RHODESIA GEOLOGICAL SURVEY
BULLETIN No. 80

An Outline of the Geology of Rhodesia

by
J. G. STAGMAN, D.Sc., C.Eng., F.I.M.M.
with contributions from
N. M. HARRISON, T. J. BRODERICK & V. R. STOCKLMAYER

ISSUED BY AUTHORITY

SALISBURY — 1978

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INTRODUCTORY NOTE

This Bulletin, which was originally published in 1978, has been in great demand as a result of renewed interest in the geology and mineral resources of Zimbabwe which followed the removal of United Nations sanctions early in 1980. In order to meet this continuing demand reprinting is necessary. In the interest of speed and economy the reprinting has been done by the photo-lithographic process with the result that the text is identical to the first printing with no alterations, updatings or corrections.

Apart from this Introductory Note the only addition to the original Bulletin is the insertion of Table IIIA, Zimbabwe Mineral Production and Value, on page 114A. Due to the then prevailing security regulations the original Table III gives statistics only to the 31st December, 1965. The new table provides information to the 31st December, 1979.

E. R. MORRISON,
Director.

GEOLOGICAL SURVEY DEPARTMENT,
SALISBURY

11th February, 1981.

PREFACE

This bulletin, the third of its kind in the 68 year history of the Geological Survey, has been written as an explanation of the 7th edition of the Provisional Geological Map of Rhodesia, which was published in November, 1977, on a scale of 1 : 1 000 000. As such it will clearly be of advantage to read or consult it in conjunction with the map.

Being seventeen years since the last report of this nature was compiled, the account contains considerably more information than previous issues and provides an up to date description of the geology of the country and its mineral resources as they are understood today.

Writing on a scientific topic can never be accomplished satisfactorily without the use of specialized terms and geology with its allied disciplines abounds in these. In this report they have been kept to a minimum with the hope that a wide spectrum of the public will find the bulletin to be of value and interest. To this end each chapter has been divided into sections dealing with the academic aspects, in abbreviated form, and followed by descriptions of the economic resources and potential.

As a departure from the norm, the report is illustrated with statistical tables, a map showing the stage of geological mapping reached by the end of 1976 and several photographic plates of geological scenes which are unique. The department is grateful to Dr. L. A. Lister for permission to reproduce her photograph of granitic terrain in Mtoko area, to the Anglo American Corporation of South Africa for views of Wankie Colliery and the Trojan nickel mine, and to the Photographic Section of the Ministry of Information for the others.

At the end of the bulletin there is a complete list of the publications of the Geological Survey which is supplemented by selected references to subjects currently of particular academic interest. To provide a complete bibliography would have been an impossibility.

GEOLOGICAL SURVEY DEPARTMENT,
SALISBURY

23rd January, 1978

J. G. STAGMAN,
Director.

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INTRODUCTION

The first publication designed to convey information on the geology of the country to the public at large was a Provisional Table of Geological Formations issued as Short Report No. 7 of this series in 1919 and reprinted in 1921 without change. The table, expanded with explanatory notes and accompanied by a small scale geological map appeared in 1924, to be reprinted as Short Report No. 24, in 1929. All of these were compiled by H. B. Maufe who had been appointed director of the Geological Survey Department on its formation in 1910. The reports illustrate what a remarkably good understanding of the geology of the country had been achieved, in a relatively short time, by a very small body of men. In 1910, the staff consisted of three geologists and one draughtsman and it had barely doubled 20 years later. Large parts of Rhodesia were almost inaccessible; there were virtually no topographic maps and transport consisted of ox or mule-drawn waggons.

A. M. Macgregor's Bulletin No. 38 prepared in 1947, to accompany the 4th Edition of the Provisional Geological Map of Southern Rhodesia on a scale of 1 : 1 000 000, was very much more comprehensive and proposed a system of classification for the mineral-rich Basement Complex which has stood up well to the test of time. It was revised in part and published as Bulletin No. 50 to accompany the 1961 edition of the map. Since then, with a much enlarged establishment, the department has accumulated a great amount of new information particularly pertaining to the Zambezi and Limpopo metamorphic belts. This has been correlated and has been summarized, together with new data on many other aspects of the country's geology, for incorporation in the present publication.

In preparing this bulletin, all available sources of information have been used. In addition to work carried out by geologists of the department, mining exploration companies have contributed greatly in the form of Exclusive Prospecting Order final reports, of which more than 500 are filed in the departmental library.

Frontispiece: Victoria Falls, occupying joint pattern in Karoo Basalt.

The researches of students from the University of Rhodesia, the African Research Institute of Leeds University and more recently those from Oxford University have also contributed. Much research work, in the fields of geochemistry and metallurgy, has been undertaken by staff of the Institute of Mining Research, a very well equipped organization, formed in Salisbury in 1969.

The accounts of the Kalahari and Pleistocene systems are those prepared by Professor G. Bond, now Vice Principal of the University of Rhodesia, for the previous edition of "An Outline of the Geology of Rhodesia". Apart from metrication and modernizing of place names they have not been altered. The section entitled "Development of the Topography" is based entirely on the thesis describing the geomorphology of Rhodesia written by Dr. L. A. Lister of the Geology Department of the University of Rhodesia and Professor J. F. Wilson, head of the same department, assisted greatly in the compilation of the chapter dealing with the Basement Complex.

In view of the very numerous sources of information that have been consulted it is deemed to be quite impracticable to include references in the text; and a table listing geological formations and events has not been included because the conventional chronological order of arrangement of the chapters in the text is a more detailed substitute which is augmented by the explanation printed on the map.

PHYSICAL FEATURES

RHODESIA is situated between 15° 40′ and 22° 20′ south latitude, and 25° and 33° east longitude, and is bounded on the south and west by the Republic of South Africa and Botswana, on the north by the Zambezi River and Zambia, and on the east side by Mozambique. The area of the country is a little over 390 000 km², or about three times that of England and Wales.

Although its boundaries were determined from political considerations, Rhodesia as part of Africa has an identity of its own, in that it is a relatively high region surrounded by lower country on all sides.

