EXPLANATION: SHEET 2526 (1:250 000)
TOELIGTING : BLAD 2526 (1:250 000)

RUSTENBURG

GEOLOGICAL SURVEY
GEOLOGIESE OPNAME

REPUBLIC OF SOUTH AFRICA

REPUBLIEK VAN SUID-AFRIKA

Frontispiece

Magaliesberg Quartzite Formation indicating cliffs and dip slope of the Magaliesberg Range near Hartebeestpoort Dam with the downfaulted block of the Brits graben distinctly visible.

Voorbladfoto

Formasie Magaliesbergkwartsiet wat die kranse en bellingsglooiing van die Magaliesbergreeks naby Hartebeestpoort-dam aandui met die afgeskuifde blok van die Britsgraben duidelik waarneembaar.

Photo:
Foto : **F. Walraven**

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GEOLOGICAL SURVEY
GEOLOGIESE OPNAME

THE GEOLOGY OF THE RUSTENBURG AREA

by/deur

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Explanation of Sheet 2526
Toeligting van Blad 2526

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Abstract

The Rustenburg 1:250 000 geological map area 2526 is dominated by the igneous rocks of the Bushveld Complex (about 1 920 to 2 100 Ma old) and the sediments and volcanic rocks of the Transvaal Sequence. Older rocks occur in the map area namely, the granite-gneiss and greenstone of the Johannesburg dome together with the overlying rocks of the Dominion Group and the Witwatersrand and the Ventersdorp Supergroups. The Transvaal Sequence and the Bushveld Complex are closely associated in time and space, being largely confined to the Transvaal sedimentary basin. Younger rocks include intrusive dykes, sills and complexes of various ages and lithologies, and also the sediments of the Karoo Sequence and the more recent Quaternary and Tertiary deposits. The area is of great economic significance because of the presence of platinum-group metals and chrome.

Uittreksel

Die Rustenburg 1:250 000 geologiese kaartgebied 2526 word deur die stollingsgesteentes van die Kompleks Bosveld (ongeveer 1 920 tot 2 100 Ma oud) en die sedimente en vulkaniese gesteentes van die Opeenvolging Transvaal oorheers. Ouer gesteentes kom in die kaartgebied voor naamlik die granietgneis en groensteen van die Johannesburgkoepel tesame met die oorliggende gesteentes van die Groep Dominium en die Supergroepe Witwatersrand en Ventersdorp. Die Opeenvolging Transvaal en die Kompleks Bosveld is tydelik en ruimtelik nou geassosieer, deurdat hulle grotendeels tot die Transvaalse afsettingskom beperk is. Jonger gesteentes sluit intrusiewe gange, plate en komplekse van verskeie ouderdomme en litologieë in asook die sedimente van die Opeenvolging Karoo en die meer resente Kwaternêre en Tersiêre afsettings. Die gebied is van groot ekonomiese betekenis weens die teenwoordigheid van platinumgroepmetale en chroom.

1. INTRODUCTION

A large part of the Rustenburg 1:250 000 geological map area is occupied by rocks of the Transvaal Sequence, the Bushveld Complex and the Karoo Sequence; only a relatively small area in the south-eastern corner of the map is underlain by pre-Transvaal rocks. Quaternary to Recent surface deposits overlie these rocks in much of the area, especially in the northern and western parts.

To accommodate the different degrees of surface cover in various parts of the map area a number of different styles of representation are used on the map. In the south-central part the surface cover is relatively thin and sufficient information is available to enable solid geology to be shown. Surface cover becomes thicker towards the north and west but geological boundaries can still be determined with accuracy. Here the extent of the surface cover is shown in addition to the geological boundaries. In the north-west, surface cover becomes very thick and no attempt has been made to show the obscured geological boundaries, and only outcrops are shown.

The explanatory notes represent a synthesis of the notes of the individual workers who mapped the various portions of the area as outlined on the geological map. Previous work in the map area which has been consulted includes the map and the explanatory notes of the 1:125 000 geological map, Sheet 4, Rustenburg (Von Backström 1960) and the article and map published by Verwoerd (1963).

2. PRE-TRANSVAAL ROCKS

2.1 GRANITE-GNEISS AND GREENSTONE OF THE JOHANNESBURG DOME

Rocks older than the Transvaal Sequence are confined to the south-eastern corner of the 1:250 000 map area. In this region pre-Transvaal rocks are exposed on a structural high known as the Johannesburg dome. The oldest of these are Swazian in age. They are often highly metamorphosed and include quartz-sericite schist of uncertain igneous or sedimentary origin, biotite granite and gneiss, and altered layered differentiated ultrabasic and basic rocks interpreted as having been dunite, harzburgite, pyroxenite and gabbroic rocks. The latter occur as greenstone remnants within the acidic rocks. Detailed investigation of the granitic rocks by Anhaeusser (1971) has led to a distinction between gneissic and migmatitic rocks, homogeneous granitic rocks and granodioritic rocks. Anhaeusser envisages processes such as intrusion of granitic material coupled with assimilation of basic material together with incomplete metamorphism, anatexis and granitisation of basic to ultrabasic crustal material as having produced the observed rock types of which the greenstones represent resistant relics.

U-Pb age determinations on samples collected from the Johannesburg dome have until now produced only discordant ages; these are undoubtedly too low (Burger and Walraven 1978) but do, however, provide a minimum age of 2 585±65 Ma for the granodioritic rocks. Earlier determinations yielded a figure of 3 200±65 Ma (Allsopp 1961) on what are probably related rocks (Anhaeusser 1971).

2.2 DOMINION GROUP, WITWATERSRAND AND VENTERSDORP SUPERGROUPS

Overlying the granite-greenstone basement, but still pre-dating the Transvaal rocks, are the acid volcanics of the Dominion Group followed by the sedimentary rocks of the Witwatersrand Supergroup. The former are quartz porphyry (quartz phenocrysts in a matrix of quartz and sericite) and the latter include quartzite and shale with marker beds (the Contorted Bed, the speckled marker and the ripple-marked quartzite). The Witwatersrand rocks are in turn overlain by rocks belonging to the Ventersdorp succession. The progressive increase in the dip and the degree of deformation with the age of these rocks records the influence of the Johannesburg dome on their depositional and subsequent histories.

