EXPLANATION: SHEET 2430 (1:250 000)
TOELIGTING: BLAD 2430 (1:250 000)

PILGRIM'S REST

GEOLOGICAL SURVEY
GEOLOGIESE OPNAME

REPUBLIC OF
SOUTH AFRICA

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Frontispiece — The valley of the Blyde River—a well-frequented tourist area excellently displaying the strata of the Wolkberg Group and Black Reef Formation (photo by F. Walraven).

Voorblad — Die vallei van die Blyderivier—'n dikwels besoekte toeristegebied wat uitstekend die strata van die Groep Wolkberg en die Formasie Swartrif ten toon stel (foto deur F. Walraven).

Republic of South Africa
Republiek van Suid-Afrika

Department of Mineral and Energy Affairs
Departement van Mineraal- en Energiesake

GEOLOGICAL SURVEY
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THE GEOLOGY OF THE PILGRIM'S REST AREA

by/deur

F. WALRAVEN, Ph.D.

Explanation of Sheet 2430
Toeligting van Blad 2430
Scale/Skaal 1:250 000

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Printed by the Government Printer and obtainable from the Government Printer, Bosman Street/Private Bag X85, Pretoria, 0002/0001, Tel. 323-9731 × 267, and from the Chief Director, Geological Survey, Private Bag X112, Pretoria, 0001/280 Pretoria Road, Silverton, 0184.

Gedruk deur die Staatsdrukker en verkrygbaar by die Staatsdrukker, Bosmanstraat/Privaatsak X85, Pretoria, 0002/0001, Tel. 323-9731 × 267, en van die Hoofdirekteur, Geologiese Opname, Privaatsak X112, Pretoria, 0001/Pretoriaweg 280, Silverton, 0184.

ISBN 0-621-12358-7

DEPARTMENT OF MINERAL AND ENERGY AFFAIRS
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GEOLOGIESE OPNAME

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Edited by/Geredigeer deur

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Direkteur — C. J. van Vuuren

CONTENTS

THE GEOLOGY OF THE PILGRIM'S REST AREA

by

F. WALRAVEN

Abstract

The geological map of sheet area 2430 (Pilgrim's Rest) includes a wide variety of rocks ranging in age from Swazian to Recent. Two main topographical divisions exist in the area, the one being the lowveld, which is underlain by Swazian granites and gneisses, greenstones of the southern extremity of the Murchison Range and also Karoo-age sediments and volcanics of the Lebombo Mountains. The other is the highveld region which is made up of clastic and chemical sediments and volcanic rocks of the Transvaal Sequence as well as intrusive rocks of the Bushveld Complex. The map area is of economic interest as a result of the presence of gold, which was actively exploited in the Pilgrim's Rest area, as well as various other mineral occurrences.

Uittreksel

Die geologiese kaart van gebied 2430 (Pilgrim's Rest) sluit 'n wye verskeidenheid gesteentes in wat in ouderdom strek vanaf Swazium tot Resent. Twee groot topografiese indelings bestaan in die gebied, waarvan die een die laeveld is, wat deur Swaziese graniete en gneise, groenstene van die suidelike deel van die Murchisonreeks, asook sedimente en vulkaniese gesteentes van Karoo-ouderdom van die Lebomboberge onderlê word. Die ander is die hoëveldgebied wat uit klastiese en chemiese sedimente en vulkaniese gesteentes van die Opeenvolging Transvaal asook intrusiewe gesteentes van die Kompleks Bosveld bestaan. Die kaartgebied is van ekonomiese belang as gevolg van die teenwoordigheid van goud, wat in die verlede aktief ontgin is in die omgewing van Pelgrimsrus, asook verskeie ander mineraalvoorkomste.

1. INTRODUCTION

The 1:250 000 map sheet 2430 Pilgrim's Rest includes a region of great geological diversity and interest. The area is located in the eastern Transvaal between latitudes 24° and 25° south and longitudes 30° and 32° east. It includes rocks ranging in age from the Swazian to the Quaternary and can broadly be divided into three geologically distinct regions. The western part of the map area is underlain by sedimentary and volcanic rocks of the Transvaal Sequence and intrusive rocks of the Bushveld Complex. To the east are rocks of the Swazian basement complex which consists predominantly of gneisses and granites and still further east are the sedimentary and volcanic rocks of the Karoo Sequence. Rocks of the Murchison Sequence and the Phalaborwa Complex are present in the northern part of the map area.

Interest in the area has been significant in the past as well as the present since it includes the Pilgrim's Rest region which is famous for its historic gold mining, and the southern part of the economically significant Murchison Range and the Phalaborwa copper mines.

There exists a striking correlation between the various rock units and the topography of the map area. The Transvaal Sequence underlies high country, generally between 1 300 and 2 000 m above sea level. These are separated from the rocks of the eastern Transvaal lowveld by a very steep and prominent escarpment cut by very deep gorges and offering spectacular scenery. The lowveld region is underlain by the basement gneisses and granites and is adjoined to the east by the Karoo strata, forming the prominent Lebombo Ranges.

The 1:250 000 geological map was compiled from data from various sources, including reconnaissance mapping by staff of the Geological Survey as well as contract mapping by a university and mapping on a honorarium scheme. Compilation of the field mapping was done on a scale of 1:50 000 and 1:100 000 (the latter within the Kruger National Park only). A considerable part of the map area lies within the Kruger National Park and the co-operation and helpful assistance of the staff of the National Parks Board in carrying out the mapping within the Park is hereby gratefully acknowledged.

2. GNEISSES, GRANITES AND METAMORPHIC ROCKS OF THE LOWVELD AREA

A number of different types of gneiss and granite underlie the lowveld region in the east-central part of the map area. These rocks include amongst others the gneisses of the undifferentiated Swazian basement complex as well as a variety of younger granites that intruded therein. The metasedimentary and metavolcanic rocks of the Gravelotte Group and the intrusive basic and acid rocks of the Rooiwater Complex are also found in this region.

2.1 MAKHUTSWI GNEISS

Two rock types are distinguished in the gneisses of the Swazian basement complex. The first of these is a biotite gneiss which is found in the central part of the lowveld. It is a white to grey, massive, equigranular, medium- to fine-grained rock consisting of quartz, plagioclase and biotite with small amounts of microcline and sphene and occasionally some pyrite. It is characterised by its homogeneity and lack of xenoliths and migmatitic textures but may include pegmatite veins.