The central portion forms a plateau dominated by a pronounced peneplain and carries the divide between the Zambezi Basin and the Makarikari Depression on the north and west, and the Sabi-Limpopo Basin on the south-east. At its north-eastern end the plateau joins a narrow belt of mountainous country striking north and south along the eastern border. It is only in this narrow area that the altitude rises above 1 800 metres, although, owing to the flat nature of the central uplands, more than twenty-one per cent of the area of the country is above the 1 200 metre contour.

The main divide runs from Inyanga in the eastern mountains through Marandellas, south-east of Enkeldoorn to Umvuma, and thence it carries the railway line through Bulawayo to Botswana. On the south-east side of the plateau the country falls into the Sabi-Limpopo Basin, which is bounded on the east by the Melsetter Mountains. Between the upper reaches of the rivers which drain into the depression, peaks have been left to form the Matopos, Selukwe and other hills. Owing to a gentle westerly pitch of the peneplain the higher peaks rise above the level of the divide, in contrast to those on the western side of it, which are all lower. The relief decreases as one goes down the slope towards the flat-lying lowveld below 600 metres. It is worthy of note that the divide between the twin rivers which drain the basin, and flow independently into the sea, makes no greater feature than do some of the minor divides between tributary streams.

With the exception of the Nata River and its tributaries which flow into the land-locked Makarikari Basin in Botswana, the rivers on the northern and western sides of the plateau drain into the Zambesi. The divide between these major basins is even more featureless than the one between the Sabi and Limpopo rivers.

From south of Bulawayo to north of Gwelo the plateau is drained by the Gwai and Shangani rivers, with their tributaries. The Gwai River joins the Zambezi near the point where it changes its course from east to north-east. East of this is the basin of the Sanyati. Unfortunately, a too strict adherence to native dialect has led to confusion, since the upper part of this river is written as Umniati. The Sanyati which formerly joined the Zambezi a few kilometres above Kariba Gorge now debouches into the lake 30 kilometres of the dam wall. On the south and north sides of the basin, spurs of the plateau extend towards the Zambezi, forming the Mafungabusi Plateau and the high ground of the Karoi-Miami area.

As the Zambezi River regains its easterly course before entering Mozambique territory the courses of its southern tributaries change to north and north-east, in contrast to the general north-westerly direction of the Gwai and Sanyati systems. The upper portion of the Hunyani however, is an exception; it is probable that at one time it drained into the Sanyati and that it has since been captured by the river which now forms its lower course. The Mazoe River with its tributary, the Ruenya, drains the north-eastern corner of Rhodesia. It joins the Zambezi River in Mozambique below the Cabora Bassa Rapids in which the Zambezi falls about 150 metres. There is a considerable extension of the plateau northwards between the Hunyani and Mazoe basins.

Escarpments 300 to 450 metres high face the Zambezi River on both sides along nearly its whole course below Wankie. They are caused by faulting, and consist of hard rocks, mainly gneiss, with softer and younger rocks at the foot. The scarps above the Kariba Gorge strike north-east and step back *en échelon*. Below the gorge the main scarp strikes east and west.

The eastern mountain range comprises two main portions. The Inyanga Mountains in the north form a plateau 2 100 metres high, about 50 km long and 8 km wide. It terminates at its southern end in Inyangani, the highest point in the country, 2 592 metres above sea-level. South of this the highlands drop with intermittent breaks, the most important of which is at Umtali. South of that the range rises again as the Melsetter Uplands. These are in part caused by a faulted uplift, but no evidence of faulting around the Inyanga Mountains has been published.

THE BASEMENT COMPLEX

Examination of the geological map of Rhodesia shows that a line drawn obliquely from a point on the border 25 km west of Plumtree to near the Zambezi River north of Sinoia divides the country into two unequal portions. That west of the line contains small areas of granite, but is composed mainly of younger rocks. The larger portion consists mainly of granite and gneiss with relatively small, irregularly shaped inclusions of other rocks which are locally referred to as gold belts and are also known as schist belts or greenstone belts. In almost every case examined where the evidence is clear the granitic rocks have been found to be intrusive into the marginal rocks of the gold belts. Taken together the granites, gneisses and gold belts are called the Basement Complex since, although they form the central highlands, they are the foundations on which all younger formations were deposited.

In every continent of the world there are tracts of country, known as crystalline shields or in more modern usage cratons, composed of granite and older rocks with similar relations to those in this country. In Canada, India, Australia and Brazil they contain important gold fields. These areas are ringed about by younger, apparently unfossiliferous rocks which in turn, are overlain by strata containing fossil remains of the earliest known Metazoan, or multicellular, forms of life that have been recognised. They have an age of about 700 million years (Ma). With the aid of the electron microscope it has been shown that evidence of life is contained in the very much older rocks always thought to be unfossiliferous. However, fossil evidence is of no value in determining the age of the greater proportion of Rhodesia rock formations, but fortunately great advances in age-dating techniques, based on radioactive decay of certain elements, provide another method of approach. Using this it has been shown that the Basement Complex is extremely old as its formation was initiated at least 3 500 Ma ago and not completed until about 2 600 Ma ago.

Owing to their economic importance the gold belts have been carefully mapped and studied, and the results of the work are published in the bulletins and short reports of the Geological Survey.

When the gold belts of the country are compared with one another, certain striking similarities appear in regard both to composition of the rocks and to their structural relations. The commonest rocks throughout are recognised as lavas with basaltic or andesitic composition. A very common feature of the basalts is pillow structure resulting from consolidation of the lava under water. Pillow lavas are found from Gwanda in the south to Darwin in the north and from Bulawayo in the west to Makaha and Umtali in the east. In interpreting the geological structure of the rocks, which almost everywhere dip steeply and are often inverted, pillow lavas are valuable aids since they afford a means of distinguishing between the original upper and lower surfaces of the flows.

