proof was available on the spot.

In 1937 Dr. B. Wasserstein of the Geological Survey suggested that the rounded forms of the Griquatown-Kuruman hills is an old glacial topography, especially owing to the presence of some fine U-shaped valleys which contrast somewhat strangely with the usual dry climate erosion forms. In the same year the writer found smoothed and potholed pavements on the boundary between the farms Bruce and Sishen at the northern extremity of the Gamara rand, just north of the Gamagara river. Early the following year these pavements were shown to Dr. S.H. Haughton,

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the director of the Geological Survey, who pronounced them to be of glacial origin. They are described and shown on plates in the Geological Survey explanation to Sheet 173, Oliphants Hoek, published in 1939. (34) During 1939 two more examples of similar pavements were discovered within the confines of the accompanying maps, one at the southern extremity of the Gamagara rand, (map G) and the other on the top of the hill immediately north of Manganore siding. (map K) The following relates only to these two latter occurrences, with minor references to others.

(B) The Traces of Glaciation.

Plate VI. Fig. 1. shows a local erratic of hard haematite lying in situ on a polished and potholed glacial floor of the same material. This floor is part of the original identified by Dr. Haughton as similar to sub-glacial floors in Switzerland. Somewhat ill-formed roches moutoneés at this locality indicate that the ice masses moved from north to south. This is in agreement with the general movement of the Permo-Carboniferous ice sheet in the central part of the subcontinent. About a mile south of the above occurrence a similar potholed pavement has been formed in aluminous Gamagara shales. (34)

At the southern end of the Gamagara rand on the farm Olynfontein is another potholed pavement in aluminous shales of the Gamagara series. Prehistoric man has utilised the smooth surfaces of this shale to chip out lively representations of wild animals, as well as peculiar patterns and signs.

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These must be very old, for this shale exhibits extraordinary resistance to weathering, and the drawings are in part crusted over with coatings of psilomelane.

An indication that after the stripping by erosion of the tillite in the intervening valleys, the valley bottoms have undergone little subsequent erosion, is provided by the presence of the haematite erratic figured in Plate VI. Fig. 2. This erratic lies midway between the Klipfontein hills and the Gamagara rand, and must have been carried many miles according to the direction followed by the ice. The erratic is of pure hard haematite and lies on dolomite. The widespread occurrence of these glacial floors, and the presence of such an erratic on the plain between the hills, suggests that the topography of to-day is essentially the same as that existing at the end of the period of ice erosion, before the valleys were filled and the hills buried by Karroo sediments. The cycle of post-Karroo erosion must be, therefore, relatively recent.

On Kapstewel, immediately north of Manganore siding, is a most instructive remnant of a glacial floor preserved in the shaly ferruginous quartzite of the Gamagara series. This rock is almost as hard to weather as the aluminous shales, owing to the high shaly content, thus accounting for its preservation from erosion. This floor has also been sheltered by the fact that it is placed in the slumped-in portion of the top of the hill.

The floor is exposed on the eastern side of the

bowl//.....

bowl of slumped-in Gamagara sediment capping the hill. The floor itself has sagged to a tilted saucer shape, the one side resting at a slope against the eastern rim of hard breccia. This case prooves conclusively that much of the slumping at any rate is post-Karroo, and may be late post-Karroo beds had first to be removed before sub-surface weathering could attack the underlying dolomite.

Grooves preserved on this floor indicate a movement of ice from north-north-east to south-south-west, and the adjacent U-shaped valley running in a northerly direction from Manganore, is therefore in all probability of glacial origin. In the light of the above, therefore, it seems probable that the isolated distribution of the Blinkklip breccia peaks, dotted about haphazardly along a wide arc, are in the nature of nunataks, around which the ice masses eroded their paths.

(C) Slumping--Its Extent and Probable Periods of Formation.

We have, as seen above, a definite clue as to the Geological period in which slumping of the relatively insoluble siliceous rocks into the far more soluble underlying dolomite has occurred. This must have been in relatively recent times when the removal of the Karroo beds allowed surface waters to renew their solvent activity on the dolomite.

Naturally such solvent activity could only occur during periods when the dolomite was exposed to erosion. It has been shown that in the geological history of this area, the dolomite was exposed to erosion during three widely separated periods of geological time.

Theoretically//....

Theoretically, then, there could have been three periods of slumping. These are.,

(a) During the pre-Matsap cycle of erosion, supposedly in late pre-Cambrian times.

(b) During the pre-Karroo cycle of erosion, in early Permian times.

(c) During the post-Karroo cycle of erosion, which may have commenced as early as the Cretaceous, but certainly extends into the present.

We have definite evidence of slumping during this third period, but in the nature of things, there is no evidence either way for slumping in the other two periods. All that can be said is that it is quite likely that slumping did occur during the first of the above periods, for the Gamagara rocks indicate a warm dry climate possibly similar to that existing to-day. That slumping occurred during the second period is doubtful, for it was cold and the land was ice-capped, conditions which may well have checked any sub-surface solution of the dolomite. The odds are therefore all in favour of the third period, during which most if not all the slumping effects seen at the present day occurred.

In addition to the remarkable evidence of slumping afforded by the breccia hills, where large masses of breccia capped by banded ironstones and Gamagara sediment have clearly subsided to depths exceeding 100 feet into the dolomite, (See sections 1.K., 2.K., and 3.K.) the manganese ore and basal beds of the Gamagara series along the Gamagara rand have everywhere been affected by the same process. This is most marked between

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Lace's Goat on Doornfontein and Bishop, on Map G., where the Gamagara rocks lie directly on the dolomite.

Wherever mining operations have been carried out, it has been found that the manganese lies on an extremely irregular surface. This is particularly well seen in the stretch of country mentioned above, where the breccias are absent, and the Gamagara rocks lie on the dolomite proper. Almost invariably quarrying has revealed that on following the ore zone down from the outcrop, the ore-body is seen to dip steeply downwards without regard to the bedding of the dolomite, in which rock it fills large pot-hole like cavities. Such potholes reach depths of 40 to 50 feet in places, and it is found that the overlying Gamagara shales and even quartzites have sagged in in sympathy with the underlying manganised grits.

As a rule, these potholes have very uneven sides and floors, irregular solution of the dolomite having left relics of this rock in the form of huge pinnacles, pillars and round pyramidal masses, between which the manganese ore has been found wedged in the company of masses of wad and chocolate coloured residual soil. Plate V. Fig. 1 illustrates this structure in a manganese quarry on the farm Gloucester. It should be mentioned that there is a distinct tendency for the best grades of manganese ore to be found adjacent to the dolomite, particularly in such deeply sunken areas.

The detailed mapping (map G) has shown that the manganese ore exposures, particularly on the farms Gloucester, Lohathla and Bishop, are composed of a maze of inter-

connecting//....

connecting or isolated lines of outcrop. This effect is produced by the wholesale slumping of a gently dipping sheet of manganese ore of variable thickness, and overlain by Gamagara beds. The result is that the anticlinal areas are shown by outcrops of the underlying dolomite, while the deeper synclinal areas are indicated by sagged-in masses of Gamagara shales and quartzite.

The manganese ore bodies in these series of depressions are subject to great variations in thickness and quality from place to place, and within short distances a variation is shown to a slightly lesser degree by the overlying zone of haematite ore and ferruginous shales and grits.

The distribution of these slumped-in areas is not entirely haphazard. They are generally aligned with their longer axes in a roughly north-south direction. This tendency to alignment is particularly marked on northern Lohathla and the adjoining portion of Bishop. Here, however, the direction of the long axes is generally west of north.

From this fact, it can be inferred that weak or shattered zones in the dolomite resulting from the post-Matsap earth movements, have been utilised by the solvent waters, causing this rough alignment of the slumped-in areas, the long axes of which are at right angles to the direction in which the tectonic forces acted. It may therefore be suggested that the date of this slumping also falls within the third period given above, because it must be post-Matsap, and owing to the capping

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of ice during the second period, it is unlikely to be pre-Karroo.

In the western belt, i.e. from Doornfontein to Bishop on map G., brecciation resulting from this slumping is practically non-existent. Slickensiding on the walls of the cavities is in evidence while cracking and distortion of the rocks is frequent, as a result of their having sagged down. Small areas of local brecciation, which may be the result of slumping, have been observed. In the eastern belt, i.e. on Map K., it is clear that the slumping has resulted in the jumbling together of large masses of uncemented/residual soil, chert and banded ironstone fragments together with cobble-like accumulations of manganese ore. The hard consolidated masses of siliceous and Blinkklip breccias have bodily sagged into the cavities, and show signs of cracking, distortion and renewed brecciation on a small scale.

Throughout the fields, I have found no convincing evidence to assign the formation of the masses of siliceous and Blinkklip breccias to the post-Karroo period of slumping, still less to any other period of slumping. The breccias were clearly in existence before the post-Karroo period of slumping, while the extent of brecciation due to the postulated pre-Matsap period of slumping is impossible of estimation. In my opinion such brecciation, if any, must have been slight, judging by the weak brecciating effect of the widespread post-Karroo slumping on both the western and eastern belts.

Nevertheless, it remains to be pointed out that

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the slumping has been on a grand scale, areas up to half a mile square having been affected, and the dolomite removed to depths exceeding 100 feet beneath the hard siliceous rocks. The grandest example is Klipfontein Kloof, at the back of the homestead. Assuming that the Gamagara rocks occupying the deepest part of the basin were in horizontal continuity, before the onset of slumping, with the portions now perched on the steep slopes and the rim, it is clear that the deepest portions have subsided a vertical distance of more than 200 feet; that is assuming that no subsidence around the rim itself has occurred. In the likely event of this having happened to some extent, the thickness of dolomite removed from below the centre of the basin must greatly exceed 200 feet.

The fact that so much dolomite has been removed, begs the question as to what has happened to the not inconsiderable manganese content of the rock removed. Nel (21) has calculated that 53.6 tons of dolomite would be required to furnish one ton of ore, since many analyses of dolomite from the region give a mean of 1.2% of MnO content. These facts throw some light on the problem of the source of the manganese composing the ore, and its mode and time of accumulation. These questions are discussed in Chapter VI. A.6. below.

CHAPTER VI.

The Ores.

(A) The Manganese Ores.

(1) General.

The manganese ores can readily be subdivided into two main types, both according to their appearance, texture and nature of impurities, and their distribution and gangue rock. The first type, conveniently called the ferruginous type, is closely associated with the Gamagara rocks, and is practically confined to the western belt. (Map G.) The second variety, conveniently called the siliceous type, is closely associated with the siliceous (chert) breccia and is found almost to the exclusion of the former type in the eastern belt. (Map K.) In addition, it is widely distributed at the northern and southern extremities of the Gamagara rand. The southern end only appears on map G. The northern end lies to the north of the farm Bishop. (See map, 34.) On Beeshoek the two types are mixed in a bewildering fashion, but are everywhere demarcated broadly on the maps, the former by black colouring, and the latter by black dot shading. Nel (21) in 1928, expressed essentially the same subdivision in his "more continuous manganese" and "less continuous manganese" respectively.

Both types of ore have outstanding physical qualities, being hard and of varying coarseness of crystallinity.

In addition they are brittle and fairly easily worked

and crushed to a convenient cobble size.

They//.......

They carry well, producing a negligible quantity of fines as waste. Their massive non-porous nature also results in great economy of space. Trucks loaded to the limit of their weight carrying capacity have, apparently, only a thin layer of ore covering their floors.

The vast bulk of the ore of both types is crystalline to a variable degree. Massive psilomelane occurs locally. In general the ferruginous type is the more coarsely crystalline, while the siliceous type is more finely crystalline, grading to massive, and exhibiting greater variations in texture.

It should be noted that tests for lead, arsenic, chromium, magnesium, titanium and copper were negative, or revealed mere traces, while nickel and cobalt could not be identified. (21. p.79.)

(2) The Ferruginous Type.

Originally designated by Nel (21) as "more continuous manganese" on his map, this type of ore is found to follow the base of the Gamagara series as if it were an interbedded sedimentary deposit. In fact it has been thought to be such by some observers. However, close investigation reveals that it is extremely irregular in shape, and may even be entirely absent locally. In contrast, large lens-like outcrops are encountered, presenting a nodular and botryoidal exterior. (See Plate IV. Fig. 3.) Such outcrops can yield quarry faces of ore exceeding 30 feet in height.

In the quarries, ore is seen to extend into and fill cavities in the dolomite along the footwall, while on //.

on the hanging wall, it is occasionally seen to transgress obliquely across the bedding of the overlying sediments, into which it often sends irregular fingers, or into which it grades with no definite junction between ore and rock. Its mode of occurrence presents many features indicating an origin by a process of metasomatic replacement.

There is, then, little doubt that this type of ore has been formed for the greater part by impregnation and replacement of the substance of the basal conglomerates, grits and shales along the base of the Gamagara series, and to a lesser extent, by accumulation in the ferruginous residual soil of, and cavities in, the underlying dolomite. (See sections, G. series.)

In consequence this type of ore is characterised by a generally high iron content in the form of haematite. This is present as duller streaks and knots of compact haematite, and in molecular combination with the constituent manganese minerals. On this latter account handcobbing is of very little avail in reducing the iron content. All gradations in composition are found, from about 5% Fe. to an iron ore containing some manganese, and finally pure iron ore. A solid ore containing about 5% Fe. usually contains about 50% Mn, but composes on the average, rather a small part of the whole. The lower grade varieties with a high Fe. content increase rapidly in quantity, especially in the higher portions of the ore bodies approaching the ferruginous zone. It must be remembered though that this is a general tendency. The ore bodies are always very

irregular//.....

irregular in manganese values.

The result of the presence of such widespread ferruginous content is to make the lower grade ore between the grades 12% Fe. and 44% Mn. and 25% Fe. and 25% Mn. available in tens of millions of tons. By contrast the ore of a grade of less than 10% Fe. and more than 45% Mn. is available in a few millions of tons, and has to be separated by careful hand sorting. The ore as a whole then may be classed as low grade. There is a distinct tendency for the Fe. ' Mn. content in the ore to total 50% to 60%, since these metals are present in complementary amounts.

It is significant that the highest grade ore is as a rule represented by the more or less bouldery masses, formed, as it seems, by accumulation in cavities and in the residual soil of the dolomite, where little replacement of rock substance occurred. The bulk of the ore, which represents the lower grade portion, has been formed by replacement of the material in the basal Gamagara beds.

Where this process of replacement has been complete, the form and nature of the original rock has been obliterated, resulting in a high grade homogeneous manganese ore, for the most part highly crystalline. For the most part, varying stages in the completion of this process have occurred, and where it has been so partial as to preserve the pebbles, grits, or shaly banding of the original rock, the ore becomes low grade and is more often than not, a highly ferruginous manganese ore.

During quarrying it is usually easy to distinguish good ore from bad or highly ferruginous ore by means of

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the following criteria;

Good Ore.	Ferruginous Ore.
Generally a bright lustre.	Generally a dull lustre.
Yields a black or dark chocolate powder.	Yields a light chocolate or reddish powder.
Generally homogeneous and crystalline.	Generally streaky, patchy, or dull and compact.
Usually brittle under the hammer.	Usually tough under the hammer.

In addition to haematite as an impurity, the ferruginous type of ore characteristically contains blades, vughs and streaks of rose-red diaspore crystals. This mineral is not of much consequence as an impurity. In fact patches of manganese ore containing diaspore, as a rule exhibit a great degree of elimination of other impurities, and are highly crystalline, usually yielding ore of a good grade. Another mineral of no importance as an impurity and occuring very sparingly in these ores is the "manganese mica" or ephesite, described by Coles-Phillips. (7) Barium is usually present, although in the ferruginous type of ore, seldom as visible barytes.

The following are representative analyses and assays of sorted dumps of this type of ore;

Table 4.

Locality.	Average of.	Metallic Mn. %	Metallic Fe. %	Total. %
Beeshoek	13 samples.	55.2	4.81	60.01
Doornfontein	7 samples	53.8	5.22	59.02
Paling	3 samples	51.8	6.85	58.65
Gloucester	17 samples	54.2	6.72	60.92

These assays indicate the nature of the high grade ferruginous type of ore as mined for export. The assays

are//......

are taken from 21. pp.73-77.