2.2 GRAVELOTTE GROUP

Metamorphosed sedimentary and volcanic rocks form the southwestern extremity of the Murchison Range along the northern boundary. They form the Gravelotte Group which is a succession of metavolcanic rocks and metasediments that initially attracted attention because of the gold-bearing reefs found within it. The Murchison rocks were correlated with those of the Barberton Moutain Land (Molengraaff 1904) and are still considered to occupy a stratigraphic position similar to the latter. Vearncombe et al. (1987) obtained an age of 2 950 Ma acid volcanics of the Rubbervale Formation; this must probably be regarded as a minimum age only.

The Gravelotte Group appears to be a typical volcanic succession consisting of basic to altrabasic lavas at the base (the basaltic komatiite, magnesium metatholeiite and peridotitic komatiite of the Mulati and Leydsdorp Formations) and more acid volcanic rocks at the top (the felsic porphyritic tuffs of the Rubbervale Formation). Interlayered in these rocks are conglomerate, quartzite, grit, quartz-chlorite schist, quartz-muscovite schist and banded iron formation. The last-named occurs in the succession from the Leydsdorp Formation up to the Mac Kop Formation. The oldest units of the Gravelotte Group form the southeastern part of the Murchison Range and younger formations occur progressively further to the northwest.

2.3 MIGMATITE AND GNEISS

The second rock type (Zbg on map) of the basement complex is migmatite and gneiss underlying a terrane located along the northern margin of the map area and separated from the biotite gneiss by an approximately east–west boundary. A variable suite of rocks is present but the predominant type is a light-grey, medium-grained, biotite-rich gneiss with white, coarse-grained (in places pegmatitic), quartz-feldspar leucosomes. Quartz, plagioclase and biotite are the essential minerals together with lesser microcline; common accessory minerals are epidote and sphene. Occasional pyroxene crystals were probably derived from inclusions of amphibolite in the gneiss. Common additional features are layering and folding in the migmatite as well as boudins and schlieren defined by mafic minerals. The rocks are considered to have undergone multiple deformation and, through partial melting, may have acted as a source for at least a portion of the biotite gneiss. Amphibolite bodies that have been involved in the deformation are common as are very coarse-grained, muscovite-pegmatite veins.

A variety of amphibolites can be recognised in the migmatite and gneiss terrane. These include dykes, xenoliths and interlayered amphibolite. The amphibolite generally consists of hypidiomorphic crystals of hornblende with either augite or diopside and variable amounts of K-feldspar, plagioclase and quartz. Similarly, small stock-like outcrops of talc-schist are sometimes found associated with muscovite pegmatite bodies and are believed to have formed by hydrothermal alteration of amphibolite. The rock consists of chlorite, tremolite and talc together with calcite and epidote.

Burger and Walraven (1979) gave a U–Pb zircon age of 2 774±70 Ma obtained on a sample of migmatite collected north of the map area. This sample may be related to the migmatite and gneiss in the map area but, although Burger and Walraven considered it to be reliable, this age is lower than that of granite in the southern part of the map area and may therefore not apply to the rocks under discussion.

2.4 NELSPRUIT GRANITE SUITE*

In the south-central part of the map area a suite of granites and gneisses takes the place of the biotite gneiss and the migmatite and gneiss. These rocks are here referred to as the Nelspruit Granite Suite and include porphyritic granite as well as migmatite and gneiss interpreted as the marginal facies of the former, formed by interaction between the granite and country rocks.

The porphyritic granite of the Nelspruit Granite Suite is a leucocratic rock consisting of a groundmass of quartz, plagioclase and microcline with variable amounts of biotite, in which are set large, euhedral, sometimes poikilitic, megacrysts of microcline. Occasionally basic xenoliths are present in the granite and coarse- to very coarse-grained pegmatitic veins are common. They vary locally from slightly to very strongly porphyritic.

The migmatite and gneiss represent a complex suite of rocks having a close spatial relationship to the porphyritic granite. They form large koppies and, in outcrop, can be recognised by their layered, folded and schlieren textures. Dark basic and ultrabasic xenoliths are common and are partly, or sometimes completely, granitised. The migmatite and gneiss consist of quartz, microcline, plagioclase and biotite and locally concentrations of microcline megacrysts are present.

Oosthuyzen (1970) reported a U–Pb age of 3 160±100 Ma which he obtained on zircon and apatite from the Nelspruit Granite Suite. De Gasparis (1967) obtained an Rb–Sr whole-rock age of 2 950±120 Ma on sample of the same granite.

2.5 HEBRON GRANODIORITE**

Isolated occurrences of a light-coloured, granitic rock are found in the central part of the map area. These are referred to as the Hebron Granodiorite and the rock is medium to fine grained with a granular texture and large poikilitic microcline crystals. The minerals in the rock are quartz, plagioclase, microcline, biotite and minor sphene.

2.6 ROOIWATER COMPLEX

Also located at the southwestern extremity of the Murchison Range but to the north of the Gravelotte Group, are basic and ultrabasic rocks of the Rooiwater Complex. SACS (1980) divided this complex into two units, the Novengilla Gabbro Suite and the Free State Diorite Suite. Only the former is found within the map area and consists primarily of

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* Name not yet approved by SACS.

** Name not approved by SACS (1980); proposed for reconsideration.

two rock types, i.e. a hornblende-rich and a plagioclase-rich gabbro. U–Pb dating of zircon from a sample of diorite from the Rooiwater Complex gave an age of 2 961±75 Ma (Burger and Walraven 1979). The Rooiwater Complex has intrusive relations with the Rubbervale Formation of the Gravelotte Group and is considered to represent the final event in the history of the Murchison Range (SACS 1980). Vearncombe et al. (1987) carried out Pb–Pb and Rb–Sr whole-rock dating on samples of Rooiwater Complex, Murchison Sequence and other rock units and reported an age of 2 650 Ma for a younger intrusive granite pluton. This limits the age of the Rooiwater Complex, but these authors additionally mentioned the possibility of a genetic relationship between the Rooiwater Complex and the Rubbervale Formation, for which they reported an age of 2 950 Ma, and suggested that this may be a minimum age for the Rooiwater Complex.

2.7 VORSTER SUITE*

Along the northern boundary of the map area a thin strip of granites belonging to the Vorster Suite is present. These rocks form the southern limit of a larger area of granites further north. Two types of granite are distinguished, the *Willie Granite* and the *Lekkersmaak Granite*. Both are biotite-muscovite granites and somewhat granodioritic in composition. Whereas the Lekkersmaak Granite has a batholitic shape, the Willie Granite is stock-like and porphyritic. Burger and Walraven (1979) quoted a U–Pb zircon age of 2 690±65 Ma for the Lekkersmaak Granite which is considered to be a reliable age.