Correlation of the lowermost acid volcanic rocks with the Dominion Group is based on stratigraphic and structural as well as lithological evidence (Jansen 1977). The overlying Witwatersrand rocks form an outlier of the lower part of the succession outside the main Witwatersrand basin and represent the part of the succession from the Orange Grove Formation up to and including the Brixton Formation.

In the map area the Ventersdorp Supergroup, although generally volcanic, is represented by coarse clastic sediments, shaly sandstone, sandy shale, conglomerate, and boulder conglomerate, all of which have a sedimentary provenance. In the central part of the occurrence the sediments directly overlie the Swazian granite-gneiss and they are unconformably overlain by the Black Reef Formation in the west. Correlation of these rocks with the Ventersdorp Supergroup is largely based on the similarity of the clastic fragments in the sediments to those of the Witwatersrand rocks (Kynaston 1929).

3. TRANSVAAL SEQUENCE

The Transvaal Sequence includes all the sedimentary and volcanic rocks deposited in the Transvaal basin. Thus it contains the stratigraphic succession from the Wolkberg Group and the rocks correlated with it up to the volcanic rocks of the Rooiberg Group and the clastic sediments of the Loskop, Glentig and Rust de Winter Formations. Neither the lowermost nor the uppermost parts of the succession are found in the map area. The absence of rocks of the Wolkberg Group is probably the result of non-deposition, and the lowermost rocks of the Transvaal Sequence in the map area are those of the Black Reef Formation. The absence of the upper part of the Transvaal Sequence is probably due to non-deposition in the case of rocks that may be correlated with the Loskop, Glentig and Rust de Winter Formations and to erosion in the case of the Rooiberg Group.

The various rock units making up the Transvaal Sequence in the map area are relatively undeformed and they display the original basin shape rather well. There is good correlation between the Transvaal rocks in the map area and other parts of the Transvaal basin. The rocks of the Crocodile River fragment do not fit this pattern because they have a much more complicated structure and the stratigraphic succession is also incomplete. The Transvaal rock units will be dealt with first, followed by the description of the rocks of the Crocodile River fragment.

3.1 BLACK REEF FORMATION

This formation includes a basal pebble bed overlain by quartzite and shale, in places carbonaceous. It forms a belt surrounding and unconformably overlying the pre-Transvaal rocks of the Johannesburg dome. Eriksson and Truswell (1974) consider that the coarse clastic sediments represent reworked fluvial material and that the quartzite was deposited in a beach and near-shore environment. The overlying shales with intercalated dolomite are clearly marine in origin. At one location Black Reef sediments can be seen overlying Swazian basement rocks that have distinctly undergone subaerial weathering prior to the deposition of the sediments.

The Black Reef sediments are comparatively thin, ranging from 7 to 21 m in thickness, and appear to have been laid down on a gently warped depositional floor, probably related to continuing deformation of the Johannesburg dome.

3.2 CHUNIESPOORT GROUP

Following conformably on the Black Reef sediments is the Chuniespoort Group which is largely represented by dolomite, dolomitic limestone, chert, shale and quartzite of the Malmani Subgroup which is the only representative of this group in the south-eastern part of the map area.

In the south-western part of the area the Penge Formation overlies the Malmani Subgroup, but the Duitschland Formation, which forms the top of the Chuniespoort elsewhere, is absent. Although often obscured by soil the transition from the Black Reef to the dolomite is considered to be gradational and an arbitrary upper boundary of the Black Reef Formation has been taken at the disappearance of clastic sediments (Eriksson and Truswell 1974).

3.2.1 Malmani Subgroup

As is evident from the ripple marks as well as algal laminations in various parts of the Malmani succession, the dolomite represents sedimentation in shallow restricted basins on a marine platform. Although direct precipitation may have played a part, algae are regarded as the principal agent for concentrating the carbonate material (Button 1976, Wefer 1980). During this time the supply of clastic material to the basin was very limited and source areas of very subdued topography must be postulated. Alternations between zones of chert-poor and chert-rich dolomite in the Malmani Subgroup form the basis for its division into a number of formations. Although regarded in the past as a syngenetic colloidal precipitate (Toens 1966), the chert layers are at present considered to be secondary in origin and were formed during intermittent subaerial exposure cycles (Button 1976). Eriksson and Truswell (1974) recognise eight formations on the basis of the presence or absence of chert as well as stromatolitic assemblages and other primary structures, but the

South African Committee for Stratigraphy (SACS) accepts only five formations for the Malmani Subgroup.

In the eastern part of the map area the uppermost formation of the Malmani Subgroup, the Frisco Formation, is absent. This is considered to be a result of a local erosional unconformity although limited development through partial non-deposition may also be possible. Removal by erosion is implied by the presence of abundant erosional chert remnants in the lowermost formation (the Rooihoogte) of the Pretoria Group. Non-deposition is suggested by the fact that succeeding formations of the Chuniespoort Group are also absent. The uppermost formation, the Duitschland, is nowhere found in the map area and the formation immediately below the Duitschland, the Penge, is restricted to the western part of the map area.

In the western part of the area a complete succession of the Malmani Subgroup is present. Here the Frisco Formation is the uppermost unit of the subgroup and is overlain by the clastic and iron-rich chemical sediments of the Penge Formation. The Malmani dolomite is well-known for its caves and sinkholes. Numerous caves occur in the dolomite in the map area, in the upper as well as in the lower parts of the subgroup (Martini and Kavalieris 1978). Sinkholes have received much publicity during the last two decades, especially in the West Rand area where dewatering of mining compartments has taken place.

3.3 PRETORIA GROUP

Sedimentation in the Transvaal basin recommenced, after a period of non-deposition and erosion following the Chuniespoort Group, with the clastic sediments of the Rooihoogte Formation, the lowermost unit of the Pretoria Group. Following the Rooihoogte, sedimentation continued with alternating units of shale and arenaceous sediments with occasional disruptions by volcanic episodes. Four shale-quartzite cycles can be recognised in the Pretoria Group, which formed the basis for the earlier subdivision of the previous Pretoria Series into four stages. The names of the four stages, Smelterskop, Magaliesberg, Daspoort, and Timeball Hill, have been retained in the new lithostratigraphy for the quartzite units.