Among the lavas, often called greenstones because their primary minerals have been altered to green-coloured amphibole and chlorite, there are beds or intercalations of sedimentary rocks. Some of these mapped as sediments in the past have been shown, by more detailed investigations, to consist of tuffs and agglomerates; and recognition of igneous textures and structures has revealed that some, thought to be quartzites, are in reality felsites, rhyolites and other acid lavas and associated pyroclastic rocks. Throughout the succession at several horizons are the ironstone formations, rocks which generally produce strong topographic features of considerable strike extent and are a primary aid in elucidation of the structure of the gold belts. The ironstones, usually hard and banded, cherty ferruginous rocks are almost invariably associated with phyllites of volcanogenic origin and many of the country's Archaean limestones occur in the same environment. Regional metamorphic grade is most commonly very low so that initial textures and structures are retained, but the thermal effects of granite intrusion are quite evident in the smaller belts and in those of the northern part of the craton.

Until a few years ago it seemed reasonable to conclude that the greenstone lavas and their interbedded sediments constituted a single eruptive mass of great extent and thickness exceeding 12 000 metres in places; that they were all formed during a single lapse of time, and therefore that they were worthy of a single geological name. The first clear description of a typical section of these rocks was given by F. P. Mennell in 1906. He called them the Bulawayo Schists so it is fitting that his work should be perpetuated in the form of Bulawayan Group in accord with modern terminology, although in the light of present knowledge difficulties in nomenclature now arise. Very detailed mapping in the southern part of the country, in Belingwe area particularly, has shown that excluding the very old Sebakwian Group, there were at least two periods of mafic lava effusion perhaps widely separated in time. The investigations are being expanded northwards and when complete it may be necessary to introduce new terminology. For the time being "Lower

Bulawayan" is used for the older suite. These older greenstones apparently do not form part of the greater extent of the country's schist belts so for the most part Bulawayan Group remains as defined by A. M. Macgregor in 1947.

Overlying the greenstones in all of the larger belts are sedimentary rocks of an undifferentiated nature such as conglomerates, greywackes and arkoses, all to some extent metamorphosed especially in the north. The differentiated sediments, sandstones, shales and limestones or their altered equivalents are rare or absent. These assemblages have been given various names in different parts of the country, but they are sufficiently similar to justify a comprehensive term to cover them all in one age group. Although the Shamva Grits of the Mazoe Valley were not the first to be described, they occupy the largest continuous area than has been well studied and the name Shamvaian Group has been adopted. Like the Bulawayan, the Shamvaian is known to be more complex than previously envisaged and acid lavas, tuffs and agglomerates are important components in the basal part of the succession in some districts.

Of restricted distribution and characteristic of the southern parts of the country are the formerly termed Magnesian Schists and those sediments which can be proved, or surmised on good grounds, to be older than the Bulawayan greenstones. They are known as the Sebakwian Group. Examples are provided in the underground workings at Selukwe where chrome-bearing talc schists underlie the conglomerate at the base of the greenstones; and in the Gwelo Valley there are sediments and magnesian schists of different structural style and attitude to the overlying greenstones.

Differentiated ultramafic complexes have been distinguished in association with the two older groups, more particularly in the southern part of the country. There are at least two categories, the younger of which is exemplified by the Mashaba Igneous Complex. This is post-Bulawayan or perhaps more correctly intra-Bulawayan in age but antedates the instrusion of the Younger Granites. Of very much greater age is the Selukwe Complex, composed of serpentinite and its derivatives, which has suffered extreme deformation and may be regarded as an intergral part of the Sebakwian Group. Both are of considerable importance on account of their chrome and asbestos mineralization, and the younger category in respect of nickel as well.

When Macgregor introduced the three-fold classification of the schist belts in 1947 little regard was paid to absolute ages although stratigraphic succession and lithological composition were very carefully considered. Radiometric dating of rock successions was then in its infancy and not even a guess could be hazarded beyond the belief that the events were far back in the geological time scale.

The following 25 years saw great advances in mapping of Basement Complex terrain and a record of radiometric ages was gradually built up, although the sampling was not fully representative and remains patchy to the present day. Analysis of this record indicated that the oldest activity was of greater age than 3 300 Ma, evidenced as Sebakwian remnants incorporated as inclusions in granitic gneiss. The time of formation of the main greenstones was placed at greater than 2 900 Ma as they were believed to be intruded by granites of that age. Other greenstones and some Shamvaian sediments were placed between 2 900 Ma and the period of intrusion of the Younger Granites which occurred between 2 700 Ma and 2 600 Ma ago. The final phase of granite intrusion culminated in consolidation of the craton to allow intrusion of the Great Dyke about 2 500 Ma ago.

A more recent analysis, discarding many of the earlier K-Ar results as unsatisfactory and placing reliance on Rb-Sr isochron determinations gives a rather different picture but one still not sufficiently definitive to warrant any major alteration to Macgregor's time-honoured nomenclature. The Sebakwian age is now placed at greater than 3 500 Ma which saw mobilization of the gneisses at Mashaba and Shabani and intrusion of the Mushandike and Mont d'Or granites in the same general area. Intrusion of the Mashaba and Chingezi tonalites at about 2 900 Ma ago has not yet been linked with greenstone deposition. The greater part of the Bulawayan, now termed Upper Bulawayan, is dated at 2 700 Ma and it was followed by deposition of the Shamvaian before intrusion of the Younger Granite at about 2 650 Ma ago. The detailed investigation in the well-exposed Belingwe Schist Belt has led to recognition of a thick sequence of lavas and sediments which have an intrusive relationship with the 2 900 Ma old Chingezi gneiss of the area. This sequence has been termed Lower Bulawayan and is without doubt unconformably overlain by Upper Bulawayan in the same area. The Upper Bulawayan transgresses northwards to rest unconformably on 3 500 Ma gneiss but the relationship of Lower Bulawayan with the same ancient gneiss has not yet been established. Should it be intrusive the Lower Bulawayan would become Sebakwian and there would be a great hiatus between Sebakwian and Bulawayan. For the time being the more likely linkage of Lower and Upper Bulawayan is preferred but there are many gaps in the record that require explanation.

SEBAKWIAN GROUP

Of the three groups which make up the schist belts, the Sebakwian is the oldest and most difficult to define. Exposures are limited and lithologies are often similar to the lower parts of the Bulawayan succession. Sebakwian rocks have been recognised only in the south-central part of the craton where age determinations and relationships with the Bulawayan are better known. In this area the Sebakwian Group can be defined as a suite of ultramafic rocks with ironstones and minor greenstones plus felsic sediments and volcanic rocks which underlie the Bulawayan Group with marked unconformity; and in certain instances exhibit a higher degree of metamorphism and deformation. Forming an important part of the group are remnant greenstone inclusions within older gneisses which have been dated at 3 500 Ma.