2.8 MASHISHIMALE SUITE

A slightly younger suite of granites is also present along the northern boundary of the map area. This is the Mashishimale Suite in which three granite types, the *Hoed*, *Lillie* and *Transport Granites*, are recognised. All three are present in the map area. The Transport Granite occurs as a stock-like body of biotite-hornblende granite and is granodioritic to adamellitic in composition. An age of 2 554±65 Ma was obtained from this granite (U–Pb on zircon) and Burger and Walraven (1979) considered this a reliable age.

The Lillie Granite is also a biotite-hornblende granite and occurs as a number of stock-like intrusions. They have a granodioritic-adamellitic composition and U–Pb-zircon age determinations indicate a reliable age of 2 612±65 Ma (Burger and Walraven 1979). No age data are available for the Hoed Granite, a plug-like intrusion of biotite granite.

2.9 MARANDA GRANITE*

A moderately well-exposed body of biotite granite is located between the rocks of the Murchison Sequence and the Transvaal escarpment in the northern part of the map area. This granite is a relatively homogeneous rock, consisting of quartz, plagioclase and biotite.

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* Name not yet approved by SACS.

2.10 TURFLOOP GRANITE

A moderately extensive area along the northern margin of the map area is underlain by the Turfloop Granite. This rock, which is more extensive to the north, is a medium- to coarse-grained, grey to pink biotite granite and is adamellitic to granodioritic in composition. It contains both orthoclase as well as microcline in addition to quartz, sodic plagioclase and biotite and has sphene and zircon as its main accessory minerals. It is generally homogeneous but in places displays a weak foliation.

2.11 HARMONY GRANITE

Jantsky (1980) proposed the name Harmony and described the intrusion as a batholith of biotite-muscovite granite of tonalitic composition. A number of textural variations, in which is included a transition zone, are present in the Harmony Granite. The most common variety is a light-grey, coarse-grained, quartz-rich, biotite-muscovite granite. Quartz, plagioclase, microcline, biotite and muscovite are the main minerals. A porphyritic variety of the granite contains large euhedral phenocrysts of microcline that are often poikilitic and in places display a preferred orientation, probably related to flow in the magma.

Towards the margin of the intrusion the Harmony Granite becomes much coarser and pegmatitic and contains large K-feldspar crystals intergrown with quartz together with large books of muscovite. A number of pegmatitic and aplitic veins, ranging in width between 5 and 20 cm, cut the intrusion. A transition zone is located at the contact between the Harmony Granite and the country rocks. This zone is characterised by the presence of very coarse-grained, muscovite-bearing pegmatite, biotite-muscovite granite, biotite gneiss, migmatite and amphibolite.

2.12 CUNNING MOOR TONALITE*

A large portion of the central part of the map area is occupied by leucocratic, medium- to coarse-grained, granular, granitic rocks consisting of anhedral quartz and subhedral plagioclase with variable amounts of biotite and microcline. These rocks are referred to as the Cunning Moor Tonalite and were first described by Robb (1978) who noted the characteristic and diagnostic presence of poikilitic crystals of sphene. Although generally massive, foliation of the tonalite is seen in some parts of the intrusion, notably near its margins. Geochemically the Cunning Moor Tonalite ranges from adamellite, through granodiorite to tonalite. A crustal origin is ascribed to the rock on the basis of its high initial $^{87}Sr/^{86}Sr$ ratio (Robb 1978) and the tonalite has an age in the order of 2 600 Ma.

2.13 PEGMATITE

Throughout the lowveld area, and especially in the northern part of the map area, abundant pegmatites of several types are present (Vpe on map). These are generally

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* Name not approved by SACS (1980); proposed for reconsideration.

muscovite-bearing and include a milky-quartz pegmatite and a quartz-feldspar-muscovite pegmatite. The former consists primarily of milky quartz and is often associated with talc schist. The latter is a very coarse-grained pegmatite consisting of microcline or perthite intergrown with quartz, anhedral quartz and large books of muscovite.

3. TRANSVAAL SEQUENCE

Rocks of the Transvaal Sequence occupy much of the western part of the map area. A fairly complete section of the Transvaal Sequence is present in this area, ranging from the sedimentary and volcanic rocks of the Wolkberg Group near the base, to the sedimentary rocks of the Pretoria Group at the top. Only the volcanic rocks of the Rooiberg Group and the sediments of the Loskop Formation, that form the upper part of the Transvaal Sequence elsewhere in the Transvaal basin, are absent.

3.1 WOLKBERG GROUP

Coarse clastic sediments, argillaceous quartzite, subgreywacke, arkose and calcareous layers of the *Sekororo Formation* form upward-fining sequences at the very base of a group of clastic and volcanic rocks that occupy protobasins of the Transvaal sedimentary basin. These rocks were deposited in terrestrial and shallow marine environments under control of the palaeotopography in existence at the time (Button 1973a). The locally discordant relation between the Swazian floor rocks and the protobasin fill is well illustrated in the cutting along the road through the Abel Erasmus Pass in the northwestern part of the map area.

These rocks are concordantly overlain by intermediate to basic volcanic rocks, lava flows as well as pyroclastic deposits of the *Abel Erasmus Basalt Formation*. The texture and geometry of the latter indicate extrusion into an irregular land surface (Tankard et al. 1982) but rare pillows indicate occasional subaqueous extrusion as well. The volcanics are in turn followed by the clastic sediments of the *Schelem, Selati Shale, Mabin Quartzite* and *Sadowa Shale Formations*. These formations represent a shallow marine progradational succession made up of deltaic and tidal-flat sediments.

An increase in the maturity of the sediments towards the top of the Wolkberg Group is evident. The sediments are less heterogeneous and quartzite, shale and mudstone predominate. This indicates that the initial phase of rapid filling of basins and troughs of limited size was complete at this stage and the scene was now set for the deposition of the overlying Black Reef Quartzite Formation as continuous layers over large areas of the Transvaal basin.

3.2 BLACK REEF QUARTZITE FORMATION

The Black Reef Formation, a succession of very clean quartzite with lenses and layers of pebbles in places with a conglomerate at the base, forms the logical successor to the Wolkberg Group, overlying it conformably and representing widespread inundation of virtually the entire Transvaal sedimentary basin. Fluvial conglomerates and sandstone form the lower part of the formation and the upper part consists largely of shallow marine sandstone deposited in a tidal-shelf environment (Button 1973b). At the top of the Black Reef Formation a zone consisting of alternating shale and sandstone represents the transition from clastic sedimentation to the overlying chemical sediments.