3.3.1 Rooihoogte Formation

The Rooihoogte Formation contains a large proportion of chert that was undoubtedly derived from the underlying dolomite-chert succession by residual concentration on eroded surfaces following subaerial exposure (Button 1968, Eriksson 1971). The chert of the Rooihoogte Formation is considered to be a response to regional uplift and is distributed basin-wide. It is also bound at its top by an unconformity but in this case it is not known whether it is an erosional or a non-depositional one. In the western part of the map area, shale forms an important constituent of the Rooihoogte Formation which also includes the Bevets Conglomerate[x] and the quartzite of the Polo Ground Member[x], both of which are more extensive than the shale of the Rooihoogte Formation.

3.3.2 Timeball Hill Formation

Immediately overlying the Rooihoogte Formation is the Timeball Hill Formation which is well developed throughout the area. This formation consists of an upper and a lower shale unit which are separated by a quartzite layer. The upper shale unit corresponds to what was formerly known as the Daspoort shale. This shale has been grouped with the Timeball Hill because in parts of the Transvaal basin the quartzites are not developed and consequently it is not possible to

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[x] Approved by SACS.

distinguish the upper from the lower shale. The lower portion of the quartzite unit is ferruginous and it is best developed in the western part of the map area.

3.3.3 Boshoek, Hekpoort Andesite and Dwaalheuwel Formations

Conformably overlying the upper shale member of the Timeball Hill Formation is a thin but persistent conglomerate-quartzite unit, the Boshoek Formation, which separates the shale from the volcanic rocks of the Hekpoort Andesite Formation. The latter overlies the Boshoek with a non-depositional unconformity. Tuffaceous and amygdaloidal horizons are interlayered between the andesite and basalt flows. Approximately 20 individual flows have been recognised in the total thickness of about 340 m of lavas and some agglomeratic and quartzite layers are locally developed.

Well-bedded and cross-bedded quartzite immediately overlying the volcanic rocks was formerly referred to as the upper member of the Ongeluk Stage (Von Backström 1960). Within the map area it was first recognised in 1977 during mapping done by the Geological Survey and is a westerly extension of the Dwaalheuwel Formation which overlies the Hekpoort Formation in the eastern Transvaal.

3.3.4 Strubenkop Shale, Daspoort Quartzite, Silverton Shale and Magaliesberg Quartzite Formations

In sequence, the Strubenkop Shale, Daspoort Quartzite, Silverton Shale and Magaliesberg Quartzite Formations follow concordantly on the Dwaalheuwel Formation. These rocks correspond to what was formerly known as the Daspoort and Magaliesberg Stages. The Strubenkop Shale is generally a siliceous and chloritic biotite shale containing andalusite. Iron-rich zones are developed within it, especially near the middle, and thin muscovite shale layers are found near the top. No chloritoid has been reported from either the Strubenkop Shale or the Silverton Shale.

In the map area the Daspoort Quartzite Formation, which includes some subordinate grey siltstone layers, is characterised by a medium-grained sugary texture. The Magaliesberg Quartzite is usually considerably coarser than the Daspoort in most parts of the area, a feature undoubtedly related to recrystallisation caused by the Bushveld Complex with which it is often in contact. Especially in the western part of the area three subdivisions can be recognised in the Silverton Shale Formation, that is a lower unit of andalusite-bearing shale, a thick middle unit of graphitic slate, and an upper unit of hard, fine- to medium-grained hornfels. The lower unit lies conformably on the underlying Daspoort Quartzite and is about 45 m thick. Locally spotted schist and thin layers of garnetiferous ironstone separate the shale from the Daspoort Quartzite. Underlying the Middle unit is in places a thin cherty quartzite which nowhere in the area exceeds 5 m in thickness. The approximately 160-m-thick graphitic slate of the middle unit is dark because of the extremely fine amorphous graphite occurring with the quartz and muscovite. The upper unit includes both amphibole and cordierite-biotite hornfels, the latter predominating. Towards the top of the hornfels intercalations of both massive, white sugary quartzite and agglomerate are locally developed. The stratigraphic position of the latter is the same as that of the Machadodorp Member of the Silverton Shale in the eastern Transvaal and a correlation between this and the agglomerate is possible (Clubley-Armstrong 1978).

Well-bedded recrystallised quartzite of the Magaliesberg Formation forms a most prominent escarpment across virtually the whole of the map area and conformably overlies the Silverton Shale. Some impure brown sandstone is interbedded with the quartzite towards its base. In the central and eastern parts of the area the Magaliesberg Formation forms the floor of the Bushveld Complex but in the western part hornfels and quartzite of the Rayton

Formation overlie and separate the Magaliesberg Quartzite from the Bushveld rocks. In this area the outcrop is exceedingly poor but apparently a large part of the Rayton Formation is included as xenolithic fragments in the basic Bushveld rocks.

3.4 ROOIBERG GROUP

Volcanic rocks of the Rooiberg Group occupy only a small part of the map area mainly to the north-west of the Crocodile River fragment. These rocks are a part of the penultimate stage of the filling of the Transvaal basin which ended with a phase of clastic sedimentation. These last sediments are not represented in the map area. The Rooiberg rocks include acid volcanic flows as well as pyroclastic rocks.

3.5 SUCCESSION IN THE CROCODILE RIVER FRAGMENT

As already noted the rocks of the Crocodile River fragment also form part of the Transvaal Sequence. There are, however, some notable differences between the stratigraphy of the rocks in this area and that in the remainder of the Transvaal basin. Furthermore the Crocodile River fragment is remarkable for its rather complex structure which differs from that of the Transvaal basin (Verwoerd 1963).

Two main stratigraphic differences can be noted. On the basis of the present state of knowledge, it is not possible to recognise the formations of the Malmani Subgroup in the dolomite of the Crocodile River fragment. Although chert is present in places no alternation of chert-rich and chert-poor layers similar to that seen elsewhere can be recognised here. Also the volcanic rocks of the Hekpoort Andesite Formation are not present in the Crocodile River fragment. Consequently the shales of the Timeball Hill Formation cannot be distinguished from those of the Strubenkop Shale Formation.

Although it is possible to correlate the remaining rock units in the fragment with those elsewhere in the Transvaal basin, it was considered advisable to coin new names for all the rock units in the Crocodile River fragment. Thus the succession here consists, from the base upwards, of the Assen Formation[x], correlated with the Malmani Subgroup; the Langrant Formation[x], correlated with the Penge Formation; the Rooisloot Formation[x], correlated with the Timeball Hill and the Strubenkop Formations, and the Ramakhatla and Makatane Formations[x], correlated with the Daspoort and Silverton Formations, respectively.