Table 5.

	1. %	2. %	3. %	4. %	5. %
MnO_2	49.20	22.45	42.7	51.2	42.9
MnO	30.47	9.9	6.5	9.55	32.35
Fe_2O_3	9.28	55.85	38.7	21.45	6.1
Al_2O_3	5.88	5.3	1.25	6.45	5.75
BaO	--	1.75	6.28	2.05	2.85
SiO_2	1.78	1.5	1.4	1.1	4.65
S	--	0.04	0.15	0.09	0.19
P_2O_5	0.45	0.15	0.10	0.15	0.10
H_2O^+	n.d.	2.0	0.95	2.85	2.65
H_2O -(CO_2)	3.0	0.60	0.40	0.90	0.40
Total	100.06	99.54	98.32	95.79	98.04
Metallic Mn.	54.69	21.85	32.02	39.75	52.16
Metallic Fe.	6.49	39.06	27.07	15.00	4.27
Metallic Mn Fe.	61.18	60.91	59.09	54.75	56.43

1. A sample of high crystalline ferruginous type of ore.

2., 3., and 4. Samples of various grades of ferruginous type of ore showing shaly parting.

5. Sample of high grade crystalline ferruginous type of ore containing diaspore crystals.

These analyses are taken from Nel, 21. pp.73-77. They illustrate rather well the tendency for the manganese and iron content to be present in complementary amounts.

The following new analyses have been carried out on samples collected by me;

Table 6.//......

Table 6.

	1. %	2. %	3. %
MnO_2	49.10	34.29	53.21
MnO	27.72	22.68	34.61
Fe_2O_3	7.03	21.72	5.75
Al_2O_3	7.31	12.58	2.33
SiO_2	3.87	5.58	1.12
H_2O +	1.40	1.14	0.79
Total	96.43	97.99	97.81

Analyst: C.J. Liebenberg, of the Division of Chemical Services, Pretoria.

In the light of the eight analyses given in tables 5 and 6 above, the average SiO_2, Al_2O_3, and Fe_2O_3 contents are 2.4%, 5.86%, and 20.64% respectively. They represent fair average samples of sorted dumps of the ferruginous type of ore. The proportions of the main impurities, i.e. silica, alumina and haematite, are as 1:2.2 :7.9 respectively. The marked preponderance of haematite as an impurity justifies the appellation "ferruginous type" to this ore.

(3) <u>The Siliceous Type.</u>

This ore has been formed for the greater part by impregnation and replacement of the substance of siliceous breccias which lie upon the dolomite. (See sections 1.K., 2.K., 3.K. 9.G., and 10.G.) It is significant that the most intense impregnation and consequently the richest and largest bodies of ore are encountered in the immediate vicinity of the dolomite, decreasing upwards

away//......

away from this rock. Plate III, Fig. 2 shows the manner in which this replacement has occurred. Ever widening veins of manganese oxides fill the cracks and interstices of the breccia, passing through a stage in which remnants of cherty material remain embedded in the ore, to solid ore.

The ore containing numerous remnants of cherty material presents a striking appearance, the white patches of chert contrasting strongly with the black matrix of ore. In the outcrop this rock has been named by the miners and prospectors "marker" rock, and sometimes "sausage ore." The latter term is more often applied to the similar looking ore from Beeshoek containing white blebby concretions of hyalite and chalcedony.

Apart from remnants of chert, this siliceous ore contains vughs and botryoidal growths of quartz, chalcedony and beautiful clear accumulations of hyalite. These no doubt represent portion of the silica removed in solution from the siliceous breccia and shaly gouge, and precipitated in shrinkage cavities resulting from the chemical alterations.

In the somewhat rare localities where the siliceous breccia is absent and the overlying Blinkklip breccia comes to rest on the dolomite, this rock in turn becomes manganised to a greater or lesser extent. The resultant ore is markedly more ferruginous than the usual siliceous type.

As in the western belt, much ore has been formed by accumulation in the masses of ferruginous soil and chert rubble resulting from the solution of the dolomite.

This//.......

This ore is as a rule of a high standard of purity and resembles in every respect the ore produced under the same circumstances on the western belt.

As a result of the mode of formation of this siliceous ore, the ore bodies are irregular and discontinuous in the extreme. Irregularly shaped masses of all sizes of good ore are to be found in the breccias, but distributed sporadically, and generally near the dolomite floor. Such bodies grade and finger into the brecciated siliceous host rock in the most bewildering fashion, resulting in all gradations of ore from masses of the highest purity to breccias merely fingered and veined with manganese. The result is that the most important impurity in the ore is represented by its inclusions of silica.

Because the silica rich areas are so easily visible on the black background of ore, it is possible to greatly improve the grade of ore by handcobbing. However, as a result of the widespread distribution of the silica inclusions a stage is rapidly reached where the cost of handcobbing becomes prohibitive, and thus vast quantities of manganese ore are discarded as worthless. Quarries in the siliceous breccia give, as a result, a low return of ore to the amount of rock quarried. On the average, production of a grade of say + 40% Mn. ore, produces approximately 5% to 10% of ore as compared to the 95% to 90% of rock and waste removed. Ore from the siliceous breccias attains, on the other hand, a considerably higher grade than that from the western belt, and in favourable localities mining operations have been handsomely repaid. Such is especially the case where

"bonanzas"//......

"bonanzas" or large bodies of pure ore are encountered. These bodies are usually pear shaped in general outline, being broad near the surface and tapering in depth. On one such large body up to 80,000 or more tons of 50% Mn. ore, or even more, can be found. Recently a large body of such high grade ore was discovered under unpromising cover in the siliceous breccias, which were admixed with contorted Gamagara shale, on the farm Pensfontein.

In further contrast to the ferruginous type of ore, the manganese ore bodies in the siliceous breccia do not readily betray their presence. They may be found anywhere within the areas marked by a dotted pattern on the maps G. and K. subject to the general rule that the best and biggest ore bodies show a prediliction for breccia intermixed with Gamagara shales, and a tendency to be found in close proximity to the dolomite. The latter rule is perhaps of more widespread applicability. Local miners lay great store by what they call "marker", which is an outcrop of manganiferous breccia. This rock often indicates the presence of bodies of pure ore.

The probable role played by the Gamagara shales in the breccias is discussed under section (6) below.

Another characteristic of the siliceous ores is that they form far less continuous bodies than do the ferruginous type ores. This fact is a natural consequence of the nature and distribution of the respective host rocks. The ferruginous ores originate in a bedded sedimentary deposit, which has the continuity of a bedded rock, and is restricted to a narrower zone than the

breccias//......

breccias, which are remarkable for their heterogeneous composition and variability of thickness.

The following representative analyses of the siliceous type of ore are given by Nel; (21.pp. 72-77.)

Table 7.

	1. %	2. %.	3. %	4. %	
MnO_2	70.30	73.15	54.35	n.d.	done as Mn.
MnO	7.30	13.50	35.25	n.d.	
Fe_2O_3	2.4	0.65	0.50	4.51	
Al_2O_3	0.60	0.15	nil	0.50	
BaO	16.19	3.88	0.35	n.d.	
SiO_2	0.30	5.00	6.60	8.56	
S	0.05	0.15	0.04	tr.	
P_2O_5	0.10	0.15	0.10	0.02	
H_2O	2.10	1.50	0.80	n.d.	
H_2O-	0.25	0.70	0.35	n.d.	
Total	99.59	98.83	98.34		
Metallic Mn.	50.08	56.68	61.64	55.40	
Metallic Fe.	1.68	0.46	0.35	3.14	
Metallic Mn.+Fe.	51.76	57.14	61.99	58.54	

In the above analyses the average SiO_2, Al_2O_3, and Fe_2O_3 contents are 5.11%, 0.31% and 2.01% respectively. They illustrate the type composition of the siliceous ores. The proportions of the main impurities, silica, alumina, and haematite, are as 1 : 0.06 : 0.4 respectively. This is a strong contrast to the proportions 1 : 2.2 : 7.9

respectively//....

respectively, in the case of the ferruginous type of ore.

A marked feature of the siliceous type of ore is the presence of barytes, sometimes in considerable quantities, as in analysis 1. above. Iron is always present as haematite, but in markedly smaller amounts than in the ferruginous type. The main impurity now is silica, while diaspore is conspicuous by its absence, and alumina is present only sparingly.

(4) Detrital Ores.

Detrital ore is found all along the eastern slopes of the Gamagara rand in the vicinity of outcrops. It is found lying on the dolomite, and, mixed with soil, filling the cavities and furrow-like depressions of the Karst surface, which presented an admirable structure to prevent the rapid dispersion of the fragments which break loose from the outcrops.

Some accumulations are extensive. For instance on southern Lohathla a great accumulation occurs in a longitudinal valley between two eminences capped by ore outcrops. Trenching revealed bouldery ore to a depth exceeding 10 feet, and approximately 90% of the rock removed consisted of manganese ore with more or less haematite mixed. (Plate V. Fig. 2.)

Many millions of tons of broken ore must occur in this fashion. However, in the western belt this ore is usually of a mediocre grade. At the large occurrence on Lohathla assays returned a fairly constant value of 38% to 40% Mn. and 18% to 20% Fe.

It is remarkable that on weathering, the haematite appears to be much more resistant than the manganese,

with//.....

with the result that haematite pebbles and fragments tend to increase in quantity further away from the outcrop.

On Doornfontein, ore of a high grade was obtained from a detrital deposit. The high grade may be due to the fact that at this locality the weathering of siliceous breccia contributed much of the ore.

In the eastern belt extensive deposits of detrital ore have been located west of the breccia hills on the lower hill slopes of dolomite, and the adjacent fringe of the dolomite plain. They are all situated on the farm Kapstewel. Unlike the similar ore on the western belt, manganese forms but a small proportion of the rubble littering the dolomite and filling the hollows in the Karst surface. Most of the rubble is composed of fragments of Blinkklip and siliceous breccias, haematite, and quartz. The manganese ore, however, is of a high grade. These eastern belt detrital deposits are much smaller than those on the western belt.

(5) The Mineragraphy of the Manganese Ores.

Since this thesis embodies the results of an intensive field study, which has been followed by similar field work elsewhere, it has unfortunately not been possible to add new mineralogical data on the composition of the ores. They have however been studied by Professor Schneiderhöhn (30), who recognises the following minerals: psilomelane, pyrolusite, polianite, sitaparite, braunite and manganite.

Concerning the relationship of sitaparite to braunite

and//.......

and haematite, he finds that in the Postmasburg ores sitaparite is younger than braunite, and grows idioblastically therein, the haematite included in the braunite largely disappearing in the process.

Judging by field specimens, the commonest manganese mineral is braunite, for ever and again fractured specimens of the crystalline ore, especially the coarser types which are often vuggy, exhibit pseudocubic crystals, which occasionally are seen to be tetragonal. Psilomelane is also commonly encountered, composing the major part of the massive non-crystalline ore. This sometimes exhibits a concentric banding or a botryoidal exterior. A peculiar type of vuggy psilomelane is pitted with wad filled cavities.

Manganite and sitaparite appear to be relatively scarce, although the invariable presence of iron even in the purest looking ore may be present in intergrown sitaparite. Pyrolusite and polianite are occasionally encountered as radial encrustations or masses, or as cavity fillings. Radial masses of these crystals up to 5 inches in length have been found. A fine specimen is in the possession of Mr. R. Brownrigg, chief chemist to the Associated Manganese Co.

On Kapstewel beautiful masses of radial polianite-pyrolusite crystals several pounds in weight have been found. On the northern part of map K. near the Klipfontein-Kapstewel boundary the writer found an area of siliceous breccia impregnated almost exclusively by silvery masses of polianite-pyrolusite crystals.

(6)////........

(6) The Origin, and Mode and Time of Deposition of the Manganese Ores.

The fact that the manganese ore is everywhere so closely associated with the dolomite, coupled with the fact that this rock invariably contains manganese in notable quantities, points to it as being the source of the metal, liberated by weathering.

In eleven analyses of the dolomites of Griqualand West, R.B. Young (40) found that the content of combined manganese and zinc oxides ranges between 0.42% and 2.0% In five analyses in a more recent paper (41) Young found that the manganese oxide content ranges between 0.5% and 2.1%. In 1927 Nel (21. p. 89.) found that the average manganese content of the dolomite from Doornfontein to Gloucester was 1.45%, expressed as metallic manganese. Hence we have as a source of the manganese a vast bulk of manganiferous rock which has undergone extensive surface and sub-aerial denudation during at least three periods of geological time.

Apart from its proximity to the dolomite, the ore is found to occur in two relatively porous zones of rock, which no doubt afforded a suitable venue for the oxidation and precipitation of the manganiferous solutions. These zones are;

(1) The ferruginous grits, conglomerates and shales at the base of the Gamagara series, permeable in themselves and unconformably overlying the dolomite.

(2) The siliceous breccias lying beneath the masses of Blinkklip breccia and banded ironstone, and forming an uneven contact with the dolomite, which was itself

probably//.....

probably much shattered. Manganisation of this rock resulted in the siliceous barytes-rich variety of ore.

Two additional factors which may have greatly aided the deposition and accumulation of the ore are the following:-

Firstly, the presence of such active mineralisers as chlorine and fluorine in the dolomite and in the Gamagara shales, as also in the matrix of shale in the grits and conglomerates. It has already been shown that where these shales are intermixed with the siliceous breccia, the largest and richest bodies of manganese ore have been found.

Secondly, the fact that the local drainage along the Gamagara rand runs across the bedding of the rocks from east to west, (See map G.) The waters carried by these drainages travel across a wide stretch of dolomite, and must be highly charged with manganese. In proof of this is the fact that on the calcareous tufa in such drainages, botryoidal encrustations of psilomelane have been found. On reaching the Gamagara rand, they have to pass over the upturned edges of the Gamagara rocks, which dip westward and are thus ideally placed to catch and absorb the manganiferous waters.

For this reason it is not necessary to postulate that all the manganese ore along the Gamagara rand resulted by accumulation of the manganese residue of the dolomite removed by sub-surface solution in situ. However, judging by the amount of sub-surface solution which has actually taken place, (Plate V. Fig. 1) much ore must have originated in this manner. It seems, though, that the main contribution came from the vast masses of dolomite weathered away from the adjacent plain.

The breccia hills, which are mostly situated at a high level along the local watershed, (map K.) could have had little such extraneous contribution. However, the brecciation of large masses of dolomite underlying the siliceous breccias must have readily released sufficient manganese to form the accumulations observed. Local migrations no doubt caused local concentrations of ore.

The chemistry of the process seems to be quite simple too. The manganese in the dolomite appears to be in the form of carbonate, (the mineral rhodochrosite) which is readily soluble in carbonated waters. Rain water is carbonated to a small extent by its passage through the air, and additionally so on making contact with the carbonate rich dolomite. The manganese carbonate in such solutions takes part in a reversible hydrolising reaction, while the hydroxide so formed is readily oxidised in contact with the air, especially when it permeates a porous medium and exposes a large surface of thin films of solution to the air. Under these conditions the reversible reaction moves continually forward, precipitating manganese, for on oxidation the manganese becomes relatively insoluble and precipitates out.

With regard to the physico-chemical reactions, the following observations are of great interest:

Tillmans (29) in 1914 determined the following reactions for iron and manganese bicarbonates -

(1)//......

(1) $2Fe(HCO_3)_2 + O + H_2O \rightarrow 2Fe(OH)_3 + 4CO_2$.

(2) $Mn(HCO_3)_2 + 2H_2O \rightarrow Mn(OH)_2 + 2H_2CO_3$.

Under oxidising conditions the $Mn(OH)_2$ readily loses water and relatively insoluble manganese oxides precipitate. Savage (29) found experimentally that,

(1) Manganese in primary distribution in rocks is taken into solution chiefly by the action of carbonated waters.

(2) Carbonated waters will take manganese carbonate and manganous oxides into solution, but the higher oxides of manganese are soluble only to a very slight degree.