A relatively thin layer of basalt, the *Serala Basalt Member*, is present in the upper part of the Black Reef Formation in the northwestern part of the map area but pinches out towards the southeast. In previous subdivisions of the Transvaal rocks the lower contact of the Black Reef was taken at the top of the basalt member. The thinning and eventual disappearance of the latter makes this boundary an unsatisfactory one and the Black Reef Formation now includes the uppermost quartzite of the former ''Wolkberg Series''.

3.3 CHUNIESPOORT GROUP

Limestone, dolomite, chert and iron formation form the Chuniespoort Group which overlies the Black Reef Formation. These rocks are predominantly chemical in origin and clastic material constitutes only a very small proportion. A principal subdivision of the Chuniespoort Group is made into the *Malmani Subgroup*, overlain by the *Penge Formation*, followed by the *Duitschland Formation*. Rocks of the latter are not present within the map area but are primarily found further to the northwest. The carbonate rocks and chert of the Malmani Subgroup are considered to have formed as tidal-flat deposits (Eriksson and Truswell 1974) and include a wide variety of algal structures.

Many of the latter are observed in modern-day evaporitic tidal-flat environments and provide clear indications of the origin of these rocks.

Prominent banded iron formation of the Penge Formation overlies the Malmani Subgroup and is considered to have formed in a depositional environment similar to that of the Malmani Subgroup (Tankard et al. 1982). Volcanic activity was undoubtedly of significance in the genesis of the iron formation, but subaerial weathering is also held responsible (Button 1976a).

3.4 PRETORIA GROUP

A regional unconformity separates the Chuniespoort Group from the overlying Pretoria Group. The latter is a clastic succession consisting mainly of shale units with intervening sandstone formations, now largely metamorphosed to quartzite. Volcanic units are found at two levels in the Pretoria Group.

The base of the Pretoria Group in the Transvaal basin generally is the Rooihoogte Formation which consists of a prominent chert-rich conglomerate/breccia, the Bevets Conglomerate Member, near its base and the Polo Ground Quartzite Member* near the top with shale and sandstone in the intervening section. This formation marks the start of a

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* Name not yet approved by SACS.

period of renewed terrigenous influx during which upward-fining, tidal-flat sequences were laid down alternating with tidal-shelf deposits and offshore-shelf sediments (Tankard et al. 1982). These units are not represented within the map area where the lowermost strata of the Pretoria Group are those of the Timeball Hill Formation. Examples of the tidal-flat deposits are quartz sandstone at the top of the *Magaliesberg, Lakenvalei* and *Steenkampsberg Quartzite Formations*, whereas the main parts of these formations are considered to have formed in tidal-shelf environments (Button 1973b). Other tidal-flat deposits are the mixed sandstone and shale deposits of the *Vermont Hornfels Formation*, and basal part of the *Nederhorst Formation*, stromatolitic carbonates of the Vermont Formation and oolitic ironstone of the *Timeball Hill* and *Dwaalheuwel Quartzite Formations* (Tankard et al. 1982). The considerable thickness of shale of the Timeball Hill and *Silverton Shale* Formations and also some other units of the Pretoria Group are interpreted as being representative of offshore-shelf deposits (Button 1973b).

Volcanic rocks in the Pretoria Group in the map area include the *Hekpoort Andesite Formation* and *Machadodorp Member* of the Silverton Shale Formation. The lavas of the Hekpoort Formation were extruded on land (Button 1973b) while abundant pillow structures as well as water-laid pyroclastics are indicative of a subaqueous origin for the Machadodorp volcanics (Button 1974).

The rocks of the Transvaal Sequence in the map area are overlain by intrusive igneous rocks of the Bushveld Complex. The latter intruded somewhat discordantly in this part of the basin and consequently in the northern part of the area the Magaliesberg Formation represents the top of the Transvaal Sequence, while further to the south stratigraphically higher formations are still present.

4. BUSHVELD COMPLEX

Within the map area the Bushveld Complex is represented mainly by basic rocks belonging to the Rustenburg Layered Suite. These are present in the western part of the area. Acid rocks of the complex are restricted to the two occurrences of Nebo Granite along the western boundary of the map. These were previously referred to as the Steelpoort Park Granite* in the south and the Magnet Heights Gabbro-Norite further north. In both cases the granites are considered to represent offshoots of the main body of Nebo Granite further to the west, outside the map area.

SACS (1980) proposed a subdivision of the basic rocks into lithological units having formation status and considered the zonal classification, accepted and used by many geologists in South Africa and overseas, to be informal. The lithostratigraphic subdivision of SACS is used here in combination with a subdivision of the Rustenburg Suite into subsuites (Walraven 1986). A number of unnamed rock types are found in the lower part of the Bushveld Complex basic rocks as well as in the underlying floor rocks. These include granodiorite, norite and pyroxenite and generally form sill-like intrusions.

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* Name not yet approved by SACS.

Age determinations point to an age in the order of 2 050 to 2 100 Ma for the Rustenburg Layered Suite. Hamilton (1977) carried out Rb–Sr whole-rock and mineral determinations on samples of basic rocks from the eastern part of the Bushveld Complex and obtained ages in this range. They are corroborated by a $^{40}Ar/^{39}Ar$ determination on a sample of magnetic gabbro from a borehole in the western Bushveld Complex (Burger and Walraven 1977).

4.1 SHELTER NORITE

All the subsuites and units for formation status of the Rustenburg Layered Suite are represented within the map area. Lowermost of these is the Shelter Norite, which is widely known as the marginal zone and includes the so-called Hendriksplaats norite, a fine-grained, orthopyroxene-clinopyroxene-plagioclase rock, containing chromite and magnetite. It is interpreted as a chilled phase of the Bushveld parental magmas (Sharpe 1980) and consists predominantly of fine-grained noritic rocks which may be both layered and discordant. The Shelter Norite is present throughout the whole contact region of the Bushveld Complex and may be developed between any of the other units of the Bushveld basic rocks and the country rocks. It may contain abundant inclusions of the latter as well as pyroxenite balls, which in places define zones known as the ''tennis-ball marker''.

4.2 CROYDON SUBSUITE

Rocks of the Croydon Subsuite overlie the Shelter Norite and incorporate mainly pyroxenitic units. The subsuite corresponds largely to the former lower zone and its rocks are referred to as the laminated marginal zone by Sharpe (1980) who considered them to represent four phases of injection. These are firstly a fine-grained pyroxenite paralleling the bedding planes and including the marginal norites; secondly a coarser, more discordant bronzitite including olivine layers; thirdly a coarse-grained websterite forming small satellite bulges into the Steenkampsberg Quartzite Formation; and lastly the intrusion of sheets of steeply dipping olivine pyroxenite.