4. BUSHVELD COMPLEX

A very substantial hiatus in time separates the sedimentary and volcanic rocks of the Transvaal Sequence from the only other sedimentary succession in the map area, the Karoo Sequence. This time gap is partly filled by the igneous rocks of the Bushveld Complex. Three main rock groups have been recognised in the complex: the basic rocks, the granophyres and the granites and these form the basis for the present three-fold subdivision of the complex into the Rustenburg Layered Suite, the Rashoop Granophyre Suite, and the Lebowa Granite Suite, respectively.

The various rock units of the Bushveld Complex have a generally tabular shape and are more or less conformably overlying each other with the basic rocks at the base overlain by the granophyres and the granites. Some notable exceptions to the conformable relations are found in the map area, the most prominent being the transgressive relation of the Bierkraal Magnetite Gabbro with the underlying basic rocks immediately north of the Pilanesberg. Here the magnetite gabbro cuts down through the underlying basic rocks as far as the sedimentary floor rocks of the Pretoria Group. The intrusive nature of this relationship is demonstrated by the conformity of the

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[x] Not yet approved by SACS.

magnetitite layers with the base of the magnetite gabbro (Coertze 1974). Smaller scale discordant relations are found in many other localities in the area and are especially well exposed in mine workings.

In general the Bushveld Complex has intruded concordantly and at a level corresponding to that of the top of the Magaliesberg Quartzite. Exceptions are found in the western part of the map area where the complex is floored by rocks of the Rayton Formation and to the north and south of the Pilanesberg Complex where the basic rocks have intruded somewhat lower down.

Vermaak (1969) considers the transgressions to be related to structural adjustments associated with the basic sills pre-dating the Bushveld Complex.

As a consequence of its general concordant relation to the Transvaal strata, the acid rocks of the Bushveld Complex occupy its central part and are surrounded by arcuate belts of basic rocks in the east and west. A large part of the western belt is included in the map area. It extends from the Pilanesberg Complex both to the north and to the south-east to Rustenburg and beyond that eastwards to Pretoria outside the map area. For convenience these are referred to as the northern and the south-eastern belts, respectively. A prominent lobe of basic rocks extends also westwards from the Pilanesberg Complex.

4.1 RUSTENBURG LAYERED SUITE

There is little doubt that the layered structure of the basic rocks is the result of crystal accumulation at the base of the intrusion coupled with fractional crystallisation and it also seems quite evident that emplacement of the basic rocks took place in a series of pulses. Interpretation of the number of pulses and the nature of the intruding magma varies. Coertze (1974) proposes six pulses of differing composition, each derived under structural control from slightly different levels in the upper mantle by progressive partial zone melting. Von Gruenewaldt (1973) considers that there had been fewer pulses all of generally the same composition. At least two major breaks at which intrusion took place can be clearly recognised in the succession. One is between the Merensky reef at the top of the critical zone and the base of the Pyramid Gabbro-Norite, the other is within the Pyramid Gabbro-Norite, immediately above a zone of dark magnetite-bearing gabbro (Walraven and Wolmarans 1979).

Markgraaf (1976) similarly distinguishes two phases in the upper part of the succession on the basis of compositional trends and general petrography.

The rocks of the Rustenburg Layered Suite range from ultrabasic pyroxenites and anorthosites in the lower parts to norite, gabbro, and magnetite gabbro in the upper parts. A general trend of iron enrichment together with a decrease in the calcium content and other concomitant chemical changes from the bottom to the top can be seen. Breaks in these trends have been used as supporting evidence for the addition of magma pulses (Coertze 1974, p. 109).

In general the basic rocks of the Bushveld Complex are extensively developed in the central and eastern parts of the map area whereas only the lower part of the Rustenburg Suite is seen in the western part. Although one cannot be certain, it seem likely from considerations of the extent of the metamorphic aureole in the floor rocks that a greater development of the basic rocks existed at some earlier stage in the western part of the map area.

The Rustenburg Layered Suite comprises all the basic layered rocks of the Bushveld Complex and corresponds to all the rocks incorporated in the previous classification of zones.

The lowermost units are the Kolobeng Norite and the Ratsegae Norite[x] which extend throughout a large part of the map area. The former is considered to be part of the marginal zone whereas the Ratsegae Norite is grouped with the sills underlying the Bushveld Complex.

Overlying these formations are the Eerlyk, Makgope and Tweelaagte Bronzitites and the Groenfontein Harzburgite which are grouped into the lower zone and the Ruighoek Pyroxenite and the Mathlagame Norite-Anorthosite of the critical zone. These rocks are principally found in the central and eastern parts of the map area. The western part of the map area contains only marginal and lower-zone rocks and higher units are absent here. Biesheuvel (1969) regards the presence of lower-zone rocks in the far western part of the map area to be a result of folding.

Chromitite layers are developed in the rocks of the critical zone in the areas to the north and south-east of the Pilanesberg Complex as well as immediately to the west of it. Chromitite is also found in the lower-zone rocks but only in the far western part of the map area. The chromitite layers in the critical zone are grouped into the upper, middle, and lower chromitite (usually referred to as the UG, MG, and LG, respectively).

The main zone in the map area consists only of the Pyramid Gabbro-Norite and covers large areas to the south- and north-east of the Pilanesberg Complex. The gabbro-norite extends further eastwards than the underlying basic units and appears to be generally transgressive to the older units. Similarly the overlying Bierkraal Magnetite Gabbro appears to transgress the underlying units and extends beyond the map area to the east. This unit is the only

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representative of the upper zone in the western part of the Bushveld Complex.

Magnetitite layers occur in the Bierkraal Gabbro; their number and positions differ from those in the magnetite gabbro in the eastern Transvaal. A good record of the magnetitite layers has been obtained from the stratigraphic holes drilled for the Geological Survey in the area north of Rustenburg. Two prominent layers, one near the base, the other about halfway up the unit, together with a number of thin layers characterise the Bierkraal Magnetite Gabbro. Magnetitite also forms an important constituent of many of the ultrabasic pipes occurring to the south of the Pilanesberg Complex. This magnetitite is considered to be genetically related to the Bierkraal Gabbro (Coertze 1974).