De Witt (11) found that pockety occurrences of manganese ore in the Montreal mine, Wisconsin, originated in solution, oxidation and precipitation of manganese contained in disseminated rhodochrosite.

It seems then that at Postmasburg the following series of physico-chemical reactions resulted in the formation of the ore, aided no doubt by the precipitative action of pyrolusite (42) and possibly the unknown action of the mineralisers chlorine and fluorine. These are the probable reactions:

(1) H_2O (rain) + CO_2, $\rightarrow$ H_2CO_3.

(2) $2MnCO_3$ (rhodochrosite in dolomite) + $2H_2CO_3$. $\rightarrow$ $2MN(HCO_3)_2$. (soluble)

(3) $Mn(HCO_3)_2 + 2H_2O \rightarrow Mn(OH)_2 + 2H_2CO_3$.

(4) $2H_2CO_3 \rightarrow 2CO_2$ (dissipates) + $2H_2O$. (evaporates).

(5) $2Mn(OH)_2 + O_2 \rightarrow 2MnO_2$ (precipitates) + $2H_2O$, (evaporates).

In reaction (5) it is seen that under oxidising conditions, manganese dioxide precipitates out, and the

whole//......

whole series of reactions move forward. However, in practice the reactions are no doubt complicated by the presence of other radicles, during which a series of manganese oxides could precipitate out, combining with more or less of iron, silica, barium, etc. to form the complex and impure manganese ore minerals found in the field.

In studying the field relations, it is found that the manganese extensively replaces the silica of the breccias, and the iron oxides and silica, and even the alumina, of the Gamagara rocks. Probably concomitant with the precipitation of the manganese, the solutions dissolved corresponding amounts of these materials, the manganese thus gradually replacing them. Another factor which may have acted strongly as a precipitative agent, is the effect of pyrolusite on manganiferous waters, as observed by Zappfe (42) at Brainerd in Minnesota. The pyrolusite tends to precipitate out manganese even in very dilute solutions. Hence, when once manganese oxides, especially MnO_2, or pyrolusite, have collected in a favourable zone, the precipitating effect is cumulative.

As regards the time of the formation of the manganese, we can in the first place say that it is definitely post-Matsap, since the Gamagara, (Matsap) sediments are replaced, as well as the breccias, which have themselves been shown to be post-Matsap. In this connection it should be repeated that not a single fragment of detrital manganese ore or siliceous breccia has been found in the Gamagara conglomerates, indicating that

these//......

these rocks were non-existent in pre-Matsap times.

Considering that the process of oxidation must occur during a period of denudation, we have to consider the two post-Matsap periods of denudation, namely the pre- and post-Karroo intervals of erosion, as favourable periods of time. In view of the glaciation in pre-Karroo times, it seems unlikely that processes of oxidation could then have been active, hence we have to conclude that it is most likely that most, if not all, the manganisation took place in post-Karroo times. Vast masses of Karroo beds had first to be removed by erosion in this post-Karroo period, and the presence of remnants of Karroo beds not far to the south of the area, and even the preservation of local glaciated pavements, indicates that the last covering of rocks was but recently removed. The above evidence, therefore, indicates that the Postmasburg manganese ores may have been formed as late as the Cretaceous, or rather that their accumulation commenced as late as the Cretaceous, and that this process of accumulation is still proceeding.

An argument, indeed the chief argument, against the recent formation of the manganese ore is its crystallinity. Expression has been given to this view by Kaiser (18) who sees in this crystallinity long periods of metamorphism. Personally, I would rather believe the Geological field evidence, and would not lay much store by armchair theorising on scanty microscope evidence. I have seen every corner of the fields, and every quarry, while Kaisers acquaintance was re-

stricted//....

stricted, I believe, to a hurried series of views from a motorcar window.

With regard to the crystallinity of the ore, it is interesting to observe that in the Krugersdorp district of the Transvaal, post-Pleistocene manganese accumulations are every whit as crystalline as the Postmasburg ores. (Recent investigations by the writer.) In addition, the possible crystallising effect of the mineralisers chlorine and fluorine in the Postmasburg area must be considered.

(7) Rough Estimates of the Ore Reserves.

(a) Method of Estimation.

Owing to the extremely irregular and sporadic nature of the bodies of manganese ore throughout the fields, accurate estimations of tonnages are impossible.

However, the painstaking survey and close study of the greater part of the manganese fields has made it possible to obtain figures which will convey a credible impression of the extent of the manganese resources. The figures moreover, convey a relatively clear impression of the comparative values of the properties listed.

The most important parts of both the western and the eastern belts have been geologically surveyed on the large scale of 100 Cape roods = 1 inch, or 1/14875. These maps, together with the personal knowledge of the properties concerned gained during the mapping, forms the basis of the estimations.

On the western belt the actual extent of the manganese and more ferruginous manganese outcrops has been shown. For each locality the actual area covered by

the//......

the ore has been gauged by superimposing an accurately drawn grid of very small squares over the map on a tracing table, and counting the number covering outcrops. Each square has a side representing a length of 4 Cape roods, or about 12.8 yards, on the map.

The thickness of the ore-beds varies enormously within short distances, from massive ore bodies 30 or more feet thick, to less than a foot. Such thin extensions were not mapped, and are of very small extent. For purposes of estimation, a low arbitrary average thickness for each locality was taken, and the tonnage of manganese rock calculated according to the number of squares counted, taking 8 cubic feet per ton. The arbitrary thickness chosen for the ore bodies were adjusted according to the prevailing thicknesses noticed at those localities during the mapping.

Finally, the mining experience for each locality was taken into account in estimating the percentage saleable ore in the gross estimate of the amount of manganese rock.

Errors may have been made, firstly, in the drawing of the boundaries of the map, but these cannot be of great consequence, for the outcrops are well exposed in the field, and during mapping the plane table was set up every 100 to 200 yards to determine the exact positions of the boundaries. In complicated sections, even closer set-ups were made. Secondly, in counting squares errors may have crept in, but recounts over certain areas, yielded substantial agreement. Thirdly, the greatest

inaccuracies//......

inaccuracies could have been made by the necessarily arbitrary thicknesses chosen, but there is no alternative. The thicknesses chosen were moderate, and must represent a low average.

No allowance was made for detrital ore, of which there are considerable quantities, nor of probable ore extending locally beneath the shales and quartzites. Only exposed ore was taken account of.

On the eastern belt and the southern extremity of the western belt, where the ore occurs in a siliceous breccia, the exposed extent of this siliceous breccia was determined by the method of counting squares, and the tonnage calculated of only the lower highly manganised portion taken at an average of 20 feet thick. The actual thickness of the manganised portion is commonly 40 to 60 feet, and the entire breccia up to 150 feet. The manganisation however, is very sporadic. It is only the lower levels nearer the dolomite that are manganised sufficiently to be exploitable.

In the mediocre quarries on this type of rock, the yield of saleable ore to rock and low grade ore is in the region of 5% to 10%. This is more the rule than the exception; therefore 5% of the bulk of the manganised siliceous breccia is taken as saleable ore. Further, owing to the difficult nature of the mining in this rock, 25% of the saleable ore so calculated is taken as readily accessible.

No account was taken of detrital ore, of which there is a considerable quantity scattered along the lower slopes of the hills on Kapstewel.

On//.....

On the western belt the ore is practically all readily accessible except on southern Doornfontein and Beeshoek, where much overlying and intercalated shaly matter usually intervenes.

In conclusion, it should be mentioned that the distinction between "saleable" and "readily accessible" ore is made owing to the fact that the narrow margin of profit makes saleable ore, which is not readily accesible because of overburden, its scattered nature, depth in quarries etc., an uneconomic proposition.

It must not be thought that the listed tonnages cover all the ore present, for the certain local extension of the ore bodies beneath shales and quartzites on the western belt, and beneath Blinkklip breccia etc. on the eastern belt, represent reserves of ore, at present unexploitable, which may treble the above figures. Besides the properties listed below, there are outlying properties not appearing on the large scale maps, which no doubt hold a considerable tonnage of ore.

(b) The Estimates.

Table 8.

Tonnage Estimates.

Locality.	Tons of Manganese Rock. (F = ferruginous type) (S = siliceous type.)	Saleable ore. Approx. grades one to four.	Saleable and Readily accessible Ore.
BISHOP.			
(a) northern hill......	1,400,000	700,000	700,000
(b) east-central hill..	1,875,000	1,600,000	600,000
(c) near quartzites....	210,000	100,000	100,000
(d) north of beacon....	1,100,000	900,000	900,000
Total.......		3,200,000	1,300,000 F.

MOROKWA/.......

MOROKWA.

....	250,000	200,000	200,000 F/

LOHATHLA.

(a) north-eastern corner..	1,200,000	700,000	700,000
(b) hill to the south.....	900,000	400,000	400,000
(c) north of poort........	90,000	30,000	30,000
(d) eastern ridge, south Lohathla.......	2,450,000	1,500,000	1,500,000
(e) western ridge, south Lohathla.......	950,000	400,000	400,000
Total.........		3,030,000	3,030,000 F.

LOMOTENG.

(a) north-eastern corner..	750,000	550,000	550,000
(b) along Lohathla fence..	730,000	100,000	100,000
(c) north of road.........	280,000	30,000	30,000
(d) south of road.........	130,000	50,000	50,000
Total		730,000	730,000 F.

GLOUCESTER.

(a) hill cappings...	40,000	20,000	20,000
(b) north of loading plant......	4,000,000	2,800,000	2,800,000
(c) south of loading plant to southern boundary.	1,360,000	600,000	600,000
Total...........		3,420,000	3,420,000 E

JAPIES RUST.

760,000	400,000	400,000 F.

MARTHAS POORT.

850,000	450,000	450,000 F.

DRIEHOEKSPAN.

900,000	500,000	500,000 F.

PALING//.......

PALING.

(a) north of poort....	1,300,000	900,000	900,000
(b) south of poort....	1,400,000	950,000	950,000
Total......		1,850,000	1,850,000 F.

DOORNFONTEIN.

(a) north of Lace's Goat	570,000	250,000	250,000F.
(b) south of Lace's Goat	3,100,000	1,000,000	500,000 F.
(c) southern part of farm	28,500,000	1,400,000	500,000 S.
Total.....		2,650,000	1,250,000

BEESHOEK.

(a) ferruginous type	11,400,000	4,000,000	1,500,000 F.
(b) siliceous type	16,800,000	840,000	210,000 S.

DOORNPUT.

	8,900,000	440,000	110,000 S.

KAPSTEWEL.

(a) south-eastern corner	4,900,000	240,000	100,000
(b) east and south of siding.......	6,200,000	260,000	80,000
(c) north of siding	24,800,000	1,240,000	350,000
Total.......		1,740,000	530,000 S.

KLIPFONTEIN.

(a) hill in south-western corner......	8,400,000	420,000	110,000
(b) low hill with large boulder.......	6,200,000	310,000	80,000
(c) large hill behind the homestead.........	43,000,000	2,150,000	500,000
Total......		2,880,000	690,000 S.

RESUME.

Tonnage//.....

Tonnage of saleable and accessible ore of ferruginous type on the western belt from Bishop in the north to Beeshoek in the south..............	14,100,000 F.
Tonnage of saleable and accessible ore of the siliceous type on same portion of the western belt...........	710,000 S.
Total......	14,810,000 F.and S.
Tonnage of saleable and accessible ore of the siliceous type Doornput, Kapstewel and Klipfontein..........	1,330,000 S.
Total for area covered by large scale maps..................................	16,140,000 F.and S.
Total reserve of saleable ore probably available in the same area,...........	26,430,000 F.and S.

(B) The Iron Ores.

(1) General.

As in the case of the manganese ores, the iron ores can conveniently be divided into two groups, called, in accordance with the nature of their parent rocks, the "Blinkklip" type and the "Conglomeratic" type. The former has been formed directly by ferruginisation of the banded ironstones of the lower Griquatown series in the zones where these rocks have been brecciated or disturbed. The latter has been formed directly by the ferruginisation of the basal beds of the Gamagara series, comprising the coarse scree-like detritus, the conglomerates, the grits, as well as the shales of this series. For this reason the "Conglomeratic" type of ore can be subdivided into a conglomeratic variety and a shaly variety.

Because the ferruginous basal beds of the Gamagara

series//.....

series were derived by accumulation of the detritus yielded by the lower Griquatown banded ironstones by weathering, the latter rocks are the main source of the iron composing the iron ores of the region.

(2) The "Blinkklip" Type.

In the areas under consideration, this type of ore is sparsely represented. Scattered and isolated patches occur in the Klipfontein hills, (map K.) where the largest bodies are seen to outcrop on the western rims of the synclinal masses of Blinkklip breccia (grading into banded ironstone upwards, or unconformably overlain by Gamagara beds), capping the hills to the east and north of Manganore rail terminus.

Other bodies are found at the extremity of the Gamagara rand from Beeshoek southwards, underlying highly ferruginous grits and conglomerates. These bodies of ore are seen to be composed of brecciated and contorted banded ironstones, in which the chert bands have been completely replaced by haematite.

A fine outcrop to study when considering the relations between this older "Blinkklip" ore, and the younger "conglomeratic" ore overlying it in conformable manner, is afforded on the low east facing hillside in the longitudinal valley about half a mile north-east of Beeshoek village, immediately opposite the explosives magazine. (See map G.)

It should be noted in this connection that Wagners interpretation of the structure and origin of the rich haematite ores on Klipfontein, is erroneous. (36.pp.184-186. and Fig. 29.) He regarded them as lens-like concentrations dipping steeply westwards, in the banded ironstones.

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It must be mentioned that he gained this impression after studying the Crocodile river ores in the Transvaal, which are indeed such steeply dipping bodies in banded ironstones.

The "Blinkklip" type of ore is the true counterpart genetically and structurally, of the Crocodile river iron ores. The outcrops depicted by Wagner on Klipfontein, however, belong to the totally different "conglomeratic" type of ore. In fact, the "Blinkklip" type of ore is sparsely represented in the whole Postmasburg region, when compared to the plentitude of the "conglomeratic" ore. In magnitude and extent the Postmasburg "Blinkklip" ores, are not to be compared with the huge lenses, up to 130 feet thick, encountered in the Crocodile river area. (Recent unpublished report by the writer, compiled for the Geological Survey.) In the Postmasburg area, the aggregate tonnage of the "Blinkklip" ores total only a few million tons, as compared to the tens of millions of tons represented by the "conglomeratic" ores. (See table 14.) The largest concentration of the "Blinkklip" type of ore along the Gamagara rand occur in the extreme north of the belt, and are dealt with in a Geological Survey publication. (34.)

The following analyses of the "Blinkklip" type of ore indicate its richness:

Table 9.

	1.	2.	3.	4.
	%	%	%	%

Fe_2O_3//.......

Fe_2O_3	96.88	95.62	87.99	89.10
FeO	0.15	0.38	tr.	0.28
SiO_2	1.90	2.83	7.30	8.18
Al_2O_3	0.09	0.11	0.16	0.80
MnO_2	0.23	0.10	tr.	1.57
$CaCO_3$	0.05	0.10	2.68	0.16
$MgCO_3$	0.11	0.12	0.11	nil
TiO_2	nil	nil	nil	0.14
P_2O_5	0.122	0.139	0.016	0.09
As_2O_3	nil	nil	nil	nil
SO_2	0.012	0.045	0.005	n.d.
Cu	tr	nil	nil	n.d.
CO_2	tr	tr	1.74	n.d.
S	tr	tr	tr	n.d.
H_2O	0.45	0.47	0.73	0.40
H_2O-	0.04	0.06	tr	0.05
Total	100.03	99.97	100.23	100.77
Metallic Fe.	67.94%	67.24%	61.59%	62.52%
Sulphur	0.005%	0.018%	0.002%	n.d.
Phosphorus	0.053%	0.061%	0.007%	0.04%

Sample 1. is from Doornput (map K) and samples 2 and 3 from Kapstewel. (map K) The analyses were done for South African Manganese Ltd. by Messrs. Riley, Harbord and Law, London. Sample 4 is a manganiferous brecciated banded ironstone from the Klipfontein hills. Analyst, Dr. B.W. Marloth, Division of Chemical Services, Pretoria.