The succession is very variable and of fragmentary nature and there appears to be no feature such as a thick pile of lavas, like those of the Bulawayan, which is diagnostic. Furthermore it has not been possible to define the basement on which the Sebakwian Group was laid down.

In 1932, Macgregor introduced the term "Magnesian Series" to denote a suite of dominantly ultramafic rocks lying beneath a granite cobble conglomerate in the Sebakwe River near Que Que. He believed that it marked the base of the "Volcanic Series". In 1947 the term Sebakwian System replaced Magnesian Series and the overlaying volcanic pile was designated Bulawayan System. With adoption of lithostratigraphic terminology, "system" has become "group".

Later mapping in the Que Que area has shown that the ultramafic rocks, serpentinized and in part heavily carbonated, represent an intra-Bulawayan intrusive complex. They are therefore not Sebakwian and the only remaining members of the group in this particular area are large inclusions in the Rhodesdale gneisses. These are elongated xenoliths of serpentinite, grunerite quartzite, fuchsite quartzite and epidiorite that trend north.

North-west of Gwelo, tightly folded ironstone, hornblende schist, pale-coloured sediments and ultramafic schists underlie the thick Bulawayan basaltic pile. They are at a higher grade of metamorphism and have been deformed prior to the deposition of the basalts. They form the rim around the northern and eastern margins of the Shangani granite terrain for some 50 km and continue sporadically to south-east of Gwelo where the ultramafic varieties are poorly represented and micaceous schists become prominent. At the point where the strike swings due south a marked disconformity with the overlying greenstones becomes apparent. The band passes southwards to form part of the Selukwe Greenstone Belt, a structurally very complex terrain in which the only known example of nappe structures, in the Basement Complex, has been recognised.

The inverted stratigraphy was suspected by Maufe and Macgregor in the early part of the century and was confirmed by Tyndale-Biscoe in 1947. However, it was not until 1960 that an extensive deep drilling programme, conducted over the chrome claims of the area, enabled the details of the structure to be elucidated. The nappe is believed to have moved northwards for some 40 km from a migmatitic zone south of Selukwe. Its upper limb has been removed by erosion and only the inverted lower limb is preserved. Numerous faults and thrusts add to the complexity. Remnants of chromite-bearing rocks preserved in the granite on the eastern side of the Great Dyke suggest that the nappe was formerly of much greater extent.

The Mont d'Or Formation is the basal part of the Sebakwian Group at Selukwe. It is a metasedimentary suite, granitized and intruded by tonalite which also cuts overlying greenstones and the ultramafic complex which contains large reserves of high-grade metallurgical chromite. Resting on these rocks with distinct erosional unconformity are the Wanderer conglomerate, grits, ironstones and further greenstones, all of which have also been involved in the nappe. The conglomerate contains chromite pebbles and was regarded as the base of the Bulawayan Group but both the Wanderer and Upper Greenstones formations are now allocated to the Sebakwian because a Mont d'Or granite, intrusive into the Wanderer Formation, has been dated at 3 400 Ma.

To the west and south of Selukwe are two additional, smaller linear folded belts of dominantly ultramafic composition. One of these, the Ghoko Belt, is thought to be an earlier phase of Sebakwian deposited prior to that part involved in the nappe tectonics.

The only other development of Sebakwian rocks of importance is in the Mashaba area where, excluding the Mashaba Igneous Complex, the entire schist belt is of Sebakwian age in spite of the fact that its metamorphic grade is of greenschist facies similar to Bulawayan rocks further east. From the western end of the belt a string of xenoliths in the banded gneisses curves from north-west round to north-north-east to produce a zone at least 50 km long by 20 km wide containing abundant inclusions. These are large and small, isoclinally folded bodies of sepentinite, talc schist and ironstone and suggest a very much more extensive coverage of the Sebakwian in this region in the past.

Other lesser ironstone-ultramafic rock assemblages as inclusions in the southern part of the craton are also probably Sebakwian remnants. However, there is little evidence to suggest that Sebakwian deposition extended into the northern half of the country.

In essence, evidence of Sebakwian deposition, which pre-dates the oldest known gneisses is retained only in a north-striking belt, 100 km wide, which extends from Mashaba in the south to near Gatooma and is not known elsewhere in the country. Furthermore the occurrence of ultramafic lavas and their feeder intrusions in a Basement Complex succession is not an exclusively Sebakwian hallmark as has sometimes been tacitly assumed.

BULAWAYAN GROUP

Lavas of basaltic and andesitic composition are overwhelming the major components of this group which also comprise the greater portion of the country's schist belts and define their overall pattern. Judging by the structural trends it seems probable that the lavas were extruded from mantle-tapping fractures to form depositories, striking north-north-east, east-north-east and north-west and that they have been modified by deformation attendant on intrusion of younger granites. Former lateral extent of the basalts and andesites was probably very much greater than at present. The most persistent trend is illustrated along the 500 km stretch from Bulawayo to Sipolilo and by the Mwanesi Belt. The Umtali, Fort Victoria, Mweza-Buhwa belts and several others follow the second trend and the north-westerly direction may be seen at Gwelo and from Filabusi to Bulawayo. The north-north-easterly and north-westerly directions are paralleled by strongly defined lineaments in the granites and gneisses, clearly visible on ERTS imagery. The structure of most of the belts is generally synclinal as a result, it is believed, of gravity induced down-sagging of the heavier basaltic material into a thin sialic crust.