4.3 DWARS RIVER SUBSUITE

Rocks of the Dwars River Subsuite, also referred to as the critical zone, are discordant to the structures found in the Croydon Subsuite and contain chromitite layers as well as the Merensky Reef. The subsuite consists of anorthosite, norite and pyroxenite and its relation to the floor rocks varies from concordant to grossly discordant and is separated from them by a marginal chill zone. Post-emplacement deformation of the Dwars River rocks and irregularities in the floor resulted in disturbed layering as well as shearing and faulting of the rocks.

4.4 DSJATE SUBSUITE

The Dsjate Subsuite corresponds more or less to the former main zone and consists predominantly of gabbro and norite with lesser anorthosite. The rocks of this subsuite rest conformably on the underlying Dwars River Subsuite but also have a chill zone similar to that of the other subsuite where they are in contact with the floor rocks. The *Leolo Mountain Gabbro-Norite* is the most prominent of the units of this subsuite and occupies most of the western part of the map area.

4.5 ROOSSENEKAL SUBSUITE

The rocks of this subsuite correspond to the former upper zone and incorporate mainly the magnetite-rich gabbros of the upper part of the Rustenburg Layered Suite. A very prominent magnetitite layer is present near the base of this subsuite and a further twenty-one layers are recognised higher up in the succession.

4.6 NEBO GRANITE

As noted above, the Nebo Granite is represented in the map area by two offshoots of the main body of Nebo Granite further to the west, outside the area covered by this map. These offshoots, the Steelpoort Park and Magnet Heights Granites, consist of coarse-grained, hornblende-biotite granite and were emplaced along northeast–southwest-oriented faults. This accounts for the elongated shape. These faults probably acted as conduits during the emplacement of the granite and might also have played a role during the preceding intrusion of the Bushveld basic rocks.

The age of the Nebo Granite is considered to have been reliably established at 2 052+48 Ma (Walraven et al. 1981), an age which is confirmed by individual U–Pb-zircon determinations on the Steelpoort Park Granite and the 2 050 Ma age obtained for the Makhutso Granite elsewhere in the Bushveld Complex (Walraven 1986). Field relationships show the latter to post-date the other Bushveld granites so that this age provides a reliable minimum for the entire Bushveld Complex.

5. PHALABORWA COMPLEX

The southern part of the Phalaborwa Complex is located in the north-central part of the map area. This complex, which expresses itself on the surface primarily as Loole Kop, was the target of copper-mining activities by ancient people, probably for as long as 1 200 years. The complex is a pipe-like structure and consists of various types of carbonatite as well as pyroxenite and phoscorite and has an age close to 2 050 Ma (Holmes and Cahen 1957; Eriksson 1984). Its geology was described in detail by Hanekom et al. (1965). The younger carbonatite carries the bulk of the copper mineralisation. Modern mining activities commenced in the early sixties after the complex was prospected for apatite.

6. TIMBAVATI GABBRO

Basic rocks characterised by a rather irregularly shaped outcrop pattern are present in the eastern half of the map area within the Swazian basement rocks. Although they outcrop comparatively poorly, these rocks are associated with a distinctly recognisable vegetation type and their distribution on the ground and on aerial photographs can consequently be clearly seen. Brandt (1948) referred to these rocks as the "Wildtuingang" and later Saggerson and Logan (1970) described them as "Older Basic Intrusions". They are now called the Timbavati Gabbro (Schutte 1974; SACS 1980).

Although the Timbavati Gabbro clearly intrudes, and is therefore younger than, the Swazian basement rocks, its relation to the rocks of the Karoo Sequence to the east is not always clear. Poor exposure obscures the field relations between the Timbavati Gabbro and the Karoo rocks and at one stage the Timbavati was considered to be related to the Karoo dolerites and therefore of post-Karoo age (Visser and Verwoerd 1960). More recent work (Schutte 1974) as well as age determinations on the Timbavati Gabbro makes such a conclusion untenable. Clubley-Armstrong (1979), working in the Pretoriuskop region (south of the map area), found clear indications of the gabbro being overlain by strata of the Karoo Sequence. $^{40}Ar/^{39}Ar$ determinations carried out for the Geological Survey yielded ages between 967+4 Ma and 1 123+13 Ma (Burger and Walraven 1979) and Rb–Sr whole-rock determinations (Bristow et al. 1982) indicate an age of 1 450+50 Ma. Thus the Timbavati Gabbro is clearly not of Karoo age and on the basis of the present data appears to have resulted from an isolated igneous event.

Recent mapping has established the sill-like nature of the Timbavati Gabbro. Its outcrop pattern is made up of arcuate sections and the sills dip towards the inside of the arcs at shallow angles of between 20 and 30°. Walraven (1983) suggested that the shape of the sills was related to Hertzian fracturing and that they were emplaced as a number of distinct intrusions.

The Timbavati intrusions consist of basic to ultrabasic rocks that range in colour from blue grey to greenish and consist predominantly of calcic plagioclase, orthopyroxene, clinopyroxene and olivine. Three distinct rock types can be recognised on the basis of petrography and chemistry: olivine gabbro, gabbro and quartz gabbro (Schutte 1982; Walraven 1984). Where the contact with the Swazian rocks is exposed, the Timbavati is seen to have chilled and the granite/gneiss host rocks display various degrees of recrystallisation and local melting (Clubley-Armstrong 1979; Michaluk 1984).

7. SABIE SANDS GRANOPHYRE*

An area underlain by granophyric quartz gabbro is located in the southeastern part of the map area, just outside the Kruger National Park. The origin and relationships of these rocks are uncertain but they resemble granophyric rocks found elsewhere at the contact between the Timbavati Gabbro and the granitic or gneissic country rocks. Thus it is possible that the Sabie Sands Granophyre represents a marginal interaction facíes between the surrounding Nelspruit Suite rocks and gabbroic rocks which were formerly overlying the granophyre but have now been removed by erosion.

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* Name not yet approved by SACS.

8. KAROO SEQUENCE

Rocks of the Karoo Sequence are found only in the extreme eastern part of the map area where they form the prominent Lebombo Mountains and also underlie a north–south elongated strip of lowveld country adjoining the Lebombos to the west. Both sediments and volcanic rocks are present, the former being comparatively poorly developed and representing only a limited portion of the total Karoo stratigraphy.