It will be noted how low in phosphorus and sulphur the ore is, and the virtual absence of manganese, except in sample 4, which lay adjacent to the dolomite, and

was//.....

was seen in the hand specimen to contain manganese. This latter ore is rare and unimportant.

(3) The "Conglomeratic" Type.

from

This ore, formed the basal rocks of the Gamagara series, grades in texture from coarse and sub-angular accumulations of banded ironstone detritus, through true conglomerates, grits, gritty shales and haematite shales, to soft aluminous shales rich in iron. The coarse conglomerate bodies yield the largest masses of ore.

(a) The Conglomerates.

Large and conspicuous masses of this rock are encountered at the northern and southern extremities of the Gamagara rand. The bodies on the southern portion appear conspicuously at Lace's Goat on Doornfontein, (map. G.) and attain their maximum in the enormous bodies on Beeshoek and Olynfontein. The ore bodies are massive and often form rounded cliff-like masses 30 or more feet high. As a rule they represent valuable deposits of high-grade ore.

As explained before, the pebbles and fragments in the conglomerate are almost exclusively formed from high grade haematite, non-ferruginous fragments being rare. It is probable that during deposition of this rock, a natural process of concentration of the iron was at work. The detritus from the underlying and adjacent banded ironstones was, apparently, largely a concentrate by weathering from the highly ferruginous portions of these rocks. By reason of its superior resistance to weathering and its high specific gravity,

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the hard rich haematite became concentrated in these coarse deposits in the vicinity of the parent rock, while the lighter non-ferruginous fragments weathered to smaller size, and were transported further afield.
A parallel to this process is afforded by the extensive "canga" scree deposits of haematite occurring in the state of Minas Geraes, in Brazil. (Leith and Harder. 43. pp. 670-686).

The matrix of the conglomerate is very subordinate in amount, and consists of ferruginous clayey matter and sandy material aligned parallel to the rude stratification of the rock. (Plate I. Fig. 1.) This matrix has in addition undergone secondary ferruginiation, and is shot with secondary intergrowths of specularite. (Plate VII. Fig. 1.) This greatly increases the total of iron present in the rock.

It is noteworthy that in the somewhat rare outcrops of these grits and conglomerates which are poor in iron, showing no sign of secondary enrichment, a scattering of pebbles of pure haematite are present amongst the siliceous pebbles of quartz, chert and jasper. This fact shows that extensive ferruginisation of the banded ironstones had taken place during the pre-Matsap period of erosion. The complete absence of pebbles or fragments of manganese ore in these conglomerates indicates that at that period the manganese ore had not yet been formed. The iron is therefore in part at least much older than the manganese.

The following analyses indicate the richness of the conglomerate ores:

Table 10//.....

Table 10.

	1. %	2. %	3. %
Fe_2O_3	97.74	97.42	89.43
FeO	nil	nil	nil
SiO_2	0.70	1.54	5.19
Al_2O_3	0.55	1.30	3.41
MnO_2	tr	tr	tr
$CaCO_3$	tr	tr	tr
$MgCO_3$	tr	tr	tr
TiO_2	nil	nil	nil
P_2O_5	0.27	nil	nil
H_2O	0.47	0.54	1.87
H_2O-	0.25	nil	0.10
Total	99.98	100.80	100.00
Metallic Fe	69.31%	68.10%	62.50%

Analyst: C.J. v.d. Walt, Division of Chemical Services, Pretoria.

The above samples are from the northern end of the Gamagara rand. The ore of this type encountered within the confines of maps G. and K. is of the same order of purity. Sample 3 in these analyses was apparently of lower grade because of the quantity of aluminous matrix, reflected in the high percentages of silica, alumina and combined water. Nevertheless, it is a high grade iron ore, owing to the quantity and richness of the pebbles of haematite.

It should be noted that manganese is virtually absent, owing to the fact that these samples were taken from ore bodies lying on banded ironstones. Where the transgression of these beds brings them to lie on the dolomite,//....

dolomite, as for instance from Lace's Goat on Doornfontein to beyond the northern confines of map G., various stages of manganisation can be observed. The manganisation is seen to have attacked the matrix first, and eventually even the haematite pebbles are more or less replaced by manganese, resulting in all grades of manganiferous iron ores.

(b) The Shales.

Ferruginised Gamagara shales represent some excellent high grade haematite ore, and a larger quantity of lower grade haematite ore, containing considerable alumina. The tonnage available, however, is much less than that represented by the often thick masses of conglomerate, because the shales are ferruginised in a more sporadic manner than the conglomerates, and the shale horizon is generally thinner.

At some localities, such as on Klipfontein (map K.) the Gamagara shales have been completely ferruginised, resulting in a massive laminated haematite often exhibiting intense puckerings. (Plate IV. fig. 2.) It is such a body of ferruginised shale occurring at the back of Klipfontein homestead which Wagner and Jourdan mistook for a steeply dipping lens of ferruginous banded ironstone. The occurrence in question is actually flat lying and represents the crest of the anticlinal fold occurring on the east side of Klipfontein hill. (Section 2. K.) Because of this habit, the ore body contains only a few thousand tons of ore, and nowhere near the estimate of Wagner of 2,400,000 long tons.(36.p.186.)

The//.....

The writer was himself misled for some time by this occurrence, until it was found that the body formed the crest of an anticline of Gamagara shales, and was seen to connect up with, and grade into, adjacent less ferruginous Gamagara shales and grits lying in an obviously unconformable manner on the lower Griquatown banded ironstones and their brecciated counterpart, the Blinkklip breccia. In addition, a close investigation revealed lens-like remnants and blebs of shaly matter in the ore itself. The presence of diaspore crystals in these "schlieren" of shaly matter showed it to be an altered Gamagara shale.

Although these Gamagara shales contained much iron originally, as shown by practically unaltered varieties, the intense ferruginisation observed is definitely post-Matsap in age. The original iron was probably, as in the case of the conglomerates, derived from the banded ironstones by erosion, in the form of ferruginous muds. The second period of ferruginisation must have been brought about in post-Matsap times by iron bearing waters, probably derived in large part by leaching of the shales elsewhere, thus explaining the intense loss of iron experienced by the pale aluminous portions of the shale horizon.

The puckering observed in the ore shown on Plate IV. Fig. 2., most likely occurred while the shale was still in its incompetent un-enriched form, and therefore its complete ferruginisation must be later than the post-Matsap deformations. It is likely that these deformations opened fissures and channels affording

easy//....

easy access to the shales by ferruginising solutions. In some cases no doubt, suitable geological structures were utilised, forming "saddle" reefs in anticlines, as seems to be the case with the ore body described by Wagner (36) from the kloof at the back of Klipfontein homestead.

The following analyses are given by Wagner (36.p. 186) of samples taken from this ore body. (N.B. The owner of the farm, Mr. Snyman, who accompanied Wagner, showed me where the samples were taken.)

Table 11.

	1. %	2. %	3. %	4. %
Metallic Fe.	66.85	65.10	68.50	69.10
SiO_2	2.60	3.70	1.30	0.90
TiO_2	tr	tr	tr	tr
P_2O_5	0.15	0.10	0.10	0.10
S	0.25	0.20	0.30	0.30

Analyst: J. Moir.

The ore is seen to be of excellent quality. Unfortunately the alumina was not determined, since this may have indicated the shaly origin of the ore.

The following are recent an analyses of the shaly haematite ore:

Table 12.

1.	2.	3.
%	%	%

Fe_2O_3//......

Fe_2O_3	98.87	38.52	71.72
FeO	nil	0.93	1.14
SiO_2	0.86	6.03	11.16
Al_2O_3	0.10	43.56	10.28
MnO_2	0.07	0.18	nil
$CaCO_3$	tr	0.23	0.12
$MgCO_3$	tr	nil	nil
TiO_2	nil	1.44	0.62
BaO	n.d.	nil	0.57
P_2O_5	nil	0.15	0.17
V_2O_5	nil	nil	nil
As_2O_3	nil	nil	nil
H_2O	0.41	8.10	4.29
H_2O-	nil	0.13	0.51
Total...	100.31	99.27	100.58
Metallic Fe.	67.82%	27.68%	51.09%

Analyst: Dr. B.W. Marloth, Division of Chemical Services Pretoria.

These three analyses are interesting since they show three stages in the ferruginisation of the shales. 1. represents the complete ferruginisation, the sample coming from Doornput, and similar to that illustrated on Plate IV. Fig. 2. 2. is a practically unaltered Gamagara shale from Lomoteng, and probably indicates the original composition of the shales, while 3. is a partially enriched shale also from Lomoteng. This sample was markedly pisolitic.

(4) The Siliceous Blinkklip Breccia.

This//...............

This rock must also be classed as an iron ore, for despite its relatively poor iron content, the small amount of deleterious constituents present, combined with the vast reserves of easily available ore of this nature adjacent to the railways, makes it of economic interest. Huge bouldery masses and cliffs of this rock lie scattered all over the area, (Plate I. Fig. 2.) and the reserves run into thousands of millions of tons. The rock as a whole appears to be richer in iron than the parent banded ironstone, for the breccia has been cemented by secondary haematite in the form of glistening specularite scales, as well as silica.

In 1937 bulk samples weighing 25 tons each were despatched to Germany for beneficiation tests, and the following analyses were carried out on samples of this material:

Table 13.

	1. %	2. %	3. %
Fe_2O_3	46.41	46.06	46.25
FeO	nil	tr	tr
SiO_2	52.31	51.41	51.65
Al_2O_3	1.00	tr	tr
MnO_2	0.67	1.68	0.92
$CaCO_3$	tr	0.17	0.11
$MgCO_3$	tr	1.11	0.92
TiO_2	nil	tr	tr
P_2O_5	nil	nil	nil
V_2O_5	nil	nil	nil
As_2O_3	nil	nil	nil
S	n.d.	0.01	0.17

H_2O //.....

H_2O	0.34	0.29	0.28
H_2O-	nil	tr	0.02
Total....	100.73	100.82	100.32
Metallic Fe	32.48%	32.24%	32.38%

Analyst: Dr. B.W. Marloth, Division of Chemical Services, Pretoria.

These analyses seem to show how remarkably constant in composition the Blinkklip breccia is. The samples analysed all come from the same portion of the hill immediately north of Manganore rail terminus. A further interesting point in these analyses is the constant presence of small amounts of manganese. It may be that this manganese is original, and that manganese leached out from the Blinkklip breccia added to the accumulation in the siliceous breccia below. There is no evidence in favour of this. On the other hand the manganese may represent an impregnation from ascending solutions from the dolomite, which deposited most of its manganese in the siliceous breccia en route. This explanation is the more likely, for the siliceous breccia immediately below the Blinkklip breccia at this locality is markedly manganised.

(5) The Detrital or Scree Deposits.

These deposits of iron ore are widespread, and represent a considerable tonnage of high grade ore. They are found covering the hill slopes and fringing the adjacent flats in the vicinity of ore outcrops, especially of the rich Blinkklip and shaly varieties, which are prominently placed and

disintegrate//.....

disintegrate readily by splitting, yielding masses of haematite rubble which are extraordinarily resistant to weathering. These scree deposits are always admixed with more or less chert and banded ironstone fragments. They are very irregular in nature, being shallow where the dolomite is near the surface, and thickening to 20 feet or more where the rubble has filled depressions in the dolomite.

This ore is of considerable economic value, both because of the extent and richness of the deposits, and because it can be so cheaply worked. If necessary production can be commenced on this kind of deposit without any development work. All that is necessary are picks and shovels and sorting of the rubble to be transported to rail.

(6) The Texture and Mineragraphy of the Ores.

The highgrade Blinkklip and shaly ores are composed of hard massive gray haematite interspersed with layers, lenses and nests of more coarsely crystalline specularite. On weathering these ores give rise to large cubical blocks tilted in all directions, the planes of parting being along the softer specularite layers, and along vertical joints. The splitting of the ore of these types on weathering will facilitate mining to a great extent, especially since these ore bodies are shallow, often being mere cappings, the whole ore body being exposed in most cases.

A further consequence of this splitting into blocks, is the production of large scree deposits, which can be very cheaply worked.

The//......

The lower grade shaly ores are interbedded in the Gamagara sediments, and closely follow their dip and strike. The haematite is contained in stars and clusters of specularite crystals dispersed in an unctuous mass of aluminous material and diaspore crystals. (Plate VII. Fig. 1.) In much of the shale however, the haematite is dispersed and imparts a brick red colour to the rock.

Mineralogically, the ores are very simple, being composed almost exclusively of haematite, which seems to be of two ages at least as in the Crocodile River ores. (36) The older generation of haematite is fine grained, hard and compact, and apparently represents the original haematite of the rock. The replaced chert or alumina is represented by the younger generation of haematite, which is composed of medium to coarsely crystalline specularite. Cavities are lined or filled with this mineral; in large cavities in a series of concentric layers, with occasionally a kernel or filling of pellucid white quartz or chalcedonic silica. This silica probably is locally precipitated from solutions which have leached it from its disseminated state in the rock.

There is very little magnetite in the ores, as the analyses show. Possibly the conditions accompanying the process of ferruginisation resulted in the oxidation of most of the magnetite, especially in such a magnetite-rich parent rock as banded ironstone.

The conglomerates form typically large massive bodies and outcrops which weather to a very different form, scaling and exfoliating to huge rounded boulders and

shapeless//......

shapeless masses. In this case much drilling and blasting will have to be resorted to in mining, since the rock is extremely tough and joints are few. However, advantage may be taken of the rude bedding in the rock, which is at places marked (Plate I. Fig.1) and will facilitate mining.

The iron is for the most part in the form of massive haematite, with to a lesser extent coarsely crystalline specularite, which apparently could not withstand weathering to the same extent as the massive variety. The pebbles have the same texture as the high grade Blinkklip and shaly kinds of ore, while the matrix has the texture of the crystalline diaspore-bearing shales, or the unctuous ferruginous shales.

(7) The Origin, and Mode and Time of Deposition of the Iron Ores.

In the previous sections it has been shown that a great deal of the iron ore was formed as early as the pre-Matsap cycle of erosion, while evidence of later ferruginisation is provided by the enrichment of the Blinkklip breccias and Gamagara conglomerates and shales. The period of this later ferruginisation is therefore post-Matsap, and subsequent to the era of deformation.

Wagner (36.p.187.) infers that there were several periods of haematitisation. Of the earliest and apparently most intense period, which seems to have been during the time of pre-Matsap erosion, he says, " -- it is to be presumed that that (period of haematitisation) which preceded the main brecciation was a result of the

convergence//.....

convergence into troughs and basins, formed by the solution of the underlying dolomite and initial slumping of the banded ironstones, of oxygenated iron-bearing surface waters, that dissolved silica and deposited haematite in its place. Subsequently, as a consequence of further solution of the dolomite, leading to renewed slumping and subsidence, the already-formed ore and associated banded ironstones were brecciated and the interspaces of the breccia filled with haematite."

The findings in the present work are in general agreement with this view, except that the main brecciation is ascribed to the post-Matsap tectonic movements, and the second period of slumping and ferruginisation is thought to have occurred during the post-Karroo cycle of erosion. That most of the formation of iron occurred in pre-Karroo times is shown by the fact that glacial floors and erratics have been formed on bodies of rich haematite of the "conglomeratic" type, and of blocks of ore plucked from these bodies. (Plate VI. Figs. 1. and 2.)

These facts all show that there were at least three periods of ferruginisation, namely, in pre-Matsap times, in pre-Karroo times, and in post-Karroo times. All three periods fall within cycles of erosion.

It is possible that the iron-bearing solutions emanated in part from the dolomite, since this rock is iron-bearing and easily soluble. In some localities, specularite is seen to have become deposited in cracks in the dolomite, and in manganese quarries lumps of specularite and haematite, pseudomorphous after limonite, are found

in//......

in the residual soil of the dolomite.