4.2 RASHOOP GRANOPHYRE SUITE

Stratigraphically overlying the basic layered rocks are the granophyric rocks of the Rashoop Granophyre Suite. Two rock types are distinguished in the Rashoop Suite in the western Bushveld, the Beestkraal Granophyre and the Zwartbank Pseudogranophyre. The Beestkraal Granophyre and the Zwartbank Pseudogranophyre have similar mineralogies. Both consist of potassium feldspar, quartz, plagioclase and mafic and accessory minerals. They are distinguished by differences in their major- and trace-element chemistries as well as on textures. The former is interpreted as a primary magmatic rock whereas the latter is regarded as a product of the metamorphism and transformation of the roof rocks of the Bushveld basic rocks (Walraven 1976). The Beestkraal Granophyre may be genetically related to the Rooiberg Group volcanic rocks in this and other parts of the Bushveld Complex. Consequently the intrusive sequence differs from the stratigraphic sequence and the granophyre predates the basic rocks (Walraven 1979).

Rocks of the Rashoop Suite are found in the map area together with large sedimentary xenoliths (up to several kilometres in size) in positions immediately overlying the basic rocks, separating it from the overlying granite, and also in a north-west—south-east-trending zone within the granite. The latter occurrence forms the basis of the structural interpretation of the area (see section 9).

4.3 LEBOWA GRANITE SUITE

In the western Transvaal, in general, as well as in the map area, the Lebowa Granite Suite is represented primarily by the Nebo Granite. This granite overlies the basic rocks but is separated from them by granophyric rocks in most of the map area except north-east of the Pilanesberg. Field evidence in the form of inclusions of granophyre in the Nebo Granite indicates that the granite is younger than the granophyre.

The Nebo Granite consists primarily of potassium feldspar, quartz, plagioclase and mafic minerals. In the eastern Transvaal and in the area north-west of Potgietersrus it has been established that the granite is not homogeneous but shows a trend of barium and rubidium enrichment and related strontium depletion from the base to the top of the granite sheet. A decrease in the hornblende content from the bottom to the top coupled with a replacement of the hornblende by biotite in the very uppermost part of the sheet can also be seen.

In the map area the trace-element geochemistry and mineralogy of the Nebo Granite to the south and west of the Crocodile River fragment (Walraven 1977) seem to indicate a correlation with the lower part of the Nebo Granite in the eastern Transvaal. Porphyritic and mineralised varieties of this granite to the north and east of the Crocodile River fragment contain biotite as their principal mafic mineral and can thus be correlated with the upper part of the Nebo Granite sheet.

The nature of the transition between the two areas is obscured by a cover of younger Karoo sediments and cannot be determined. It seems likely, however, that a continuous section of the granite is not present below the cover and faulting associated with the Crocodile River fragment has resulted in the removal of part of the granite sheet.

4.4 AGE OF THE BUSHVELD COMPLEX

Geochronological results are available which provide reasonable estimates of the ages of some of the suites of the Bushveld Complex. Hamilton (1977) reports a Rb–Sr isochron age of 2 095±24 Ma for the rocks of the Rustenburg Layered Suite in the eastern Transvaal. A single sample of Bierkraal Magnetite Gabbro from a deep stratigraphic hole in the map area yielded a $^{40}Ar/^{39}Ar$ age of 2 096±12 Ma. Other earlier determinations also place the age of the Rustenburg Layered Suite close to 2 100 Ma so this age seems acceptable. Samples of the Nebo Granite collected from the map area contribute to a U–Pb concordia age of 1 920±40 Ma for this granite throughout the Bushveld Complex. Some 19 samples are involved in this determination (Coertze et al 1978); all samples are discordant to various degrees, however, so that this figure must still be regarded as a minimum age only.

A sample of Beestkraal Granophyre together with three other samples from the Rashoop Suite elsewhere in the Bushveld Complex and two granite samples have yielded an U–Pb age of 2 050±30 Ma (Coertze et al. 1978). This age is considered too young for the Rashoop Granophyre Suite. Faurie (1977) obtained an U–Pb age of 2 090±40 Ma on granite porphyry which is correlated with the Rashoop Suite and which intrudes the Rooiberg volcanics in the eastern Transvaal. Although the samples used by Faurie are more concordant than those reported by Coertze et al. (1978) they still show the effects of a significant degree of lead loss and consequently even this age remains open to interpretation. Consequently the geochronologic data available on the Rashoop Granophyre indicate only that these rocks are either the same age or older than the basic rocks of the Bushveld Complex.

5. PILANESBERG AND OTHER COMPLEXES

The Pilanesberg Complex is a very large body of intrusive and extrusive alkaline rocks and has associated with it alkaline dykes of extreme length. The complex itself is located in the north-central part of the map area, more or less on the contact between the basic and the acid rocks of the Bushveld Complex and measures about 25 km across. It consists of a suite of intrusive and extrusive alkaline rocks, xenoliths of Bushveld basic rocks and granite and is intruded by dolerite dykes and kimberlite pipes. The alkaline rocks form incomplete ring dykes and cone sheets and include syenite, red foyaite, micro-foyaite, white foyaite, tinguaite, and green foyaites. Retief (1963) and before him Shand (1928) describe the rocks in detail. A more recent study of the complex, concerned mainly with its geochemical aspects, is that of Lurie (1974). Ferguson (1973) relates the complex as a whole to alkaline plutonism in the Transvaal.

Associated with the main complex are alkaline dykes which extend over very large distances. Trending about 150° they are recorded from north of Pilanesberg southwards as far as the Vaal River and they consist of syenite and lesser diabase. The syenite is porphyritic and contains phenocrysts of alkali feldspar in a groundmass of plagioclase and mafic minerals. The ages of two samples of syenitic dyke rock obtained from the Witwatersrand are 1 290±180 Ma and 1 330±80 Ma (Burger and Coertze 1973, p. 11). An age determination on the main complex was carried out using a hybrid rock obtained from the lava-red foyaite contact and its age, 1 250±50 Ma (Retief 1963), agrees well with the younger of the two dyke-rock ages.

Within the area mapped there are a number of carbonatite complexes measuring over 2 km in diameter. Three of these are located along longitude line 27°30'E and are known as the Gelukshoek, Kruidfontein, and Tweerivier Carbonatites, named after the farms on which they occur. A fourth major carbonatite complex is located in the north-western part of the map area. It was previously known as the Goudini Complex, but has been renamed Ystervarkkop Complex to avoid duplication with similarly named rocks in the Cape Province. Verwoerd (1967) describes in detail these and other carbonatites in the Bushveld.