8.1 UNDIFFERENTIATED KAROO

Shale, siltstone and sandstone containing coal-bearing horizons form the lowest part of the Karoo succession in the map area. These rocks unconformably overlie the Swazian granites and gneisses.

8.2 CLARENS SANDSTONE FORMATION

A fine-grained red siltstone overlies the basal sediments and forms the *Red Rocks Sandstone Member* of the Clarens Formation. It outcrops extremely poorly and may possibly not have been developed everywhere. It is correlated with the Elliot Formation of the Beaufort Group in the main Karoo basin to the south.

Overlying this is a fine- to medium-grained, homogeneous sandstone ranging from white to pale cream in colour. This is known as the Tshipise Sandstone Member; it outcrops somewhat better than the underlying siltstone and in places contains calcareous concretions.

8.3 LEBOMBO GROUP

The Lebombo Group overlies the sedimentary rocks and constitutes the volcanic portion of the Karoo succession. It consists of a thick (in the order of 10 km) succession of ultrabasic to acid volcanic rocks which form an essential part of the so-called Lebombo monocline, a major flexural feature bordering South Africa, Swaziland and Mocambique to the east. SACS (1980) distinguished two formations within the Lebombo Group: the *Letaba Formation* includes the ultrabasic to basic volcanics and the *Jozini Formation* incorporates the acid volcanics.

The rocks of the Lebombo Group, and the Lebombo belt in particular, received considerable attention in the past although relatively few people dealt with the rocks within the map area. Du Toit (1929) considered the acid volcanics to be differentiates of the basic magmas and concluded that the *Tshokwane Granophyre* represents feeders for the acid lavas. Van Eeden et al. (1955) carried out a regional mapping programme in the northern part of the Lebombo belt. The most recent in the map area is that of Bristow (1980) who made a detailed study of the geochemistry and geochronology of the Lebombo Group. The following descriptions draw largely on his work.

8.3.1 Letaba Formation

The Letaba Formation consists predominantly of olivine-rich and olivine-poor tholeiitic lavas. Nephelinitic and picritic lavas, glassy olivine-bearing lavas and olivine-basalt flows are present at the base of the succession. Towards the top of the formation intercalations of rhyolitic lava become increasingly abundant and their presence gives rise to topographic ridges in the otherwise flat country underlain by the basic rocks. The basic rocks are greenish in colour, fine grained and in places contain pillow structures. Bristow (1980) considered the basic volcanism to have started at about 190 Ma ago.

The layering in the Letaba Formation dips eastward at angles between 5 and 25° and the formation has an estimated total thickness of more than 2 km. The transition into the overlying Jozini Formation is a gradual one marked by an increasing occurrence of rhyolitic intercalations.

8.3.2 Jozini Formation

The Jozini Formation consists of a very prominent succession of acid volcanic rocks. They are resistant to weathering and erosion and consequently have a strong topographic expression, forming the backbone of the Lebombo Range. The volcanics are predominantly pale cream to red and purple in colour and range from dacite to rhyolite in composition with rhyodacite forming the predominent rock type. Rocks intermediate in composition between the basic and ultrabasic Letaba volcanics and the Jozini acid volcanics do exist but are volumetrically insignificant.

The acid units range in thickness between 80 and 350 m and can be traced along strike for considerable distances. Composite units in which a number of zones can be recognised are present among the thicker units (Bristow and Cleverly 1979). At the base of the units there is often a tuffaceous zone which is in part reworked material from an underlying unit. This is overlain by a microcrystalline or glassy basal streaky zone with a banded appearance which grades upward into a massive zone which has a micrographic to felsic texture and contains phenocrysts of quartz and feldspar. The massive zone constitutes 90 to 95 per cent of the flow unit. A contorted zone followed by a breccia zone commonly overlies the massive zone and forms the upper part of the flow unit. Bristow and Cleverly (1979) considered the majority of the flow units to be ignimbritic in origin and regarded conditions of high heat retentivity of the ash flows to have resulted in homogenisation and destruction of the primary ignimbritic textures.

Cleverly and Betton (1979) considered the rhyolite of the Jozini Formation to form a co-genetic suite with the Karoo dolerites. The magma was probably derived by fractional crystallisation or partial melting of basic material previously emplaced at the base of the crust.

9. TSHOKWANE GRANOPHYRE

A number of separate bodies of granophyre, named Tshokwane Granophyre, are present within the volcanic units of the Jozini and Letaba Formations. It forms north–south elongated bodies that are clearly intrusive in the volcanic units. It is a pale cream-coloured rock, forming topographic highs (hills and ridges) and consists of quartz, K-feldspar and augite. A large proportion of the quartz and feldspar are micrographically intergrown. Its geological setting resembles that of the Stavoren Granophyre of the Bushveld Complex which is considered to be a hypabyssal equivalent of the volcanic rocks of the Rooiberg Group (Hall 1932; Walraven 1982). In similarity to the former, the Tshokwane Granophyre probably represents feeder channels for the rhyolite of the Jozini Formation as well as shallow intrusive equivalents of the rhyolite (Willson 1977). Age determinations carried out on correlated granophyre from Swaziland indicate ages in the order of 175 to 202 Ma (Vail 1968; Manton 1968) and suggest that the Tshokwane Granophyre could be of a similar age.

10. DYKES OF VARIOUS AGES

Basic to intermediate dykes traverse much of the map area. In the pre-Transvaal lowveld area three dyke trends are present, north–south, east–west and northeast–southwest. These dykes exert a strong control on the topography of the area and much of the drainage pattern is located on such dykes. Where they outcrop, most of the dykes have been found to be diabasic in composition.

A prominent east–west dyke extends across the lowveld, just north of Bushbuck Ridge, from the escarpment in the west up to the Lebombo Range in the east. Schutte (1982) informally referred to this dyke as the "Rykoppies dyke" since it forms a prominent row of koppies extending across the lowveld. Although the name *Rykoppies Gabbro** was proposed to SACS, the dyke is andesitic to basic in composition and contains numerous inclusions of the host-rock material as well as other material of unknown origin. It is considered to be older than the rocks of the Transvaal Sequence, since the latter overlie it and are not penetrated by the dyke and it also predates the Timbavati Gabbro which intrudes it. It is offset in places by north–south-trending shear zones.

Numerous prominent dykes are present in the rocks of the Transvaal Sequence along the escarpment and in the high country in the western part of the map area. Most prominent among these are the long, continuous dykes trending slightly east of north. These dykes exert an obvious control on the topography of this region also, especially near to the escarpment where deep gorges have formed along the dyke trends. As will be mentioned in the section on economic geology, these dykes have also had an influence on mineralisation processes in the region. Both doleritic and diabasic dykes are observed.