However, most of the ferruginisation seems to have taken place by selective leaching of the rocks of their siliceous and aluminous content, leaving the iron residue. Frequent shrinkage cracks and vuggy cavities filled by specularite or chalcedony and quartz, support this view.

(8) Rough Estimates of the Ore Reserves.

(a) Method of Estimation.

These were estimated according to the maps and general field observations in the same manner as the manganese ores, with the exception that the iron ores were estimated in bulk, and were not reduced by calculating according to a probable percentage in "Ferruginous" rock, as was necessitated by the scattered and intermixed nature of the manganiferous rocks.

The tonnage of the various iron ore bodies for each individual locality were calculated according to the approximate average thickness of the bodies for the local area. In all cases these thicknesses were reduced below the probable average to be on the safe side.

Little account was taken of probable and possible ore dipping away beneath cover. Only the outcrops as seen in the field were taken account of, and local extensions beneath isolated patches of Gamagara beds. In the case of the Blinkklip type of ore the figures must be essentially correct, for these ore bodies have little of their bulk hidden. In the case of the "conglomeratic" type of ore, there is the possibility that great reserves of ore hidden beneath cover exist,

over//.....

over and above the estimates, for such sedimentary bodies will continue for some distance down the dip of the beds.

The detrital iron ore, mainly scree deposits, was estimated by calculating the area they cover and multiplying by a low average figure representing solid haematite.

(b) The Estimates.

Included in the following are considerable quantities of the "conglomeratic" type of ore, which are more or less impregnated with manganese, an ore which is frequent along the Gamagara rand. Remarks are added as to the type and quality of the ore from each locality, and their situation and accessibility.

Table 14.

Note: In the following table under each farm heading are given:

(1) The approximate area of the outcrops in square feet.

(2) The approximate thickness of the ore bodies in feet.

(3) The estimated ore reserve calculated from these figures taking 8 cubic feet per ton.

(4) The type and quality of the ore, where C.C. = "Conglomeratic" type; C.S. = "Conglomeratic" type of the shaly variety, i.e. mainly shales; B = Blinkklip type; S = Screes; M = Manganiferous ore.

(5) Miles from rail and locality remarks.

A. Western Belt.

BISHOP.

(1)//......

(1)	(2)	(3)	(4)	(5)
560,000	5	350,000	C.C;M. good.	5 miles; in vicinity of Bishop beacon.
600,000	3	225,000	C.S;M. poor.	5 miles; nearer quartzites.

MOROKWA.

(1)	(2)	(3)	(4)	(5)
132,000	8	132,000	C.C;M. excellent.	5 miles.

LOMOTENG.

(1)	(2)	(3)	(4)	(5)
88,000	5	55,000	C.C;M. good.	1 to 4 miles. n.e. corner of farm.
1,200,000	3	450,000	C.S;M. poor.	1 to 4 miles. On western boundary.

LOHATHLA.

(1)	(2)	(3)	(4)	(5)
486,000	7	425,000	C.C;M. excellent.	4 miles. On north of farm.
270,000	3	100,000	C.S;M. poor.	Half mile. On south of farm.

GLOUCESTER.

(1)	(2)	(3)	(4)	(5)
345,000	4	172,000	C.C;M. good.	Half mile. North of branch line.
450,000	4	225,000	C.S;M. poor.	Half mile. West of branch line.
700,000	4	350,000	C.C;M. good.	1 mile. South of branch line.
225,000	2	56,000	C.S;M. poor.	1 mile. South of branch line.

JAPIES RUST.

(1)	(2)	(3)	(4)	(5)
150,000	3	56,000	C.S;M. poor.	1 mile. West of Gloucester mine.
370,000	6	270,000	B. excellent.	4 to 5 miles. On mountain and difficult of acess.
228,000	3	85,000	B. excellent.	Ditto.

MARTHAS POORT.

(1)	(2)	(3)	(4)	(5)
1,200,000	5	750,000	C.C;M. good.	1 mile. Occupying closed folds.

DRIEHOEKSPAN

(1)	(2)	(3)	(4)	(5)
950,000	6	712,000	C.C;M. excellent.	2 miles from Palingpan siding.

PALING.

(1)	(2)	(3)	(4)	(5)
2,320,000	6	1,740,000	C.C;M. good.	2 miles from Palingpan siding. On north of farm.
520,000	3	195,000	C.S;M. poor.	2 miles from Palingpan siding. On north of farm.
960,000	4	480,000	C.S;M. poor.	2 to 3 miles. South of Paling poort.
140,000	12	210,000	C.C. excellent.	2 to 3 miles. Low hill on dolomite flats on south-east of farm.

DOORNFONTEIN.

(1)	(2)	(3)	(4)	(5)
870,000	7	760,000	C.C;M. good.	0 to 1 mile from Lace's Goat rail.
130,000	8	130,000	C.C. excellent.	2 miles. Prominent hill on dolomite flats.
1,600,000	6	1,200,000	C.C;M. good.	Half mile east of rail, on south of farm.

BEESHOEK.

(1)	(2)	(3)	(4)	(5)
300,000	5	185,000	B. excellent.	1 mile. At beacon on south-east corner of farm.
2,815,000	10	3,500,000	C.C. excellent.	1 mile. On hill-slopes east of Beeshoek village.

330,000	4	165,000	B. excellent.	On reservoir hill half to 2 miles.
2,100,000	8	2,100,000	C.C;M. good.	On reservoir hill half to 2 miles.
3,500,000	10	5,200,000	C.C. excellent.	0 to 2 miles south of Beeshoek village.

OLYNFONTEIN.

(1)	(2)	(3)	(4)	(5)
1,750,000	10	2,170,000	C.C. excellent.	3 to 4 miles south of Beeshoek village.

B. Eastern Belt.

DOORNPUT.

(1)	(2)	(3)	(4)	(5)
21,000	8	21,000	C.C. excellent	On s.e. corner of farm, 3 miles from Manganore rail.
1,980,000	1	247,000	S. excellent.	On s.e. corner of farm, 3 miles from Manganore rail.
60,000	4	30,000	B. excellent.	Half a mile from rail on large hill s.e. of Manganore.
240,000	6	180,000	C.C. and CS. excellent	Ditto.
1,200,000	4	100,000	C.C. and CS. fair.	Ditto Under shale cover.
2,500,000	1	310,000	S. excellent.	On hill slopes, an average of half a mile from manganore.
210,000	4	105,000	C.C. and CS. fair.	Under covering of shale. Half a mile, on hill n. of siding.
135,000	4	67,000	C.C. excellent.	Half a mile. On hill north of siding.
800,000	1	100,000	S. excellent.	Screes around hill north of siding.

KLIPFONTEIN.

//........

(1)	(2)	(3)	(4)	(5)
210,000	5	130,000	C.C. excellent.	3 miles. On s.w. corner of farm.
5,950,000	1	746,000	S. excellent.	3 miles. Screes on s.w. corner of farm.
170,000	8	170,000	S. (lens) excellent.	1 mile. On hill behind homestead.
200,000	3	82,000	S. excellent.	4 miles around hill to siding. On hill behind home.
510,000	6	382,000	C.C. fair.	Ditto.
4,000,000	1	500,000	S. excellent.	Ditto Distance variable.
3,500,000	2	875,000	C.C. and C.S. fair.	1 mile direct to siding. On hill behind home. Ore beneath shale.

C. Resume. Western Belt.

Locality.	Pure Haematite Ore.	Good Manganiferous Ore.	Poor Manganiferous Ore.	Totals.
Bishop.	....	350,000	225,000	575,000
Morokwa	....	132,000	....	132,000
Lomoteng.	....	55,000	450,000	505,000
Lohathla	....	642,000	100,000	742,000
Gloucester	....	522,000	281,000	803,000
Japies Rust	....	....	56,000	411,000
Marthas Poort	....	750,000	....	750,000
Driehoekspan	....	712,000	....	712,000
Paling	210,000	1,740,000	675,000	2,625,000
Doornfontein	2,090,000	x	x	2,090,000
Beeshoek	11,150,000	x	x	11,150,000
Olynfontein	2,170,000	x	x	2,170,000
Totals.....	15,975,000	4,903,000	1,787,000	22,665,000

N.B. The above farms showing no pure haematite ore,

have//.....

have in fact small scattered pockets impossible to estimate. They are included in the second column.

* indicates the presence of highly ferruginous manganese.

D. Resume. Eastern Belt.

N.B. In the Eastern belt manganiferous iron ore is absent, but there are large scree deposits.

Locality.	Haematite in Outcrops.	Haematite Screes and under shales.	Totals.
Doornput	210,000	559,000	769,000
Kapstewel	483,000	862,000	1,345,000
Klipfontein	764,000	2,265,000	3,029,000
Totals......	1,457,000	3,686,000	5,143,000

We can summarise the above into the following; (The summary refers to iron ore only within the limits of the large scale maps.)

Total of pure haematite ore....... in outcrops..............	17,432,000	tons.
Total of pure haematite ore in screes and under shale.......	3,686,000	"
Total of good manganiferous ore...	4,903,000	"
Total of poor manganiferous ore...	1,787,000	"
Grand Total...	27,808,000	"

Before concluding it should be stated that the above estimates have been conservatively calculated, and the total may be doubled if the extension of the Gamagara beds down the dip beneath the covering of Gamagara quartzites be taken into account. The average thickness of the haematite scree deposits may also considerably exceed the one foot used as a basis of calculation.

CHAPTER VII.//......

CHAPTER VII.

Accessory Minerals and Structures.

(A) Minerals Accessory to the Mineralisation.

Mineralisation by metasomatic alteration has been so active in the area, that an interesting assemblage of accessory minerals has resulted. Most of these have been described before, but two new ones to the area have been identified and new data obtained on others, as shown below.

(1) Diaspore.

A rose-red variety of this mineral was found in the manganese ore, and was in the beginning mistaken for the manganese metasilicate, rhodonite. The mineral was first indentified as diaspore by Chudoba (6).

Two varieties are found on the manganese fields. The most striking variety is the rose-red sort associated with the manganese ore. In habit it is blade-like and is encountered in vuggy manganese ore of the ferruginous type, containing residual aluminous matter from the Gamagara beds. Blades of this diaspore one tenth of an inch thick, half an inch wide, and up to four inches long, are known.

The following are analyses of this rose-red manganese diaspore:

Table 15.

1.	2.	3.	4.
%	%	%	%

SiO_2//......

SiO_2	0.30	0.20	Nil	0.11
TiO_2	n.d.	tr	0.15	nil
Al_2O_3	83.99	84.85	84.00	78.58
Fe_2O_3	0.89	0.65	0.80	1.96
FeO	nd.	n.d.	n.d.	
MnO_2	n.d.	0.10	0.45	4.32(Mn_2O_3)
CaO	nil	tr	tr	tr
Cl	0.08	n.d.	n.d.	n.d.
F	nil	n.d.	n.d.	n.d.
H_2O	14.25	14.70	14.75	14.65
H_2O-		0.10	0.20	
Total....	99.51	100.70	100.95	99.62
Specific Grav.	n.d.	3.300	3.393	3.328

1. Recent analysis by C.J. Liebenberg, Division of Chemical Services, Pretoria. Sample from northern Doornfontein. 2,3 and 4, from (21. p. 80.)

The other variety of diaspore occurs scattered as stubby laths or rods in the altered Gamagara shales, occasionally occurring so thickly as to crowd out the matrix. Besides the different habit of these crystals, (Plate VIII. Fig. 1.) the colour in the hand specimens is also different, being a glistening greenish gray.

Two samples of diaspore shale containing coarse diaspore crystals, were gently crushed and centrifuged in heavy liquid to obtain reasonably pure samples of the gray diaspore crystals, and the white to greenish flaky matrix.

This material yielded the following analyses:

Table 16.

//.........

	1.		2.	
	Matrix. %	Crystals. %	Matrix. %	Crystals. %
SiO_2	51.74	2.14	62.22	7.74
Al_2O_3	37.42	80.63	30.64	74.01
Fe_2O_3	nil	0.89	nil	1.27
MgO	0.14	nil	0.20	nil
CaO	0.33	nil	0.16	nil
Na_2O	0.17	nil	0.26	nil
K_2O	0.01	nil	nil	nil
Cl	0.13	0.15	0.04	0.06
F	0.19	tr	tr	nil
CO_2	nil	nil	nil	nil
H_2O	9.21	14.38	4.85	13.20
Total....	98.84	98.19	98.37	96.28

Analyst: C.J. Liebenberg, Division of Chemical Services, Pretoria.
Fluorine determinations: Mr. Hamersma, Division of Chemical Services, Pretoria.

1. From 800 yards east of Lace's Goat, Doornfontein.
2. From the kloof behind homestead, Klipfontein.

The following analysis from Nel, (21.p.36.) was carried out on a sample from the same locality as sample 1. in table 15:

Table 17.

	%
SiO_2	1.00
TiO_2	0.30
Al_2O_3	82.80
Fe_2O_3	0.35
FeO	0.15
Cr_2O_3	0.40
H_2O	14.90
H_2O-	0.20
Total....	100 .10

Analysis//....

Analysis of diaspore from northern Doornfontein. (map G.)

The above analyses of diaspore all agree substantially in the essentials, in spite of the differences in colour and habit. It is noteworthy, however, that the purest diaspore is presented by the rose-red variety occurring in association with the manganese. The gray variety occurring in the aluminous shales shows higher silica values. The sample from Klipfontein is especially high in silica and low in water. The rock from which it was obtained showed signs of silicification, and it is likely therefore that silica may have replaced some of the water in the diaspore, which was harder than usual and had a more brilliant lustre.

The analyses are further interesting in that they show notable quantities of chlorine and even traces of fluorine. These diaspore samples come from some of the most intensely altered and re-crystallised shales in the area, and it is probable that these active elements in the rock largely aided the alterations. As mentioned before, these elements provide a clue which throws much light on the extensive manganese and iron mineralisation of the area.

Thin sections of diaspore from various localities were studied under the Federoff Universal stage. The crystals were seen to be all biaxial positive, with somewhat varying values for 2V. At some localities 2V tends to be generally lower than at others. The following are determinations of 2V carried out on coarse grained specimens:

<u>Table 18</u>.

Thin//......

Thin Section No.	Locality.	2V. Values.
L.B. 171	Lace's Goat, Doornfontein,	87°,88°,82°.
L.B. 174.	" " "	89°,86°,84°.
L.B. 175	Southern Doornfontein.	80°,74°,82°.
L.B. 213.	Klipfontein	76°,72°,70°.
L.B. 214	Klipfontein.	87°,82°,85°.
L.B. 217	Klipfontein	84°,82°,84°.
L.B. 216.	Klipfontein.	74°,72°,78°.

Average 2V for Doornfontein, 83.5°
Average 2V for Klipfontein, 78.8°

(2) Zunyite.

The rare mineral zunyite, a hydrous silicate of aluminium, is one of the chief mineral curiosities of the area. Nel, (21.p.37.) describes two localities where the mineral has been found, namely, the small knoll 800 yards east of Lace's Goat on Doornfontein, and in the kloof behind the homestead on Klipfontein. The writer discovered a third locality on Doornfontein, which is also a low knoll, but about 2 miles north-north-east of Lace's Goat, and about three quarters of a mile east of the railway line, where it makes a long straight run from Doornfontein to Paling.

At this locality diaspore is not so closely associated with the zunyite as at Lace's Goat. Perfect tetrahedrons of zunyite lie scattered in highly altered Gamagara shale, which is of a pale creamy to eggshell blue colour. Fresh crystals up to a millimetre in diameter are found, but specimens of decomposed shale near the surface contain casts of weathered zunyite crystals up to one centimetre across. It is likely that quarrying at this spot will reveal fresh crystals of this unusual size.

Belonging to the isometric system, the zunyite crystals are isotropic under the microscope, and have a refractive index by sodium light of 1.5996 or 1.5997. (22.p.220.)//....

(22.p.220.) The crystals are always idiomorphic with perfect 111 cleavages. (See Plate VIII. Fig.1.) The following includes an analysis from the Lace's Goat occurrence. (21.p.38.)

Table 19.