The Gelukshoek Carbonatite (formerly called Nooitgedacht) measures about 3 km across and consists predominantly of sövite with subordinate beforsite. It has a well-developed concentric flow structure dipping steeply inwards. The somewhat larger (about 5 km diameter) Kruidfontein Complex consists of volcanic breccia, tuff and lavas with a plug of metabeforsite in its centre. Both are located within the dolomitic rocks of the Crocodile River fragment and the former was not known until about 1955 (Verwoerd 1967, p. 102). The Tweerivier Carbonatite, located south of the Crocodile River fragment, is made up of two intrusions, a northern older one of carbonatite and tremolite-bearing carbonatite, tremolite schist, and some magnetitite, and a southern younger one which cuts the former and which consists of fragments of gabbro and anorthositic gabbro surrounded by veins of sövite.

The Ystervarkkop Complex is emplaced within the basic Bushveld rocks on the margin of an area of pyroxenite and harzburgite within the Ratsegae Norite, and consists of concentrically arranged pyroclastic breccia, bedded tuff and metasövite and metabeforsite.

Smaller carbonatite bodies occur on and to the south of Bulhoek 75 JQ. They are usually marked by hills of red indurated Nebo Granite centred around a central network of beforsite dykelets containing smaller magnetitite veins. In many cases the carbonatite bodies are associated with diabase dykes and it is thought that this association is because both the diabase and carbonatite used the same planes of weakness as intrusion emplacements. It is interesting to note that the three larger carbonatites along longitude 27°30'E, besides being aligned north–south, are also associated with faults and lineaments trending 150° and it seems probable that their intrusion was also controlled by faults and joints.

No direct evidence is available concerning the age of the carbonatites. However, Verwoerd (1967) tentatively dates the main ones on the grounds of similarity with other dated carbonatites occurring elsewhere. Thus he suggests ages of about 200 Ma for the Geluksshoek and Tweerivier Carbonatites and between 1 250 and 1 290 Ma for the Kruidfontein Carbonatite (Verwoerd 1967, p. 283).

6. KAROO SEQUENCE

A large portion of the eastern part of the map area is taken up by the Springbok Flats which is underlain by rocks of the Karoo Sequence. These rocks form a shallow basin overlying the granite of the Bushveld Complex and the south-eastern part of the Crocodile River fragment and are extremely poorly exposed. Four holes were drilled into the Karoo rocks to investigate the possible presence of economic coal deposits and the description of the Karoo sediments is drawn from the logs.

The oldest formation of the Karoo Sequence in this area is the Ecca Formation, consisting of mudstone, shale and sandstone near the top, with infrequent marl and limestone beds. Near the base, coarse quartz grains increase in abundance downwards to end in a bed of very coarse sandstone some 20 cm thick. The thickness of the formation is 85 m. Many beds of the Ecca Formation are carbonaceous and two coal seams were intersected during the drilling. A dolerite body with chilled margins was also intersected.

The Beaufort Group and Molteno and Elliot Formations cannot be conclusively delineated in the Springbok Flats region and for this reason a new formation, the Irrigasie Formation, was proposed to include the strata in this area between the Ecca and the Clarens Formations. This formation consists of multi-coloured siltsone, sandstone, marl, mudstone and shale. The sandstone can vary from fine grained to conglomeratic. Vari-coloured shales, which may be correlated with the Elliot Formation, were encountered in one hole only. Fine-grained sandstone, massive and pink to cream in colour, overlies the Irrigasie Formation and forms the Clarens Formation.

7. DYKES AND SILLS

Basic dykes and sills of various ages as well as syenite dykes are found in many parts of the map area. The term dolerite is used to indicate a medium-grained pyroxene-plagioclase rock without evidence of alteration or metamorphism whereas the term diabase is used for the altered or metamorphosed equivalent of this rock.

Basic sills are very prevalent at certain stratigraphic levels below the Bushveld Complex in the Pretoria Group and the majority are found in the Silverton and the Strubenkop Formations. A number of distinctly different rock types can be recognised amongst the sills, which include diabase of various types and pyroxenite. Studies of the mineralogical associations and metamorphic effects observed in the sills have led to the conclusion that some sills pre- and others post-date the Bushveld (Cawthorn et al. 1980).

Syenite sills in the dolomite of the Chuniespoort Group to the north of the Johannesburg dome are problematical in terms of their genetic relationships and age. On the basis of present knowledge they could either be related to the Pilanesberg Complex or they could belong to one of the phases of sill emplacement preceding the Bushveld Complex.

Basic dykes are widespread throughout the area mapped. Dolerite and diabase are the most common rock types although syenite dykes are prevalent in places especially in the dolomite in the south-eastern and south-western corners of the area. A prominent dyke swarm traverses the granite and adjoining areas in the north-central part of the map area. The swarm is about 30 km wide and trends 135° while the individual dykes trend 120°; the result is an en echelon pattern. Dyke width varies between about 10 and 30 m and the most prominent rock types are dolerite and diabase. Composite dykes occur, a particularly good example being the dykes at Moordkop, 30 km north-east of Rustenburg. Here an outer margin of diabase separates the central syenite part from the granite country rock.

Differences between dykes of various types and age can also be recognised geophysically on the basis of their magnetic expression. Very prominent linear aeromagnetic anomalies traverse the map area in an east-west direction. Occasional outcrops of basic rocks along the lineaments and a borehole intersection along one of the lineaments demonstrate that these are probably all related to basic dykes, though not all of the same age.

A $^{40}Ar/^{39}Ar$-age spectrum analysis of a dolerite sample obtained from the borehole mentioned above yielded an age of 184±7 Ma (Burger and Walraven 1976, p. 323).

8. QUATERNARY AND TERTIARY DEPOSITS

A variety of Quaternary and Tertiary deposits are found in the map area. These include a thin, patchy surface cover formed more or less in situ by weathering of the underlying rocks, alluvial deposits including gravels along the river courses, and extensive areas of deep soils effectively obscuring most of the underlying lithology.