The type area of the *Lower Bulawayan* is Belingwe where it flanks the schist belt on the west and south-east, having rather different development on the two sides. The basal part of the succession on the south-east, known as the Brooklands Formation, is obscured but total thickness may be several thousand metres. Lower quartzites, grits and conglomerates pass upwards into high-magnesium basalts which are in part pillowed and contain intercalations of ironstone and phyllites. The western occurrence has been separated into three formations. The lowermost is a poorly exposed formation of amphibolites infolded with the Chingezi gneiss. It is overlain by the Hokonui Formation consisting dominantly of felsic lavas and pyroclasts. The uppermost or Bend Formation has an alternating sequence of pillowed basalts, spinifex-textured high-magnesium basalts and ultramafic rocks with intercalations of the ironstone-phyllite assemblage. Capping the volcanic rocks is a thick conglomerate that contains an interbed of felsic agglomerate. All of these have been subjected to at least one episode of deformation prior to deposition of the Upper Bulawayan.

Being of variable stratigraphy, extrapolation of the Lower Bulawayan away from Belingwe would lack assurance were it not for the presence of the thin basal formation of the Upper Bulawayan known there as the Manjeri Formation. It is a stratigraphic unit of consistent nature and of widespread distribution which may be traced from the southern part of the craton up into the Midlands area and is everywhere overlain by a thick pile of basaltic lavas. From Belingwe it may be followed through the Filabusi Belt around past Fort Rixon and Shangani to the Lonely Mine area and thence in a sweep around the northern margin of the Shangani granite terrain towards Gwelo. Formations underlying this marker which in many stretches contain ultramafic rocks are assigned to the Lower Bulawayan on this basis. The Mweza-Buhwa Schist Belt, a short distance south of Belingwe across intrusive granite, is similarly correlated on the grounds that its lithology is markedly like portions of the Bend and Brooklands formations. The status of other similar successions containing prominent ultramafic units, such as the western end of the Fort Victoria Belt and the Odzi-Umtali Belt, remains obscure.

Using the Belingwe model as a starting point and expanding it through neighbouring greenstone belts the succession tabulated below has been established for the *Upper Bulawayan* of Rhodesia. In the light of present knowledge the basalts which dominate the succession are believed to have an age of extrusion of about 2 700 Ma. The total combined thickness of the order of 15 000 metres but in no individual area are all the units fully represented and it is doubtful if much more than half of this thickness obtains in any one schist belt. The succession generally holds well for the country south of Gatooma but has not been extrapolated to the north and north-east.

> CALC-ALKALINE SUITE: Andesite and dacite flows and pyroclasts. Basaltic lavas uncommon in the north, become more prominent southwards. Mafic sills are present. Metamorphic grade is generally lower than that of other Bulawayan formations. Thickness may exceed 4 000 metres.
>
> DIVERSE SUITE: Tholeiitic lavas with some development of high-magnesium, spinifex-textured basalts and ultramafic lavas alternate with felsic lavas and pyroclasts. Pyroclastic sediments of felsic composition are common in some areas as sericite schists; and pelitic sediments, as phyllites which are believed to be time-equivalent, are an important component in the country's south-eastern greenstone belts. Banded ironstone and local limestone, in places stromatolitic, are also a feature of the suite. Thickness is up to 4 000 metres.
>
> MAIN BASALT SUITE: This consists of a great thickness, up to 7 000 metres of tholeiitic basalts as massive and pillowed lavas. In the lower parts there is development of magnesium-rich lavas some of which are ultramafic. Pyroclasts and sedimentary intercalations are rare but there is a consistent basal formation composed of the banded ironstone-phyllite association with locally developed conglomerate, grit and limestone which may be stromatolitic.

The Manjeri Formation is the basal unit of the Main Basalt Suite in the Shabani-Belingwe Greenstone Belt. It is some 250 metres thick and has thin grit, conglomerate and limestone overlain by banded ironstone and phyllites. These are succeeded by 1 000 metres of high magnesium basalts and ultramafic lavas plus a differentiated ultramafic intrusion coupled as the Reliance Formation. The main unit of the suite is the Zeederbergs Formation of some 6 000 metres of tholeiitic basalts. The only representative of the Diverse Suite in this area is the

Cheshire Formation composed of 3 000 metres of pelitic sediments with intercalations of banded ironstone and lenses of stromatolitic limestone. Equivalent formations to the east at Fort Victoria and west at Filabusi contain in addition, mafic and felsic lavas and pyroclasts.

Most of the basaltic lavas of the Fort Rixon-Shangani Belt belong to the Main Basalt Suite occupying the peripheral portion of the major synclinal structure which tends towards closure at its northern end. On the north and east ultramafic units and the basal ironstones and phyllites are clearly defined. In the central part of the belt phyllites, ironstones and basalts are allocated to the Diverse Suite although the basaltic lavas are lithologically no different from those underlying them.

North-westwards in the Bubi area development of ultramafic rocks in the lower part of the Main Basalt Suite is well illustrated as a strip of spinifex-textured lavas striking almost due north along the eastern edge of the schist belt for some 30 km. They are overlain on the west by a 6 km width of tholeiitic basalts, here known as the Inyati Formation, and covered in the synclinal core by basalts, dacites and felsic agglomerates plus ironstone and limestone lenses of the Diverse Suite. These in turn are overlain, apparently conformably, by andesitic and rhyodacitic lavas and pyroclasts of the Calc-Alkaline Suite. All splay out southwards through the Lonely and Queens Mine areas to form the Bulawayo Greenstone Belt.

From Nkai towards Hunters Road, now striking east, the Main Basalt Suite has thinned considerably and dips north directly under andesites of the Maliyami Formation of the Calc-Alkaline Suite. Between Redcliff and Gwelo all elements of both lower suites thicken and basaltic lavas become prominent in the Diverse Suite. This raises the problem of distinguishing them from underlying basalts in some parts of the area.

In the country from Redcliff to beyond Gatooma the structure is extremely complex and whereas basalts of the Main Basalt Suite and both basalts and felsic volcanics of the Diverse Suite have been recognised and variously described as the Mafic, Felsic and What Cheer formations in the Que Que, Battlefields and Gatooma bulletin accounts, the stratigraphic successions have not yet been satisfactorily resolved. The same problem pertains to the Salisbury-Mazoe-Shamva Greenstone Belt and the smaller belts to the north and east but felsic lavas and pyroclastic rocks are more common in these areas than in the southern part of the country.