	1. %	2. %	3. %	4. %
SiO_2	24.33	24.11	24.11	29.10
Al_2O_3	57.88	57.20	57.68	54.25
Fe_2O_3	0.20	0.61	0.18	0.50
CaO	nil	0.11	nil	tr
MgO	nil	nil	nil	tr
Na_2O	0.24	0.48	0.31	tr
K_2O	0.10	nil	0.18	tr
Li_2O	tr	nil	nil	nil
F	5.61	5.81	5.19	0.80
Cl	2.91	2.62	2.90	2.45
P_2O_5	0.60	0.64	0.52	0.15
H_2O	10.89	11.12	11.12	13.45
H_2O-	nil	nil	nil	0.90
Deduct O_2 equivalent to Cl and F.	3.02	3.03	3.01	0.90

1. Mean of several partial analyses; Hillebrand, 1884.
2. Zunyite in altered porphyrite near Red Mountain, Ouray Co. Colorado.
3. Zunyite from Zuny mine, Colorado. B. Grossner, Neues Jahrb. Min. Abt. A. 1926.
4. Zunyite from Lace's Goat, Doornfontein, collected by Nel (21.p.38.) Analyst: Dr. J. McCrae.

Nel, (21.p.39) discusses the composition of the zunyite, and gives various formulae for the mineral.

The//.....

The analysis given in Table 1. in Chapter II. B.1. was carried out on a specimen of dolomite taken adjacent to the knoll of zunyite shales discovered by the writer on Doornfontein. It is instructive to note the presence of chlorine in this dolomite. In Italy large bauxitic deposits have accumulated by the collection in situ of the residual clays derived from the weathering of large masses of dolomite. It is most likely then that the Gamagara aluminous shales had a similar origin, and that chlorine, and to a lesser extent fluorine, held in the original dolomite, became concentrated in the shales and actively aided the metasomatic alterations observed. This concentration most likely occurred by means of the post-Matsap mineralising solutions, which dissolved the halogens from the dolomite. Furthermore, in pre-Matsap times, wide areas of the Ongeluk lavas were exposed to erosion. These would also yield aluminous and ferruginous clays, besides barytes and sulphates of other kinds, for the lavas are pyritic, and contain barium; vide the Blaauboskuil barytes deposit in the lavas south of Postmasburg.

(3) Pyrophyllite.

In the matrix of the diaspore shales, Nel recognised two intergrown minerals, one strongly and the other weakly refracting. (21.pp.36,37.)

For the former, he detected the following properties; Ng. 1.594, Ng-Np, large, z/c mostly straight.

In suitably coarse grained sections the writer made a number of optical observations by means of the Federoff universal stage, and found that the mineral is optically negative. 2V was found to vary from 45° to 60°,

with//...

with most of the values falling between 50° and 58°. These facts, combined with the analytical data on the matrix quoted in Table 16 above, lead to the conclusion that the mineral is pyrophyllite. (37. pt.2. p.371.) In a number of thin sections of the shales, especially of the highly aluminous varieties, it was seen that the matrix was largely composed of this mineral, the weakly refracting mineral being in subordinate amount.

(4) <u>Gibbsite</u>.

This mineral, seen by Nel to be weakly anisotropic, is intimately intergrown with the pyrophyllite in the matrix of the shales containing diaspore crystals. It occurs in the form of pale irregular scales. Nel determined the following properties:

Np. about 1.56, S.G. about 2.6., z/c. 0° to 12°. (21.pp.36-7.)

Under the Federoff universal stage, the writer found the mineral to be optically positive, with the majority of the 2V values falling in the neighbourhood of 0°, but values as high as 36° being obtained. The optic axial angle is therefore variable. In the frequent cases where it approaches 0°, it was seen that the optic axes approach and merge with the gamma or z direction, resulting in a large oval area of darkness.

The longer axis of the dark area, which lies in the plane of the optic axes, is roughly 25° in length and 12° in width. It can be seen therefore that the positions of the optic axes are not clearly defined, and in such cases the 2V can be set at any angle between 0° and 25°, if the dark areas were of equal density all

over//....

over the field. In practice however, it is seen that these areas have a spot of maximum darkness approximately at their centre, which must mark the position of the optic axis, and enables readings accurate to within 3° to be taken.

On the strength of the above properties, and the analyses of the matrix given in Table 16, the mineral appears to be gibbsite, $Al_2O_3.3H_2O$. (37.pt.2.p.48.)

In one thin section, aggregates of gibbsite flakes were seen to be pseudomorphous after diaspore. This change would be a simple matter of hydration of the diaspore, the formula of which is $Al_2O_3.H_2O$.

(5) <u>Ephesite</u>.

This mineral, called provisionally by Nel "manganiferous mica" (21.p.81.), is found sparingly in veins and cavities in the manganese ore of the western belt, in the same stretch of country in which the manganese or rose-red diaspore occurs. It has been found most frequently on Gloucester and the adjoining farm Japies Rust, (map G.) and occurs as pale pink aggregates. Often it lines vuggy cavities in the manganese ore in the form of beautiful little barrel shaped crystals up to 1 centimetre in diameter. During blasting operations pretty little pearly books of a delicate pink colour are broken loose.

The mineral has been identified and described by Coles- Phillips (7) who says, "Untwinned portions show an acute bisectrix interference figure, with Bxa nearly perpendicular to the cleavage plane, and a small axial angle. The plane of the optic axial angle is perpendicular to (010) of the hexagonal cleavage flake; optic//...

optic sign negative." ---- "2E for sodium light varied in six measurements from 42°32' to 43°8', with dispersion 2V red less than for 2V blue. The intimate lamellar twinning makes accurate determinations of the refractive indices somewhat difficult, but good results were finally obtained by the Kohlrausch total reflection method on a Hutchinson Universal instrument, using an artificially-polished plate (natural cleavage flakes were always too distorted to give sharp shadows).

Alpha = 1.595, beta = 1.625, gamma = 1.627, +- 0.002, whence gamma - alpha = 0.032, and 2V calculated = 28°32'.

The following analyses of ephesite are given:

Table 20.

	1. %	2. %
SiO_2	29.40	28.90
TiO_2	0.10	
Al_2O_3	50.60	
Fe_2O_3	0.55	51.60 ....Titania, alumina, and iron.
FeO	0.35	
CaO	1.40	n.d.
MgO	0.40	n.d.
MnO	0.10	n.d.
Na_2O	8.65	9.20
Li_2O	1.50	0.90
K_2O	tr	0.30
H_2O	5.30	n.d.
H_2O-	1.25	n.d.
F	0.20	n.d.
Total....	99.80	

1. Analysis by H.G. Weall, F.I.C. Govt. Chemical Lab. Johannesburg.

2.//.....

2. Partial analysis by Coles-Phillips.

(6) Barytes.

This mineral is found associated with the manganese throughout the fields. It is, however, comparatively rare in the ferruginous type of ore, but is common in the siliceous type, where it is occasionally so plentiful as to render the ore valueless as a manganese ore.

Rarely, large water-clear individuals are found, or intergrown masses, which yield beautiful cleavage fragments, as found on Pensfontein on a west facing slope of siliceous breccia. The mineral is not, however, found in quantities sufficient to be of economic value.

(7) Rutile.

In some samples of altered Gamagara shale from Beeshoek analyses revealed notable amounts of titanium. (See Table 2.) Under the microscope it was seen to be present as fine needles of rutile scattered between the diaspore crystals. No large concentrations of this mineral have been found. It is difficult to assign an origin for this titanium. It is possible that muds carrying titanium, and originating from the Ongeluk lavas by weathering, went to form part of the material composing the Gamagara shales.

(8) The Origin of the Accessory Minerals.

The origin of this group of accessory minerals found in the Gamagara rocks and manganese ore presents an interesting problem. Metamorphic effects on the rocks resulting from regional pressure could hardly produce the above mineral assemblage, while no definite effects of load metamorphism have been observed. The effects of thermal metamorphism are virtually absent in the area. Indeed, there are no large bodies of

intrusive//.....

intrusive rock exposed in the area which could have produced such effects on any appreciable scale. The few thin basic dykes have had a negligible effect on the country rock.

My view is that the explanation is to sought in the original composition of the shales, allied to the mineralising and crystallising effects of solutions carrying such active catalysing agents as chlorine and fluorine, shown to be present in the Gamagara rocks and the shales.

The whole process then, by which the valuable ore deposits have been formed, as well as the assemblage of accessory minerals, depends on the set of geological circumstances found in the area, aided and abetted by the mineralisers acting on rock types amenable to chemical alteration.

(B) Structures Accessory to the Mineralisation.

(1) Slumping.

Slumping can be regarded as a structure accessory to the mineralisation, for as explained in the foregoing, it is deduced that the solution of the dolomite has been caused by the mineralising solutions which deposited the manganese and the greater part of the later iron. The nature and extent of the slumping has already been described.

(2) Vughs and Shrinkage Cavities.

These are common in the manganese and iron ores, and are a natural consequence of the metasomatic replacement of the gangue rock by the ore material. Such replacement is considered to have proceeded by solution of the original material and deposition of the ore matter, molecule by molecule.

//....

Fossilisation of wood and bone etc. is considered to have proceeded in this manner, resulting in the almost perfect preservation of the fine structures of these materials. For instance, the banding of the original shale and banded ironstone is well preserved in the manganese and iron ores, except where subsequent crystallisation of the ore material has resulted in partially or wholly obliterating the structures. The extent of the obliteration naturally depends on the intensity of the crystallisation.

Since a molecule of manganese or of haematite weighs more, or rather occupies less space than, the original molecule of silica or of alumina, the mass tends to shrink with the progress of replacement, resulting in cavities and lens-like openings. These cavities and openings in turn afford an easier passage for the mineralising solutions, thus aiding and accelerating the process. Such cavities moreover afford additional spaces for the accumulation by a process of crustification and crystal growth, of more ore material. (See cavities in the ore, Plate III. Fig. 2.) It is in such cavities that growths of polianite-pyrolusite crystals occur, as well as fillings of hyalite and chalcedony.

(3) Additional Structures and Textures.

Another effect of the mineralisation is the production of "manganese marker" and "sausage ore" varieties of low grade manganese ore. These rocks have been described in the foregoing. Their texture may be summarised as "original cherty silica fragments enclosed in manganese ore" and "secondary

cherty//....

cherty, or chalcedonic silica and hyalite, enclosed in manganese ore" respectively.

The shales show in addition wide changes in texture, as well as composition, resulting from the mineralising activity. On the zunyite knoll on Doornfontein near Lace's Goat the shales have been altered to a peculiar crystalline grit, composed of a mass of interlocking diaspore crystals, averaging about 5 millimetres in length, in a scanty matrix of scaly pyrophyllite and gibbsite.

On southern Klipfontein a remarkable manganese rock was encountered, consisting of an even intergrowth of manganese ore and barytes. The superficial appearance is like that of a coarsely crystalline norite.

CHAPTER VIII.

Conclusion.

(A) Water Supplies in the Area.

Being a semi-arid area, supplies of open water are non-existent. However, supplies of fresh or potable water are almost everywhere obtainable in sufficient quantity for present demands. The strongest supplies of water are obtained in the lower lying valleys filled with sand and calcareous tufa, through which the underground drainage percolates. Such an area supplies the water for Beeshoek village. (map G.)

On the higher lying dolomite area underground water is scarcer, but supplies are obtainable by sinking wells or boring to intersect porous zones on or more usually adjacent to dolerite dykes, which act as underground barriers or channels, depending on the extent of weathering of the rock. (Chapter II. B.6.a.)

The supplies obtained in this manner are as a rule comparatively small and inconstant, consisting of local seepages. This difficulty is accentuated along the eastern mineralised fringe of the Gamagara rand, (See map G.) which follows the edge of a small scarp. Difficulty is therefore often experienced in supplying the local needs of the mines.

The following water supplies are available on the farms under review in this thesis:

Table 21.

On map K:

Farm//......

Farm.	Locality.	Nature of Hole.	Water Level.	Yield per diem in gals.	Type of pump.
Kapstewel.	Adjacent to Manganore siding.	Borehole	300'	7,000.	Petrol engine.
Klipfontein.	Near home on dyke.	Borehole.	80'	3,000.	Windpump.
	Next to dyke on south of farm.	Borehole.	150'	4,000.	Windpump.

Table 22.

On Map G:

Farm.	Locality.	Nature of Hole.	Water Level.	Yield per diem in glass.	Type of Pump.
Bishop	On east side of farm.	Well.	30'	5,000	hand pump.
	At homestead.	borehole.	100'	3,000	Windpump.
Lohathla	north	borehole.	100'	3,000	Windpump.
	south	well	60'	2,000	Windpump.
Gloucester	at old homestead.	well.	50'	2,000 or less.	handpump.
	near rail junction.	borehole.	130'.	5,000.	Windpump.
	South of mine.	borehole.	80'	6,000 to 20,000	petrol engine.
	on Beeshoek road.	borehole	120'	6000	oil engine.
	near the poort	borehole	150'	2,000 or less.	handpump.
Paling.	homestead on dyke	well	45'	3,000	windpump.
	homestead near poort	well	50'	1,500	windlass.
	north-west of poort	borehole.	60'	8,000	handpump.
Doornfontein.	old homestead on dyke.	well.	25'	5,000 or less.	windpump.

Beeshoek//....

Beeshoek.	northwest of village	borehole	100'	8,000	not in use
	south-west of village	borehole	110'	30,000	oil engine
	south-east of village.	borehole.	65'	15,000	oil engine.

These boreholes on Beeshoek yield the strongest supplies of water encountered on the fields. Their situation is low-lying and the holes pierced what is apparently Gamagara shales, deeply weathered.

(B) Summary and Acknowledgements.

Summary.

The area provides an absorbing geological and mineralogical study, and includes within its boundaries a wealth of features of scientific and economic interest probably unequalled elsewhere in an area of similar size. Thus, in spite of the number of investigations already carried out, there is still much room for scientific enquiry, and the preceding work is regarded as only another step forward in the accumulation of our knowledge.

Of scientific interest is the wealth of information appertaining to the formation of the various rocks, and the evolution of the complex geological structures and breccias during the post-Matsap orogeny and the effects of the Permo-Carboniferous glaciation. In addition, the origin, time and mode of deposition of the iron and manganese ores are of great interest, and their elucidation of economic value, while the study of the formation of the associated mineral assemblage, including the beautiful crystals of the rare mineral

zunyite,//.....

zunyite, is a study in itself.

Of economic interest are the large deposits of iron and manganese ores, which are of such basic importance in the nations industrial economy. To a lesser extent, the highly aluminous shales may yet prove to be of value as a source of aluminium, pending the discovery of a suitably cheap method of extraction.

In view of the many-sided appeal of the area to scientists, it must be stressed that there is much room for additional research along specialised lines. Unfortunately, in such a general survey as the above, this was not possible. For instance, much is to be learned about the chemistry of the mineralising processes, especially the role played by such elements as chlorine, fluorine and the sulphate radicle, an aspect which has been barely touched upon here. In addition there is the detailed mineralogy of the ores, as well as other aspects of the general problem.

Acknowledgements.

I gratefully wish to acknowledge the helpful discussions and suggestions of Proffessors L.C. de Villiers and B.V. Lombaard of the University of Pretoria, and the keen interest of Professor D.L. Scholtz of the University of Stellenbosch, whose enthusiasm in the subject prompted the undertaking of this work while he was still at Pretoria University.

Furthermore, I am grateful to my colleagues Drs. F.C. Truter and D.J.L. Visser for their helpful contributions and discussions, especially during the latter stages of my work, in the field while they were engaged

in//.....

in surveying neighbouring portions of the area.

To Mr. R. Brownrigg, of the Associated Manganese Co. of Postmasburg, I am indebted for the major part of the information in connection with the water supplies of the area.

My sincerest thanks are also due to the Director of the Geological Survey for permission to use the data embodied in this work, and to Messrs. Hopwood and Mauch of the Department of Irrigation for their valuable aid in the reproduction of the maps and sections, in the face of difficult wartime conditions.