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* Name not yet approved by SACS.

Both north–south- and east–west-trending dykes are present in the Lebombo Range along the eastern margin of the map area.

11. QUATERNARY DEPOSITS

Quaternary deposits in the map area include residual soils, alluvial deposits and scree deposits. Outcrop in the map area, especially on the granites and gneisses of the lowveld, is very poor and the greater part of the area is covered by residual soils formed *in situ* on the granites, gneisses and migmatites. These residual soils are predominantly sandy and gritty in nature and consist mainly of feldspar and quartz. Residual soils formed on the rocks of the Transvaal Sequence are more clayey and better suited to agricultural activities.

Alluvial deposits are found along most of the streams traversing the map area. The actual deposits vary according to the geology of the area and in the lowveld the alluvium consists mainly of sandy material with occasional pebble layers. Silty and clayey material predominate in the alluvial deposits on the Transvaal Sequence rocks.

Prominent scree deposits, including alluvial fans, are present in parts of the map area, predominantly along the escarpment. Here thick wedges of coarse conglomeratic material adjoin the escarpment, obscuring the underlying geology. Evidence of cyclicity is seen in the presence of scree deposits on the top of small hills some distance away from the escarpment. The rock types making up the conglomeratic scree include chert, indicating that the former were evidently derived from the rocks of the Transvaal Sequence.

12. STRUCTURE

The older rocks in the map area, especially the migmatites and gneisses in the northern part of the lowveld, underwent a number of periods of deformation during which they were intensely folded and strongly metamorphosed. Further to the south, the biotite gneiss has a strong regional foliation but appears to have gone through fewer periods of deformation than the migmatite and gneiss. Still further south, the granites of the Nelspruit Suite underwent relatively little deformation, except for their marginal zones where intense interaction between the Nelspruit granites and the gneissic and migmatitic country rocks resulted in highly deformed rocks.

A number of north–south-oriented shear zones are present in the pre-Transvaal rocks and some have displaced older dykes. Faulting is seen in the Transvaal Sequence rocks and also in the younger Karoo rocks of the Lebombo Range. These faults are predominantly oriented northwest–southeast and northeast–southwest and in places have resulted in moderate displacements. North–south-oriented faults are also present in the Lebombo

Range and their presence is possibly related to the East African Rift and the Mozambique Monocline. Prominent northeast–southwest-oriented faults in the southwestern corner of the map area, including the Steelpoort Fault, are considered to have played a significant role in the intrusion history of the Bushveld Complex, acting both as channels for the movement of magma as well as terminators of moving blocks of crust and overlying strata.

13. ECONOMIC GEOLOGY

The information in the following section was largely obtained from the Geological Survey's handbook on the mineral resources of the Republic of South Africa (Coetzee 1976). It is of necessity highly condensed and the reader is referred to this publication for further details.

The area covered by the Pilgrim's Rest map is of economic interest mainly as far as the Transvaal rocks and the rocks of the Bushveld Complex are concerned. *Gold* was a very important resource in the Pilgrim's Rest–Sabie region where both prospecting and mining were undertaken during the early and middle parts of this century. Gold was recovered as alluvial gold, from gold-bearing conglomerates in the Black Reef Formation and in the dolomite of the Chuniespoort Group higher in the succession. In the latter, sheetlike veins, having a lateral extent of over 8 to 10 km, tend to group at specific stratigraphic levels. These veins are referred to as flat lodes and form by far the most important source of gold. Glynns' Reef was one of the most prominent of the flat lodes and produced about 40 000 kg. Vertical lodes, leaders, blows and irregular ore bodies, although less important generally, also proved significant at times. *Copper, silver* and *lead* accompany the gold in places.

The rocks of the Bushveld Complex constitute a valuable resource of *platinum-group metals* and *chromium,* which are found in the Croydon and Dwars River Subsuites in the Merensky Reef and the chromitite layers respectively. Significant differences exist in the chromitite layers to the north and south of the Steelpoort Fault, which affect their economic potential. South of the fault only the upper and middle groups of chromitite layers are present, whereas north of it the middle group is absent and only the upper and lower groups are developed.

Titanium and *vanadium* are present in significant quantities in the magnetite layers in the Roossenekal Subsuite. Although being exploited to the west and south of the map area, no active mining for any of these elements is presently taking place within the area. Another valuable resource associated with the Bushveld Complex is *magnesite* which occurs in a peripheral belt along the base of the complex. Active mining took place in the past on and around Aapiesdoorndraai 298 KT but at present the major activities are centered on Aapiesbomen 295 KT, nearby.

Andalusite, which is indirectly associated with the Bushveld Complex as a causative agent, was formed in shales of the Pretoria Group by metamorphism caused by the basic rocks of the complex. Its development is directly related to the metamorphic aureole of the complex and is restricted within the so-called "andalusite isograd" of Button (1976b) which transgresses to lower stratigraphic levels from south to north. Exploitation of andalusite is taking place at a number of localities within the map area.

Asbestos forms an important resource in the rocks of the Chuniespoort Group in the northwestern part of the map area. Both *amosite* and *crocidolite* asbestos, the latter being better developed towards the northwestern part of the map area, are being actively mined in the area around Penge and to its west and southeast.

Iron is present in the banded iron formation of the Penge Formation but it is not sufficiently enriched to constitute an economic proposition at the present time. *Manganese*, which was concentrated in wad formed on the dolomite and limestone of the Chuniespoort Group, was mined in the past in the Graskop area. It is, however, of low grade and limited to a few million tons of reserves.

Rocks of the Murchison Range extend from the north into the map area and quite a number of deposits of various minerals are associated with them. These include deposits of semiprecious *gemstones*, *mica*, *feldspar*, *beryllium*, *tantalum*, *phosphate*, *talc* and *magnesite*. Many of these deposits were mined in the past and a number of the prospects are still being worked on a minor scale today.

A major source of *copper* is the carbonatite pipe at Loole Kop, Phalaborwa, the southern part of which is located within the map area. The copper is produced as a by-product from phoscorite. The annual production from the Phalaborwa Mine is in the order of 100 000 tons of anode copper. *Phosphate* is also a major product of the Phalaborwa Mine where it is present as apatite in the carbonatite and in pyroxenite. At the end of 1972 the annual production of phosphate concentrate was 4,5 million tons at 36,4 per cent P_2O_5.

Deposits of other commodities are also to be found in the map area. Few of these are of sufficient size, however, to warrant commercial exploitation.