The Sinoia-Banket Belt has the Main Basalt Suite very well developed as an east-striking succession of epidiorites and greenstone schists 11 km wide with a thin ironstone, phyllite, talc-chlorite schist association in the south and passing directly under the Shamvaian sediments in the north. It seems likely that some of the felsic volcanics recorded in the Sipolilo area as part of the Shamvaian Group will on review be assigned to the Diverse Suite of the Bulawayan Group.

The Calc-Alkaline Suite has not been recognised anywhere north of Gatooma where it was first distinguished and provisionally named Umniati Group. It forms a strip of country, 20 km or more wide, characterized by poor soil and stunted vegetation. On the west it is overlain unconformably by ophitic Deweras basalts of Proterozoic age. Field relations along the eastern margin with older formations of the Bulawayan Group are obscure due to the presence of a major zone of fault dislocation. The suite in this area consists essentially of dacites and trachytes with a high proportion of agglomeratic varieties. The rocks are little deformed, very lowly metamorphosed and gold mineralization is meagre and scattered. These characteristics are in strong contrast to those of adjacent Bulawayan rocks on the east. South of the Umsweswe River and followed down through Lower Gwelo the succession has been named the Maliyami Formation and is more mafic in composition, being composed largely of pyroxene andesites which may be porphyritic or amygdaloidal. The pyroxene is completely fresh except in the thermal aureole surrounding the Sesombi tonalite where the rocks have been converted into hornblende-bearing greenstones. Metallic mineralization, essentially gold, is more common surrounding this granitic intrusion. Southwards of Lower Gwelo the andesitic rocks pass under Karoo and Kalahari cover to reappear in the Lonely area from where they have been traced as a belt of lesser width through the Bulawayan Schist Belt until they wedge out in the narrow neck joining the Bulawayo and Filabusi belts. Total strike extent is more than 300 km.

There are two categories of metallic mineralization of economic importance in the Bulawayan Group. Nickel is stratigraphically controlled and occurs in spinifex-textured basalts and ultramafics in two horizons of the Upper Bulawayan. These are in the Diverse Suite and near the base of the Main Basalt Suite. Gold and associated mineralization is hydrothermal in nature and structurally controlled although its primary source may well have been in the banded ironstones and stratabound massive sulphide accumulations in the lavas. All major goldmines are concentrated either along extensive shear zones or in close proximity to intrusive granite contacts irrespective of lithology or stratigraphy. Iron ore is exploited from secondarily enriched ironstone deposits in the Lower Bulawayan at Buhwa and from the basal part of the Upper Bulawayan at Redcliff. Limestone is quarried from generally small local deposits at several different horizons in those divisions other than the Calc-Alkaline Suite.

SHAMVAIAN GROUP

When first defined as a system this group was characterized as resting unconformably, after major erosion, on basaltic lavas and other formations of the Bulawayan; and consisting essentially of conglomerates, meta-arkoses and metagreywackes. These characteristics generally hold true for the formations that were previously described under the following names:

Shamva Grit Series of the Mazoe Valley.
Eldorado Conglomerate Group of Sinoia-Banket area.
Battlefields Pebbly Quartzite and Barton Farm Group of Hartley.
Lower and Upper Sedimentary Series of Que Que.
Ndutjana Series of Bubi.
Greywacke Group of Gwanda.
Mbeza Series of Umtali.

Differentiated sediments such as quartzites, phyllites, slates and carbonate rocks are absent or entirely subordinate as are banded ironstones. In some areas fine-grained felsic rocks termed leptites and various sericitic schists were believed to be of igneous origin but were not separated because of very sporadic exposure and the production on weathering of pale sandy loams not readily distinguishable from soils overlying the sediments.

In the areas of Sinoia-Banket and the Mazoe Valley the arkoses and greywackes, on account of their mixed composition, tend to simulate igenous rocks. This is because they have been recrystallized under the influence of thermal metamorphism and metasomatism engendered by granite intrusion. Arkosic varieties are composed of quartz, feldspar and biotite and the darker coloured greywackes contain amphibole in addition. Conglomerate beds and lenses contain pebbles and boulders in great variety, among them various granites, banded ironstone and vein quartz. In the Mazoe area they are often perfectly rounded but the Eldorado Conglomerate has flattened pebbles and a strongly schistose matrix containing a high proportion of actinolite. Metasomatized arkoses and greywackes, with feldspar metacrysts several millimetres in length, are distinguished as porphyroids.

These rocks, derived from an eroding granite-greenstone provenance, were deposited in relatively small, local, shallow water basins and had much lesser original extent than the mafic lavas of the Bulawayan Group with which they are infolded. In some instances a clear unconformity can be established but more often Shamvaian deformation extends into the underlying rocks impressing parallelism of strike. Generally, unless invaded by granite, the Shamvaian occupies a synclinal core position in the gold belts surrounded by Bulawayan greenstones but it is not often that the stratigraphic units in the lavas can be matched on the fold limbs.

Away from the type areas, particularly southwards, a much greater lithological variety has been included in the Shamvaian provided that sequences so classified contain appreciable thicknesses of arenaceous sediments and give indications of being younger than the more common greenstones.

In the Sipolilo area a three-fold division has been made. The lowest formation is predominantly volcanic and the other two predominantly sedimentary although there are intercalations of mafic and felsic lavas. An unsual feature is the anticlinal structure of the belt. In the Midlands around Hartley and Gatooma there is a lower grit and quartzite unit and an upper unit, in the centre of the synclinal structure, that is composed of greywacke, conglomerate, ironstone, pelitic sediments and andesitic rocks. Further south a volcaniclastic formation has been mapped at the top of the succession. East of Gwelo poorly exposed, pale coloured pelitic sediments previously assigned to the Shamvaian Group are now classified as Bulawayan. At Que Que grits, phyllites and ironstones are separated by an unconformity from two upper formations composed of typical Shamvaian greywacke and conglomerate. In the Bembesi Valley the rocks are similar to those comprising the upper formations at Que Que and some of the conglomerates contain jaspilite pebbles that were folded and mineralized with pyrite before being deposited. South of Bulawayo similar conglomerates are apparently overlain by a thick phyllitic formation and phyllites are described from Filabusi too but are probably of Bulawayan age. The Shamvaian of Fort Victoria has been divided into two formations both of which contain felsic volcanic rocks. The lower unit, composed of grit and conglomerate with some phyllites and ironstones, rests with partial unconformity on the Bulawayan greenstones. The upper formation has a greater development of pelitic rocks and, most unusually, has a thick basal limestone. Granite, dated at 2600 Ma intrudes the southern margin.