In many parts of the area there has been relatively little movement of the soil and the distribution and nature of the underlying rock type can be determined from the soil distribution. Thus the soils formed on the gabbro and magnetitite gabbro of the Bushveld Complex are distincly black and red respectively and they outline the distribution of these rocks quite clearly. In the area to the west of Pilanesberg extensive black soils, also known as turf, are however not entirely representative of the underlying lithology. A large proportion of these are transported soils derived from the weathering of dolomite of the Malmani Subgroup to the north of the map area and do not reflect the underlying norite, quartzite and hornfels.

9. STRUCTURE

The structure within the map area is dominated by the basin formed by the rocks of the Transvaal Sequence and largely followed by the Bushveld Complex. The strata have a general north to north-easterly dip which is only locally upset by minor structures. Three major fold structures have produced deviations from the general trend. The first is the Johannesburg dome which is considered to have been active during the deposition of the rocks of the Transvaal Sequence and around which the sedimentary layers display a dip away from the centre of the dome. The second is the Crocodile River fragment which is currently the subject of a detailed mapping project of the Geological Survey. The relation of the fragment to the Transvaal basin is still uncertain and it is not known whether it represents an upwarped portion of the floor of the Bushveld Complex, whether it is a large xenolith, or whether it is the remains of a roof pendant. The third feature is the broad north-east–south-west-trending anticlinal structure south-west of Rustenburg which has resulted in regional changes of the strike direction of the Transvaal Sequence rocks in this area. This structure most probably formed after the deposition of these rocks and may be a result of basin deformation related to the intrusion of the Bushveld Complex involving sagging of the basin around a more stable cratonic block.

Local folding found primarily in the Magaliesberg Quartzite immediately below the Bushveld Complex is almost certainly a result of the intrusion of the latter.

Folding along north-west–south-east-trending axes is observed in the cores of stratigraphic boreholes in the area north of Rustenburg and can also be seen in the granite of the complex in the area south and west of the Crocodile River fragment. A monocline with a north-easterly dip as steep as 60° is located within the Bierkraal Magnetite Gabbro close to the boundary between the basic and acid rocks of the complex south-east of Pilanesberg. Adjoining the monocline towards the north-east is a broad syncline anticline–syncline system which has been interpreted on the basis of the distribution of granophyric rocks in a zone in the granite and also by the gravimetric data of the area (Walraven 1974). The granophyric rocks within the Nebo Granite are interpreted as being situated on the crest of the anticline.

A number of faults of major dimensions are found within the map area. The most prominent of these are the faults associated with the Brits graben and which appear to continue northwards up to the Crocodile River fragment, and the so-called Rustenburg fault, downthrown to the east, which is in fact a fault zone. Both these fault systems appear to have had a long history and were probably active at various times in the geological history of the area. Both fault systems are considered to be the result of movement along planes of weakness which were formed prior to the initial stages of the intrusion of the Bushveld Complex. These and associated parallel faults probably provided intrusion planes for the different portions of the complex (Coertze and Walraven, in press). A marked increase in the thickness of the granophyre suggests movement along the Brits graben faults after the intrusion of the basic rocks and the granophyre but before the intrusion of the granite. Indications of movement after the intrusion of the granite is also clearly seen as re-activation along the faults within the granite. The Rustenburg fault has certainly also experienced movement after the intrusion of the Bushveld Complex and is in part responsible for the relative denudation levels of the parts of the complex east and west of Pilanesberg (Coertze 1974).

Faults found further to the west, parallel to the Rustenburg fault and the Brits graben, are generally more limited in length and displacement.

Various authors have speculated on the presence and orientation of deep fracture zones which control and guide features observed on the surface. In the map area the north-west—south-east direction appears to be very prominent. It is interesting that such a direction does not feature prominently in many of the recent discussions of abyssal fracture zones (Jansen 1975, Verwoerd 1967). Coertze and Walraven (in press) consider faulting in this direction to be related to the tectonic framework governing the emplacement of the Bushveld Complex. Folding along similarly orientated axes probably took place after the emplacement of the complex during subsidence of the Transvaal basin under the load of the magmatic pile.

This north-west—south-east direction features very prominently as one of two directions of folding in Ferguson's (1973) synthesis, in which he places many carbonatite and kimberlite occurrences on anticlinal axes. Intrusions such as Ystervarkkop, Tweerivier and Bulhoek do not conform to this trend, however.

No significance can be seen in the north–south orientation of the carbonatite complexes along 27°30'E.

10. METAMORPHISM

To a large extent the metamorphic effects observed in the map area can be ascribed to the Bushveld Complex, and some lesser effects to the intrusion of the numerous diabase sills and basic dykes. The relatively pristine state of most of the sedimentary rocks away from the sphere of influence of the complex suggests that no regional metamorphism of any significance took place. This observation ties in with the relatively undisturbed nature of the Transvaal Sequence which generally displays only gentle inward tilting as a result of the deepening of the Transvaal sedimentary basin.

Blain (1974) demonstrates that the metamorphic effect of the diabase sills is on the average limited to a zone 5 m from the sills and is expressed as bleaching, silicification and spotting. Metamorphism in the dolomite and chert is reflected by the presence of tremolite needles, the random orientation of which suggests that pressure effects during metamorphism were limited to overburden pressure and that this was no more than about 1,3 kbar. The metamorphic facies reached in the dolomite is that of the albite–epidote–hornfels facies.

Engelbrecht (1976) studied the metamorphic effects seen in the sediments of the Pretoria Group immediately underlying the Bushveld Complex in an area directly north of Zeerust. He concludes that the temperatures may have reached values in the range 530 to 630°C and that the pressures were not more than 2,5 kbar. His conclusions place considerable restraint on the total thickness of basic rocks plus roof rocks that could have overlain the sediments at any time.

Andalusite is developed in the shales and slates of the Pretoria Group but is not accompanied by the formation of potassium feldspar. In addition, chlorite and quartz are seen to exist together which is again indicative of the albite–epidote–hornfels facies. Low-temperature garnet is found in the Boshoek Formation. The andalusite development outlines an isograd which is discordant to the sedimentary layering. Although this can be partly explained in terms of discordant intrusion of the Bushveld Complex, the reason seems to be insufficient, and an additional cause may be the variation in the thickness of the Bushveld Complex in different parts of the area, thus resulting in aureoles of different widths.

Walraven (1976) interprets the Zwartbank Pseudo-granophyre as being metamorphic in origin and having been formed in the contact metamorphic aureole of the basic rocks of the Bushveld Complex. The parent rocks were probably subarkosic in composition and may have formed part of the Rayton Formation.