Note:

It is regretted that the details of the relations between the manganese- and iron-rich zones of the Gamagara rand are not brought out in the copies of the map. These details, which are well exposed almost everywhere, appear on the original map, but could not be shown on the black and white reproductions.

Furthermore, the maps in their entirety, as well as the sections and diagrams, were done by hand by the writer without any professional aid, and forbearance must be asked for the draughtsmanship. In addition, all the photographs and plates of thin sections were taken, and most of them printed and enlarged, by the writer, and bear traces of amateurishness.

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BIBLIOGRAPHY.

(1) Baldry, R.A. "Slip Planes and Breccia Zones in the Tertiary Rocks of Peru." Quat. Journ. Geol. Soc. Lond. 1938.

(2) Boardman, L.G. "The Geology of the Manganese Deposits on Aucampsrust, Postmasburg." Trans. Geol. Soc. Sa. Afr. 1940.

(3) Burchell, W.J. "Travels in the Interior of Southern Africa." London. 1822.

(4) Cadell, H.M. "Experimental Researches in Mountain Building" Trans. Roy. Soc. Edinburgh. XXXV. 1890. pp. 337-357.

(5) Chamberlin, R.T. and Miller, W.Z. "Low Angle Faulting" Journ. Geol. 1918. XXVI.pp. 1-44.

(6) Chudoba, K. "Uber "Mangandiaspor" und Manganphyll von Postmasburg (Griqualand West, Sudafrika." Centralblatt f. Min. etc. Jahrg. 1929. Abt. A. No.1.p. 18.

(7) Coles-Phillips, F. "Ephesite (soda margarite) from the Postmasburg district, South Africa". Miner. Mag. March 1931. Vol. XXII. No. 132. pp.482-485.

(8) Cooper, J.R. "Geology of the Southern Half of the Bay of Islands Igneous Complex." Newfoundland Dept. Nat. Resources. Geol. Sec. Bull. No. 4.

(9) Dake, C.L. "The Hart Mountain Overthrust and Associated Structures in Park County, Wyoming." Journ. Geol. 1918. XXVI. pp.45-55.

(10) Dana, "Textbook of Mineralogy." John Wiley and Sons.

(11) de Witt, C.C. "Leaching Ore." U.S. Patent No.1,835,474. 1931.

(12) Dickey, R.M. "Manganese in the Montreal Mine, Montreal, Wisconsin." Ec. Geol. No.6. 1938. pp. 600-624.

(13) du Toit, A.L. "The Manganese Deposits of Postmasburg, South Africa." Econ. Geol. No. 28. 1933, pp.95-122.

(14) Emmons, W.H. "The Enrichment of Ore Deposits." U.S.G.S. 1917. Bull. 625. pp.437-443.

(15) Geikie, Jas. "Mountains, Their Origin, Growth and Decay." Oliver and Boyd, Edinburgh.

(16) Hall, A.L. "The Manganese Deposits near Postmasburg, West of Kimberley. " Trans. Geol. Soc. Sa. Afr. Vol. XXIX. 1926.

(17) Hayes, C.W. "The Overthrust Faults of the Southern Appalachians." Bull. Geol. Soc. Amer. II. 1891. pp. 141-154.

(18) Kaiser, E. "Zur Frage der Enstehung der Manganerzlagerstatten von Postmasburg in Griqualand West, Sudafrika." Neues Jahr. Min. Geol. Palaont. Beil. Bd. 64. 1931.pp. 727-738.

(19) Lahee, "Field Geology." McGraw Hill.

(20) Link, Theo. A. "En Echelon Folds and Arcuate Mountains." Journ. of Geol. Vol.36. pp. 526-238.

(21) Nel, L.T. "The Geology of the Postmasburg Manganese Deposits and the Surrounding Country." Geol. Surv. Pretoria, So. Afr. 1929. (Expl. Geol. Map.)

(22) Nel, L.T. "A New Occurrence of Zunyite near Postmasburg, South Africa." Miner. Mag. March 1931, Vol. XXII. No. 132.

(23) Norton, W.H. "A Classification of Breccias. " Journ. of Geol. XXV. 1917. pp. 160-194.

(24) Reynolds, S.H. Breccias." Geol. Mag. Vol. LXV. No. 765. pp. 97-107.

(25) Rogers, S.W. "Geological Survey of Parts of Bechuanaland and Griqualand West. Rep. Geol. Comm. Cape of Good Hope 1906.

(26) Rogers, A.W. "The Campbell Rand and Griquatown Series in Hay." Trans. Geol. Soc. So. Afr. Vol. IX. pp. 1-9. 1906.

(27) Rogers, A.W. "The Glacial Beds in the Griquatown Series", Rep. So. Afr. Assoc. for Adv. of Science. pp. 261-265. 1906

(28) Rogers, A.W. "Pioneers in South African Geology and Their Work." Trans. Geol. Soc. So. Afr. Annexure, Vol. XXXIX.

(29) Savage, W.S. "Solution Transportation and Precipitation of Manganese." Ec. Geol. May 1936.

(30) Schneiderhohn, "Mineralbestand und Gefuge der Manganerze von Postmasburg, Griqualand West, Sudafrika:" Neues Jahrb. f. Mineralogie. Beilage Band 64. Abt. A (Brauns-Festbuch) pp. 701-726. 1931.

(31) Schneiderhohn, and Ramdohr, "Lehrbuch der Erzmikroskopie." pp.572-274.1931.

(32) Stoces, B. and White, C.H. "Structural Geology." McMillan and Co. Ltd. Lond.

(33) Stow, G.W. "Geological Notes Upon Griqualand West." Quat. Journ. Geol. Soc. 1874.pp.651-53.

(34) Truter, F.C., Wasserstein, B.W. Botha, P.R., Visser, D.J., Boardman, L.G., and Paver, G.L. "The Geology and Mineral Deposits of the Oliphantshoek Area, Cape Province - Expl. Sheet 173, (Oliphantshoek.) Govt. Printer, Pretoria, So. Afr. 1939.

(35) Visser, D.J. - Doctorate Thesis, Univ. of Stellenbosch, So. Afr. 1939.

(36) Wagner, P.A. "The Iron Deposits of the Union of South Africa." Mem. Geol Surv. So.Afr. No. 26. 1928.

(37) Winchell, "Elements of Optical Mineralogy." John Wiley and Sons.

(38) Willis, B. and R. "Geologic Structures." McGraw Hill, 1934.

(39) Woolnough, W.G. "Origin of White Clays and Bauxite." Ec. Geol. Vol. 23. No. 8.

(40) Young, R.B. "The Calcareous Rocks of Griqualand West." Trans. Geol. Soc. So. Afr. Vol. IX.

(41) Young, R.B. "Pressure Phenomena in the Dolomitic Limestones of the Campbell Series in Griqualand West." Trans. Geol. Soc. So. Afr. Vol. XXXI. 1928.

(42) Zappfe, Carl. "Solution, Transportation and Precipitation of Manganese." Econ. Geol. Vol. 31. No. 3.

(43) Leith, C.K. and Harder, E.C. "Haematite Ores of Brazil and a Comparison with Haematite Ores of Lake Superior." Ec. Geol. VI. 1911. pp. 670-686.

PLATE. I.

Fig.1. Gamagara basal conglomerate on the farm King. The bedding is well shown. An assay from this outcrop yielded 95% Fe_2O_3.

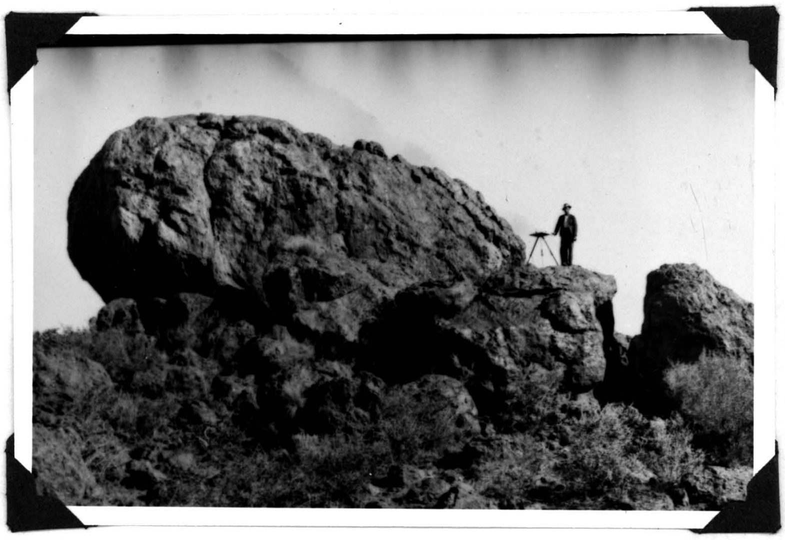

Fig.2. Outcrop of Blinkklip breccia on the Maremane Native Reserve; Shows the spheroidal weathering into granite-like tors.

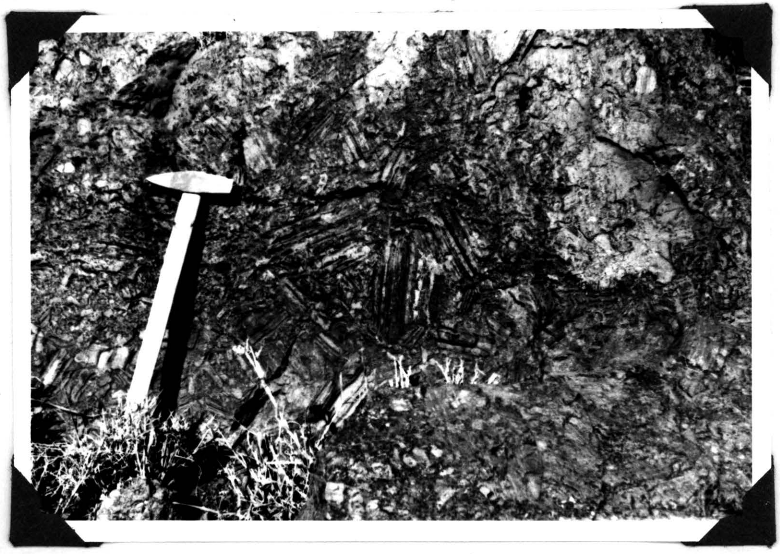

Fig.3. Close-up view of the Blinkklip breccia showing the heterogeneous size and disposition of the banded ironstone fragments.

PLATE. II.

Fig.1. Close-up of the siliceous breccia. Shows mainly chert fragments with a few banded ironstone chips. Note finer texture as compared with Blinkklip breccia.

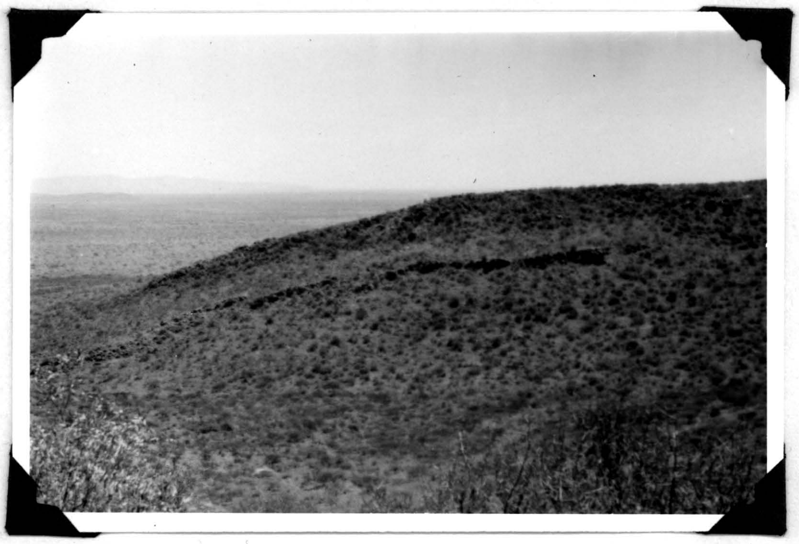

Fig.2. Plane of the Gamagara thrust dissected in a transverse gully on the s.e. corner of Lomoteng. The plane passes immediately above the narrow prominent ridge of Gamagara quartzites.

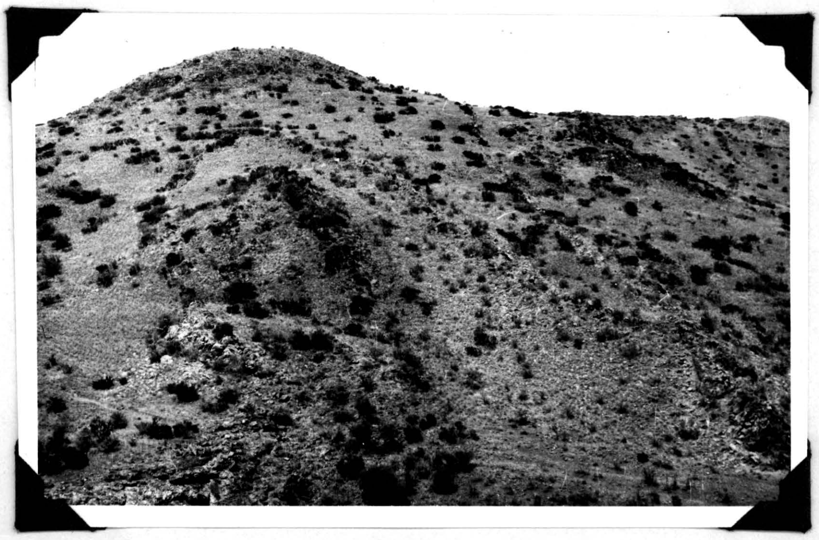

Fig.3. Overturned folds in Gamagara beds on s,e. corner of Marthas Poort. The axial plane is inclined to the east.

PLATE. III.

Fig.1. Weathered dolomite surface, with outstanding "sandstone dykes." From the plane of the Gamagara thrust on Paling.

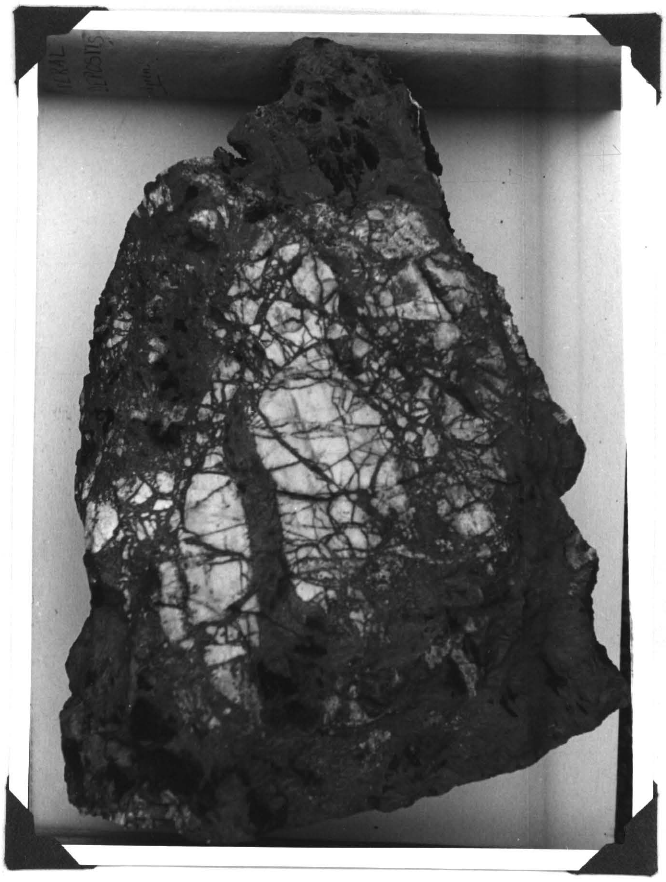

Fig.2. Chert breccia being replaced by manganese, forming "siliceous" type of ore.

PLATE. IV.

Fig.1. Slickensides in ferruginised Gamagagara grits. Small step-like breaks indicate the direction of movement, as shown by the arrow.

Fig.2. Contortions in ferruginised Gamagara shales on southern Klipfontein. An assay of this ore yielded about 98% Fe_2O_3.