14. SITES OF GEOLOGICAL INTEREST

14.1 ABEL ERASMUS PASS

Road cuttings along the main road through the Abel Erasmus Pass (Fig. 1) expose a very interesting and informative site of geological interest. This road extends from the pre-Transvaal lowveld up to the Drakensberg escarpment to the Transvaal highveld. Here can be seen, from north to south, a complete profile of the Wolkberg Group from its basal contact where it rests unconformably on the Swazian basement gneiss, up to and including its upper contact where it is overlain by the Black Reef Formation and the Pretoria Group.

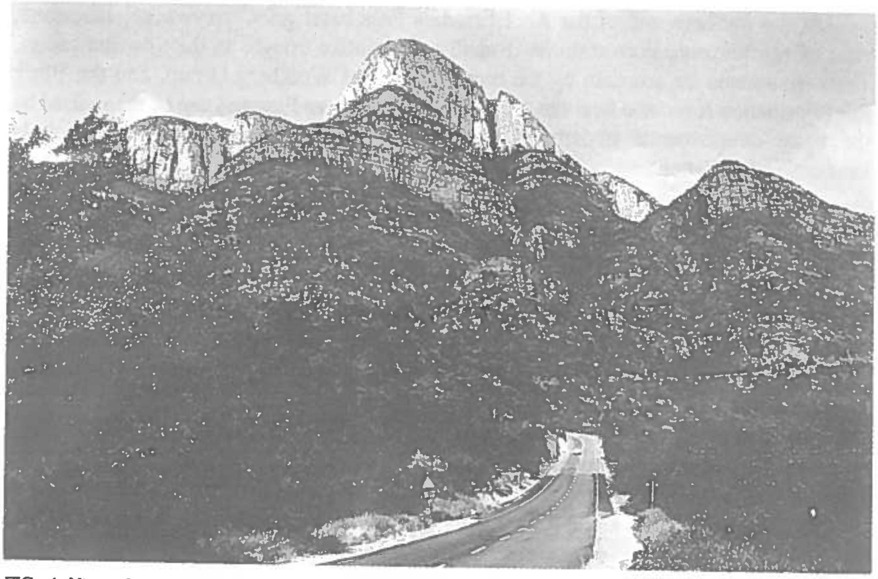

FIG. 1 View of the cliffs at the Abel Erasmus Pass presenting a clear impression of the various strata constituting the Wolkberg Group and the Black Reef Formation (photo by F. Walraven).

FIG. 2 View of the Rykoppies dyke forming a prominent ridge across the granite-gneiss lowveld terrain (photo by F. Walraven).

At the northern end of the Abel Erasmus Pass basal grits, greywacke, limestone, etc., of the Sekororo Formation lie in shallow, basinlike troughs in the Swazian gneiss. These sediments are overlain by the remainder of the Wolkberg Group, and the Black Reef Formation is located near the top of the Abel Erasmus Pass and can be recognised by the basal conglomerate underlying the massive, thick succession of clean, pebbly sandstone of the latter.

14.2 RYKOPPIES DYKE

A short distance north of Bushbuck Ridge, in the eastern Transvaal lowveld, a very prominent dyke extends east–west across the granites and gneisses of the pre-Transvaal basement. This dyke (Fig. 2), which is intermediate to basic in composition and which in places is extremely contaminated by inclusions of country rock, stands out prominently above the relatively flat topography formed by the granites and gneisses. It extends from the Transvaal escarpment in the west up to the rocks of the Karoo Sequence in the Kruger National Park in the east, becoming gradually less prominent eastward. The main road through Bushbuck Ridge to the north passes through a gap in the Rykoppies Dyke and at this location, as well as along a secondary road extending to the east, the rocks of this dyke may be inspected.

FIG. 3 Contact relations between the Cunning Moor Tonalite and granites of the Nelspruit Granite Suite (photo by F. Walraven).

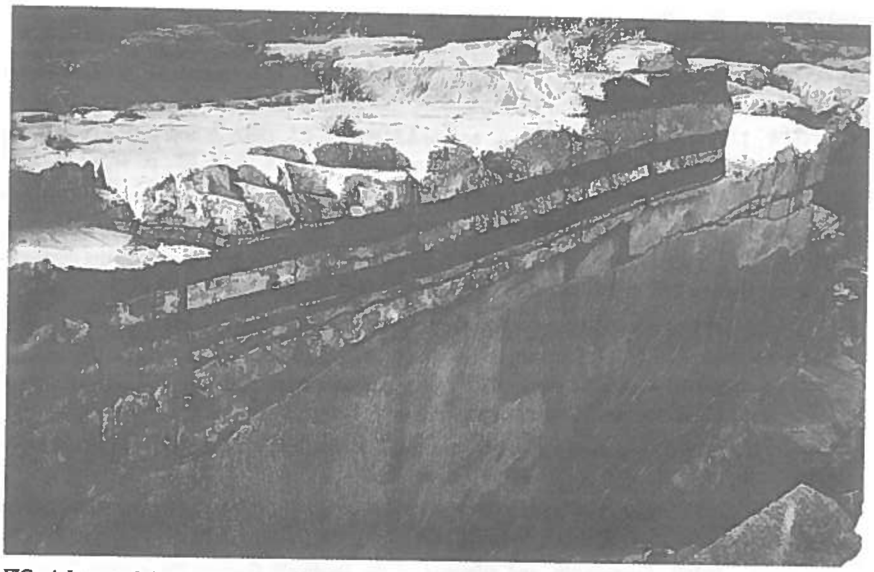

FIG. 4 Layers of chromitite in anorthosite exposed in the riverbed of the Dwars River, eastern Transvaal (photo by F. Walraven).

14.3 CONTACT BETWEEN CUNNING MOOR TONALITE AND NELSPRUIT SUITE GRANITES

Immediately north of Bushbuck Ridge contact relationships between a number of granite types of the eastern Transvaal lowveld are exposed in a cutting along the main road (Fig. 3). The rock types involved are granites of the Nelspruit Granite Suite and the Cunning Moor Tonalite and complex relationships are evident between various phases of both rock groups.

14.4 DWARS RIVER CHROMITITE IN ANORTHOSITE

The riverbed exposure of chromitite in anorthosite located in the southwestern part of the map area is not only a site of geological interest but was also declared a national monument. At this site (Fig. 4) the Dwars River produced an unparalleled exposure of rocks of the Dwars River Subsuite of the Bushveld Complex, displaying in detail the relationships between chromitite layers and the enclosing anorthosite.

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