11. ECONOMIC GEOLOGY

The Rustenburg 1:250 000 map area is of great economic significance. Not only are occurrences of a wide variety of minerals known in the area (see the economic legend on the map) but a very active and important mining industry is based on these minerals. The more important minerals and occurrences are described below.

11.1 PLATINUM-GROUP METALS (PGM)

Together with chromite, the most important among the economic minerals in the map area are the platinum-group metals. Both are found in the basic rocks of the Bushveld Complex. Platinum and associated elements are mined and recovered from the Merensky reef in the critical zone in the northern and south-eastern belts of Bushveld basic rocks. The northern belt falls largely outside the area mapped. Cousins (1976) estimates the total reserves for the entire Bushveld Complex as being of the order of 6,2 x 10^6 kg for the period up to the year 2 000. More recently Von Gruenewaldt (1977) states that reserves of PGM plus gold in the Merensky reef amount to 18,15 x 10^6 kg for the entire Bushveld Complex of which 5,5 x 10^6 kg is located within the map area.

Even greater reserves are located in the upper chromitite layers (UG2 specifically). Reserves in the UG2 for the entire Bushveld Complex are 32,50 x 10^6 kg of PGM plus gold (Von Gruenewaldt 1977). An estimated 10,7 x 10^6 kg of this is located in the map area. The PGM from UG2 until recently presented metallurgical problems. These have now been solved and the UG2 ore will be exploited according to a report in Mining Week of 17 September 1980.

11.2 CHROMITE

Chromite is present in chromitite seams in the lower part of the Rustenburg Layered Suite in the northern and south-eastern belts as well as in the western lobe. The seams are divided into upper, middle and lower groups, but only the middle and lower seams have so far been used for the production of chrome ore. In the map area chromite is mined in the south-eastern belt (in the Rustenburg-Kroondal-Mooinooi area) as well as to the west of Pilanesberg, at Nietverdiend, north of Zeerust. The latter chromite differs from that in the other areas in the western Bushveld by having a higher Cr/Fe ratio. During 1979 more than 1,2 x 10^6 tons of chrome ore, concentrate and chrome sand were exported and more than 1,3 x 10^6 tons were sold locally. According to Von Gruenewaldt (1977) there are reserves of 772 x 10^6 tons of chrome ore with more than 45 per cent

Cr_2O_3 for the western Bushveld Complex as a whole, the larger part of which is located within the map area.

11.3 VANADIUM

Vanadium pentoxide is present in quantities up to 2 per cent in the titaniferous magnetite of the magnetitite layers in the Bierkraal Magnetite Gabbro. Mining of the magnetite is restricted to the eastern Transvaal but an excess of 300 x 10^6 tons of magnetite ore (to 30 m vertical depth) is present in the western Bushveld (Von Gruenewaldt 1977), by far the larger part of which is located within the map area.

11.4 DIAMONDS

East-west-striking kimberlite fissures in the Swartruggens area are being mined for diamonds. Active mining is restricted to a single farm but payable fissures extend over a larger area. The kimberlite post-dates the Bushveld Complex. Other kimberlites within the map area are located in the Pilanesberg Complex but no diamonds have been found in them. The fissures north of Swartruggens are remarkable for their high yield between 2,8 and 4,0 carats per ton. Production is in the order of 1,5 x 10^6 carats per year but the quality of the diamonds is generally rather inferior.

Diamondiferous alluvial gravels are found in the south-western part of the map area. These gravels form part of the Lichtenburg alluvial diamond field which is largely located to the south of the area. The field covers a belt some 140 km long and 20 km wide and although it was actively mined in the late twenties, the present output is small.

11.5 RARE EARTH ELEMENTS

Concentrations of rare earth elements are found in the Pilanesberg Complex in a number of localities.

The mineralisation is mainly found on contacts between different rock types and in tuff layers and veins in the alkaline rocks. The predominant REE mineral is britholite and concentrates containing more than 50 per cent REE have been obtained. Some uranium occurs together with the rare earths. No mining is taking place.

11.6 FLUORITE

Fluorite is found in a number of different associations in the map area. It is associated with the dolomite of the Malmani Subgroup in the western Transvaal where some of the world's largest deposits are located and are being mined on a large scale. These are considered to include both hydrothermal deposits (Crocker and Martini 1976) and stratiform deposits. Only the latter are at present of economic significance. Fluorite is also found in the Nebo Granite in the north-eastern part of the map area, north-east of the Crocodile River fragment. Small deposits of fluorite with quartz and specularite and hematite have been mined in the past on Ruigtepoort 162 JQ and Slipfontein 551 KQ. Some fluorite is also found in some of the alkaline and carbonatite complexes in the map area. The Kruidfontein Complex contains a large and potentially important deposit but this is not mined because of beneficiation problems.

11.7 COAL

Coal is present in economic quantities in the Karoo strata (Ecca Formation) of the Springbok Flats area in the central-eastern part of the map area. Exploitation of these deposits is planned in the near future. Uranium is associated with coal in places.

11.8 DIMENSION STONE

Quarrying of magnetite gabbro from the upper part of the Pyramid Gabbro-Norite is carried out at numerous localities along the strike of this unit. The quality (i.e. colour) of the stone in the map area is, however, generally inferior to that of the stratigraphically equivalent Belfast "black granite" quarried in the eastern Transvaal.

Other dimension stone that has been quarried in the past in the map area includes the Nebo Granite from the farm Veekraal 221 JQ north of Brits (known as Veekraal granite in the trade), and syenite and lujavrite from the Pilanesberg Complex. Slate for roofing and paving purposes is extensively quarried in the western Transvaal to the south-east and south-west of Swartruggens.

11.9 LIMESTONE

Limestone is quarried for use in the cement industry in the southern part of the Crocodile River fragment. The material has to be blended with low-magnesium calcrete before it can be used for manufacturing cement.

11.10 ANDALUSITE

Andalusite is developed extensively in the lower part of the Strubenkop Shale Formation and the Timeball Hill Formation in the western part of the map area. It is totally sericitised in the Strubenkop Formation and of no economic value. The best development in the area occurs over a strike length of 25 km immediately west of Groot Marico. It is recoverable from the soft parts of the shales as well as from alluvial deposits. Both types have been mined in the past but only limited activity continues at present.

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