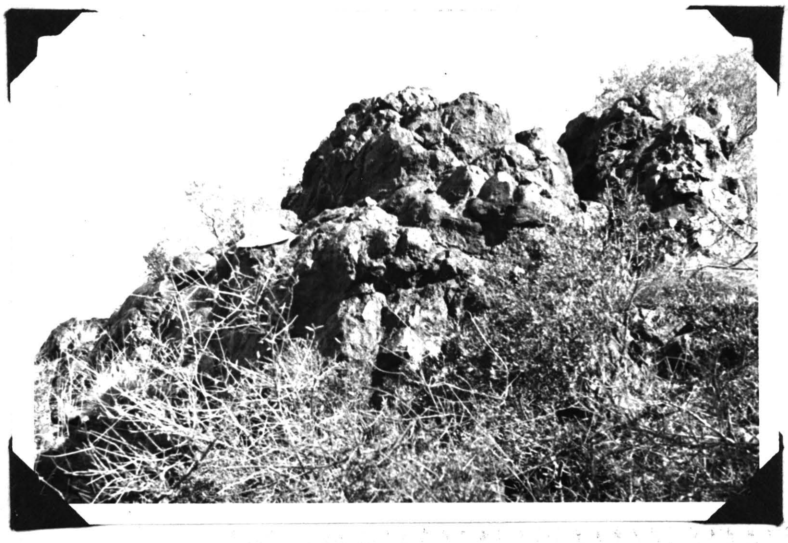

Fig.3. A massive outcrop of ferruginous type manganese ore on Lohathla north. The helmet indicates the size.

PLATE. V.

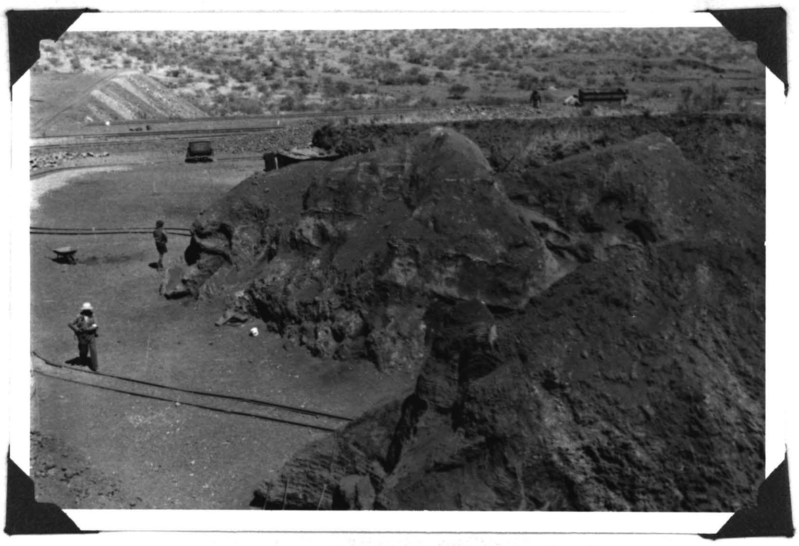

Fig.1. Ferruginous type manganese ore quarry on Gloucester, showing exposure of huge karst pillars of dolomite.

Fig.2. Trench in deposit of ferruginous type manganese ore on Lohathla south. Solid outcrops of ore occur up the slopes to the left of the picture.

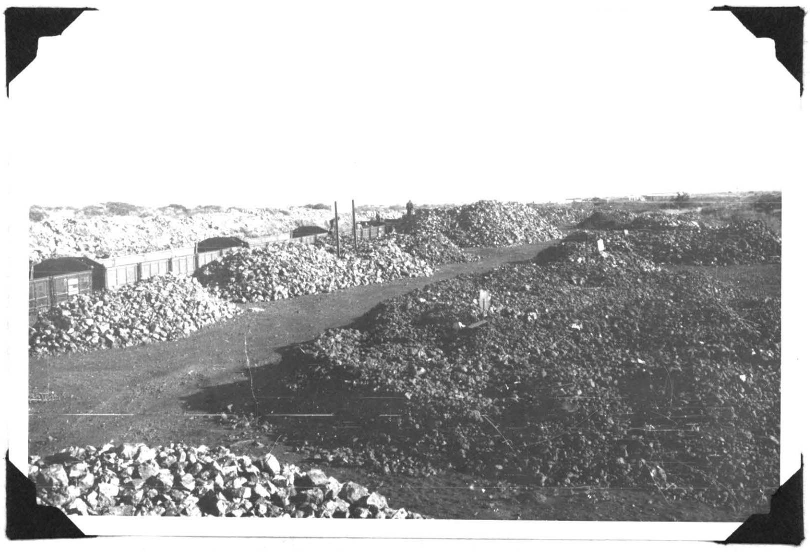

Fig.3. Piles of mined ore (coarse) and detrital ore (fine), both of the siliceous type, on Manganore siding.

PLATE. VI.

Fig.1. Erratic boulder of hard haematite, (ferruginised Gamagara grits) lying on the Permo-Carboniferous glacial pavement of the same material on the farm Sishen, north of the Gamagara river.

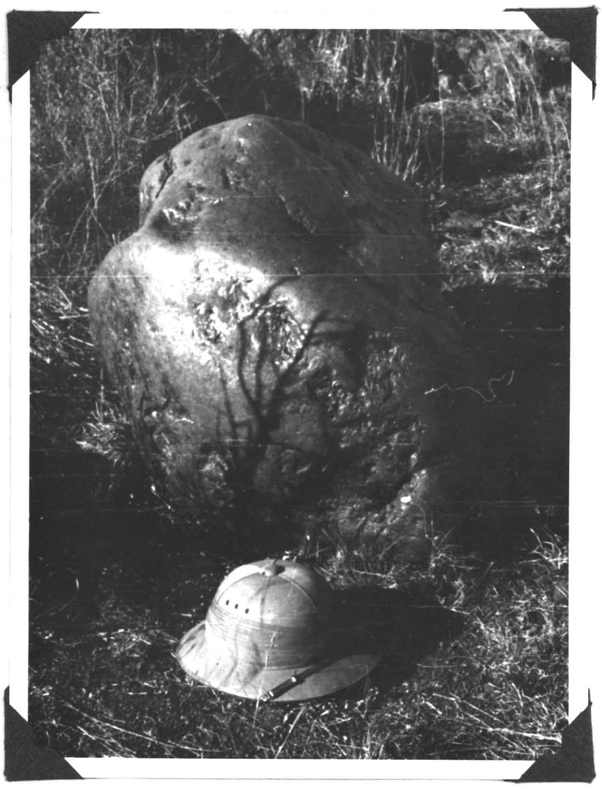

Fig.2. Erratic boulder of hard haematite, (ferruginised Gamagara shale) lying on dolomite 1 mile west of Manganore siding.

PLATE VII.

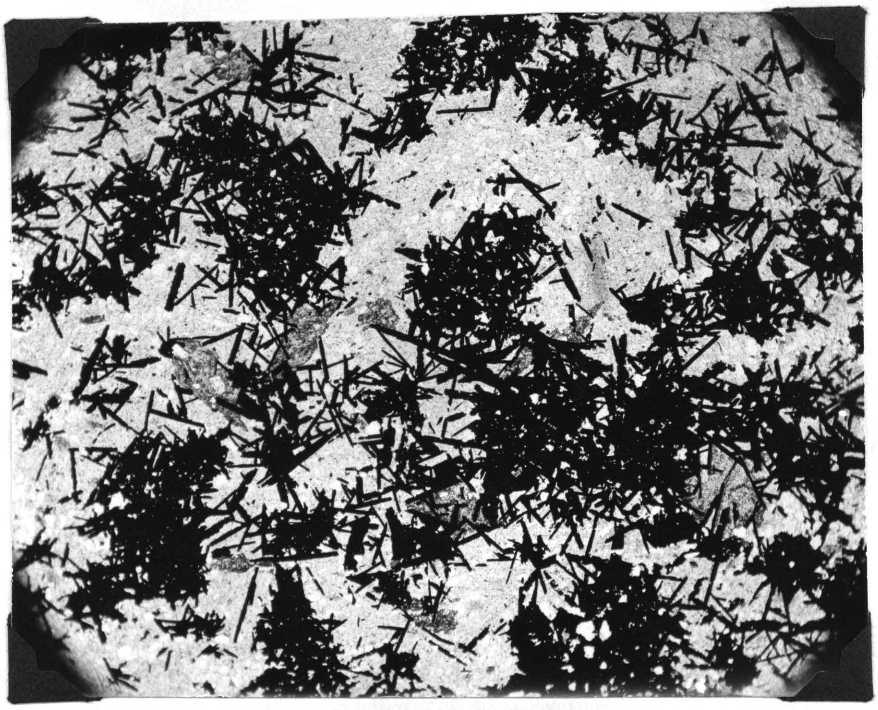

Fig.1. Thin section of a ferruginised Gamagara shale, showing stellate growth of needle-like haematite crystals (black) and a few diaspore crystals, (gray) in a fine-grained groundmass of pyrophyllite and gibbsite.

Fig.2. Thin section through a piece of ephesite rock, showing haphazard orientation of individual mica books. Ephesite was formerly termed "pink manganiferous mica" where found on the manganese fields.

X 32. ordinary light.

PLATE VIII.

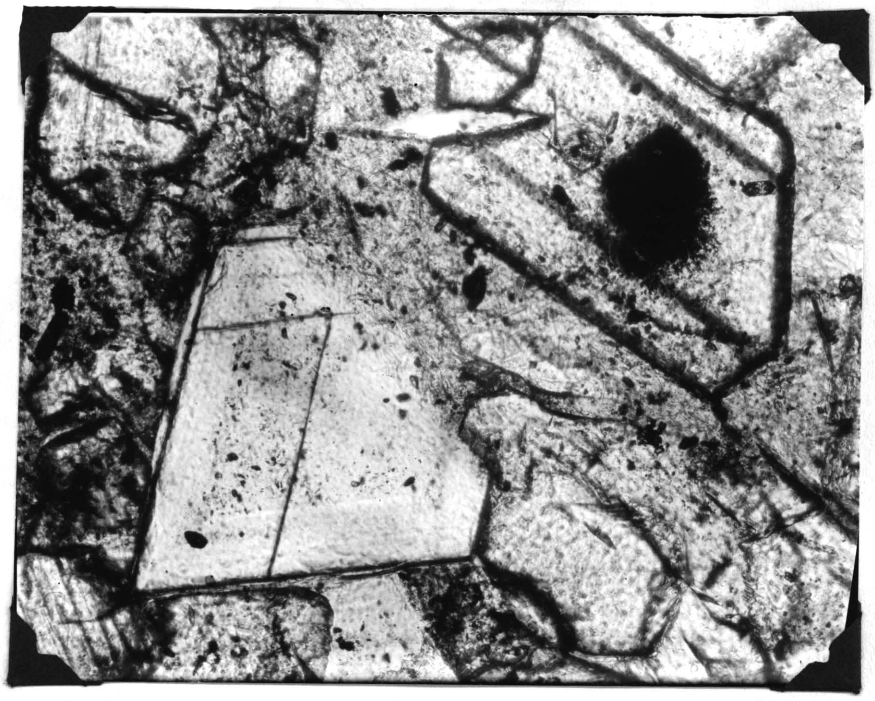

Fig.1. Section of a Gamagara shale from Doornfontein, showing (bottom left), a zoned tetrahedron of x zunyite with a marked cleavage and two corners truncated by the secondary tetrahedron. A well-formed diaspore crystal (top right) shows prism faces, a base and a dome. The shaly groundmass is an intergrowth of pyrophyllite and gibbsite.

X 360. ordinary light.

Fig.2. Shattered dolomite (fine-grained, dark) surrounded by rounded detrital quartz grains derived from overthrusted Gamagara quartzite. This sandstone dyke effect occurs on the plane of the Gamagara thrust on Paling.

X 32. ordinary light.

PLATE IX.

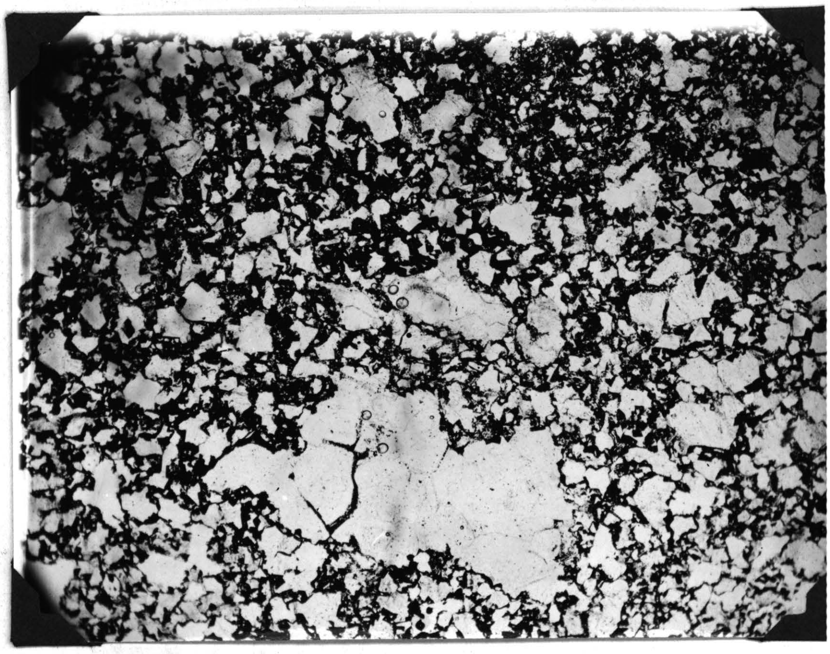

Fig.1. Mylonitised Gamagara quartzite from Mt. Huxley. This quartzite is found forming irregular sandstone dykes in the dolomite on the hillside below Mt. Huxley beacon.

X 80. Ordinary light.

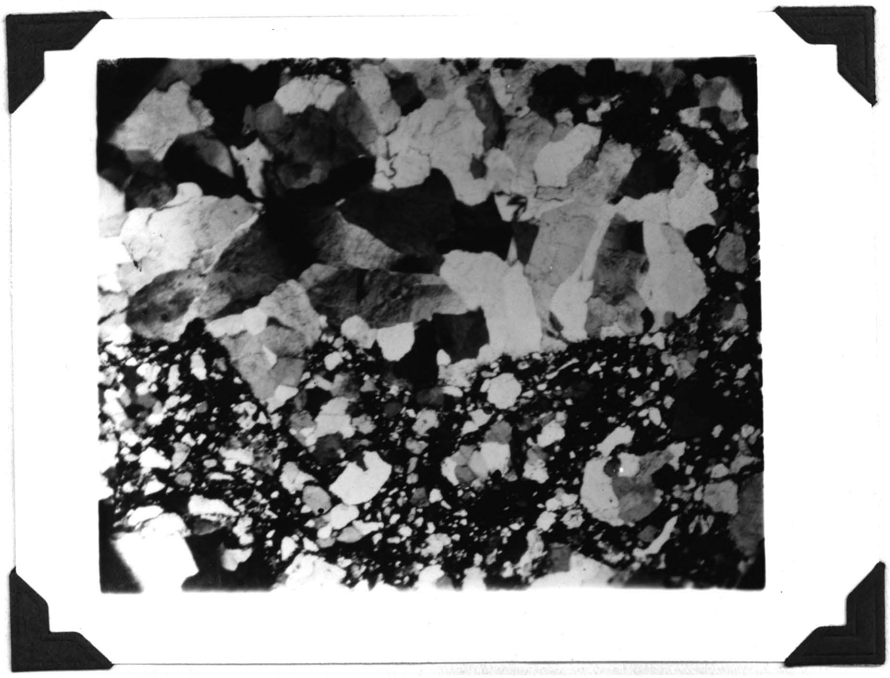

Fig.2. Mylonitised Gamagara quartzite from Aucampsrust, found approximately on the plane of thrusting. Note the deformed quartz grains with strain shadows passing into breccia and mylonite.