Many of these descriptions give the impression that relationships are more complex than formerly believed. Felsic rocks of volcanic origin are much more common and often occupy a basal position and some former arkoses, as a result of remapping, are known to be crystal tuffs. At Shamva itself the host rocks of the mine orebody were classified as microgranite in the early part of the century. With the discovery of trains and lenses of round and flattened pebble-like fragments it was regarded as a recrystallized arkose with pebble bands but recent study suggests that it is in fact a reworked acid pyroclastic formation.

With these considerations in mind, and the often expressed doubts regarding the nature of the relationships between some of the Shamvaian and underlying formations, a review of the position seems to be necessary. It is probable that parts of the group will be reallocated to a newly defined Bulawayan super-group as more detailed remapping of the gold belts proceeds.

Economic mineralization peculiar to the Shamvain itself is restricted to several limestone occurrences and possibly the Barton Farm magnesite deposit south-east of Gatooma. This consists of a massive, brecciated bed of magnesite occurring within dolomitic argillites. Being unique it has been extensively studied and no association with any ultramafic intrusion has been recognised. Choice of origin is said to lie between it being a primary sediment or a replacement body. If so, Shamvaian age is doubtful.

There is no record of other mineralization of primary nature within the group, but it does act as host to hydrothermal metallic mineralization generated by granite intrusion into the schists belts as a whole and contains many deposits of this type which are described in a subsequent section.

The Eldorado gold mine has been cited as an exception to this general statement. There were and still are adherents to the theory that it is a fossil placer deposit analogous to those of the Witwatersrand. The rich ore shoot, enclosed in wall-rocks of Eldorado Conglomerate, had a strike of little more than 100 metres but was mined to a depth of 700 metres. It was lacking in vein quartz and was regarded as a "banket deposit" by many of those who examined the property in the early years of the century. A small supply base was in consequence named Banket and a pegging rush ensued. Nearly 20 000 blocks of claims covering some 80 km of strike of the conglomerate were registered but no similar ore deposit was located. Major mining operations commenced in 1906 and terminated in 1919. Sporadic reworking continued until 1940 by which time 492 000 troy ounces of gold had been produced from nearly a million tonnes of ore milled. A basic fact that militates against the placer theory is that 95 per cent of all gold produced from the Banket-Sinoia Schist Belt has been won from a major shear zone which strikes north-east across the area for 50 km and along which the Eldorado Mine and all other major producers are situated.

STRUCTURAL TRENDS

In the Mashaba gneiss and the Rhodesdale gneiss near Que Que, Sebakwian remnants are isoclinally folded on north to north-north-easterly axes. The linear Ghoko Belt to the west of Selukwe also has a northerly trend but shows evidence of later deformation on north-westerly and north-easterly axes.

In the Selukwe Greenstone Belt itself there is evidence of an early, pre-Bulawayan fold system trending north-west. The Selukwe nappe is thought to have originated in a north-west-trending fold belt which, from structural evidence, appears to be younger than the north-striking Ghoko Schist Belt, but it nevertheless also of Sebakwian age.

In the extensive outcrops north-west of Gwelo, the Sebakwian rocks have been folded first on an east-west trend and later refolded about north-north-westerly and possibly north-easterly axes. The north-north-west trend is the dominant direction in the adjacent Bulawayan rocks of the Gwelo Greenstone Belt and the north-easterly trend may be reflected in the gentle warping of the north-north-west axis, but the east-west trend is nowhere represented in the overlying Bulawayan rocks.

Several different fold trends affect Bulawayan rocks. The Lower Bulawayan rocks at Belingwe and in the Mweza-Buhwa Belt are folded about east-north-easterly axes. In other areas, in the units assigned to the Lower Bulawayan, deformation trends earlier than the Upper Bulawayan folding, have not been recorded. In the southern part of the country to the south of Que Que the dominant fold trend of the Upper Bulawayan rocks is, with two exceptions, either north-north-west or north-west. The two exceptions are at Gwanda where the major fold axes strike west-north-west, and in the Lower Gwanda-Antelope Belt where northerly folds and an east-north-east cross-fold occur.

To the north of Que Que the dominant trend is north-easterly with a minor north-north-west trend. The intersection of these two trends could be responsible for the shape of the Salisbury Greenstone Belt.

To the east of the Great Dyke, the narrow linear belts at Umvuma and Felixburg trend east to east-north-east as does the Umtali Greenstone Belt. The main fold trend in the Bulawayan rocks in the Fort Victoria Belt is north-east. These trends may be related to deformation of the Limpopo Mobile Belt.

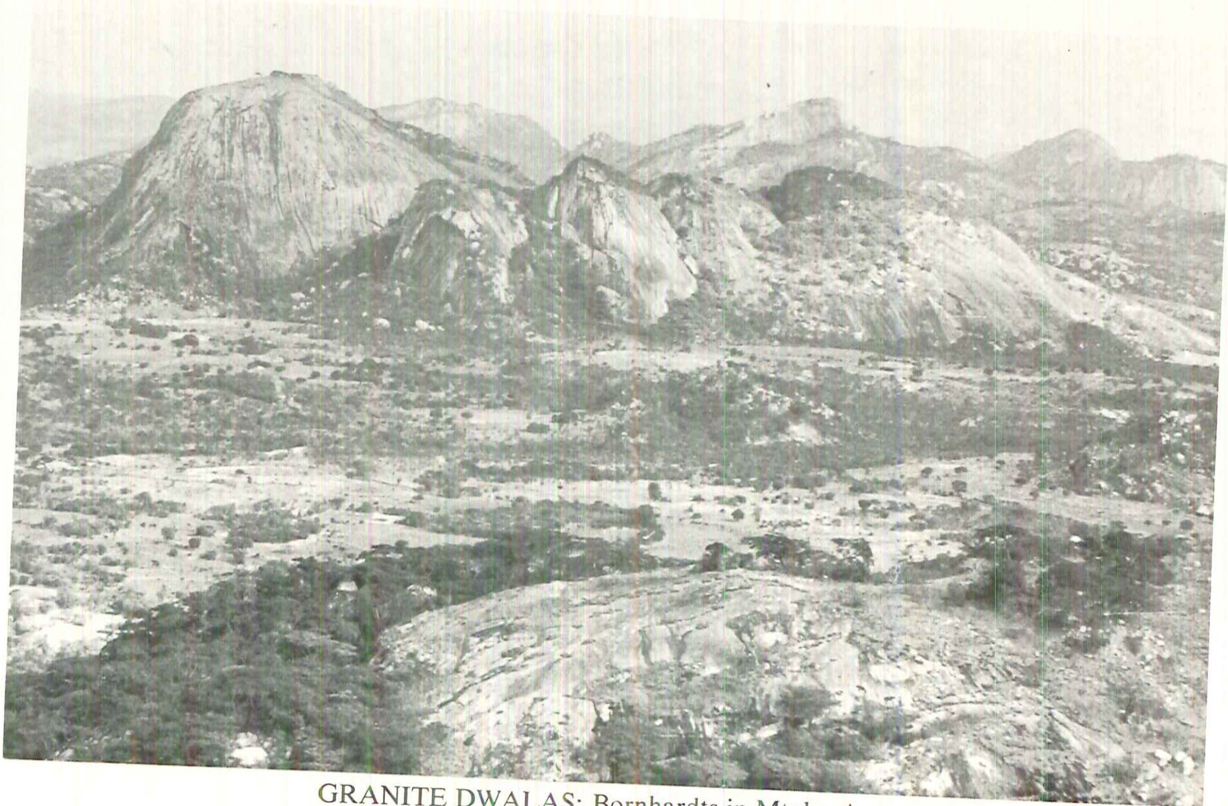
Shamvaian trends generally throughout the country affect only the immediately adjacent Bulawayan rocks and are restricted to directions in the quadrant between north and east.

The reason for the geographical distribution of several apparently different Bulawayan fold trends is not understood. It has been suggested that certain deformations in the Limpopo Mobile Belt were caused by a large cratonic block moving to the south-west and that this block contained smaller units that may have responded independently. This could have given rise to north-westerly to north-north-westerly folds in the Bulawayan rocks and might explain the strong deformation of relatively incompetent greenstone belts as compared with more competent granitic areas, and also the shape and arcuate pattern of the belts in the southern part of the craton. Many strongly sheared zones in the greenstones and the intensely deformed core of the Bulawayo Greenstone Belt may be explained in this hypothesis as release of strain during movement and crumpling on the leading edge of the cratonic block.

The present shapes of the greenstone belts have been assumed in the past to be largely the result of updoming of the intervening granitic areas. The gregarious batholiths postulated by Macgregor in 1951 in his presidential address to the Geological Society of South Africa related the arcuation of the greenstone belts to large ovoid granite areas. That intrusive granites and gneisses have modified the margins of the belts is beyond doubt but tectonic deformation which updomed granitic areas and depressed greenstone belts into synclinal troughs should also be considered.

Not all of the greenstone belts are synclinal structures. Shabani, Gwelo-Hunters Road and to a large extent Gwanda and Umtali belts

PLATE II



GRANITE DWALAS: Bornhardts in Mtoko Area.

seem to be synclinal but many others are remants of larger structures, destroyed by invading gneiss or granite. Foliation and bedding planes almost invariably have steep dips and it might seem logical to assume that the greenstone belts should extend to great depths. However, gravity traverses across the Mweza Belt on the southern margin of the craton, in the only investigation of this nature conducted in the country, have shown that the depth of the belt is almost exactly equal to its width.

ARCHAEAN GRANITIC ROCKS

The granitic rocks of the Basement Complex occupy the greater part of the craton. They give rise on weathering to pale-coloured sandveld soils and are responsible for such spectacular land forms as the high domes and balancing rock features, variously known as dwalas or whale-backs and castle koppies. On field evidence they are divided into an Older Gneiss Complex and Younger Granites as distinguished, for the first time, on the 7th edition of the geological map of the country. But neither division is by any means homogeneous. Each contains a variety of rocks formed at various periods over a great span of time.

The triangular area between the towns of Selukwe, Shabani and Mashaba has been well dated radiometrically and seems likely to represent the oldest crustal segment of the country. Some of the banded gneisses here are 3 500 Ma old, as is the granodiorite which intrudes the Mashaba Schist Belt. The Mashaba tonalite is younger at 2 970 Ma. The rest of the country has not been as thoroughly investigated in this manner but determinations of the order of 2 650 Ma have quite commonly been recorded for the Younger Granites.

The term granite is used in its widest sense to describe coarsely crystalline rocks composed of quartz, oligoclase and microcline with variable though small amounts of the dark coloured minerals, biotite and hornblende. Increase in dark mineral content due to digestion in the granitic magma of mafic inclusions leads to the formation of such rocks as diorite and appinite. The proportion of sodic feldspar to potassic feldspar, in the modal classification currently used, determines the nomenclature adopted for the common varieties. The term *tonalite* denotes a granitic rock in which potassic feldspar constitutes less than 15 per cent of the total feldspar; in *granodiorite* the proportion is between 15 and 35 per cent; in *adamellite* between 35 and 65 per cent and in *granite* itself, more than 65 per cent. True granites, of the last category, are extremely rare in Rhodesia and most of the rocks to which the name is applied are in fact adamellites. It is also worthy of mention that the orthoclase variety of potassic feldspar is virtually unknown in the country.

The origin of granites was one of the early subjects of controversy in geology, and remains a live issue on which divergent views are held. These range from the belief that all granites welled up as molten magma displacing the rocks among which they are found, to the opinion that they were formed by the partial fusion and recrystallization of pre-existing rocks *in situ*, with only very little addition of fluids. Rhodesia provides evidence in support of both views. It is concluded that the process started with granitization, that is to say fusion and recrystallization, and later became cancerous, working its way upwards in places by a process known as magmatic stoping. The later mobile activity led to the formation of bodily intrusive stocks and cupolas.

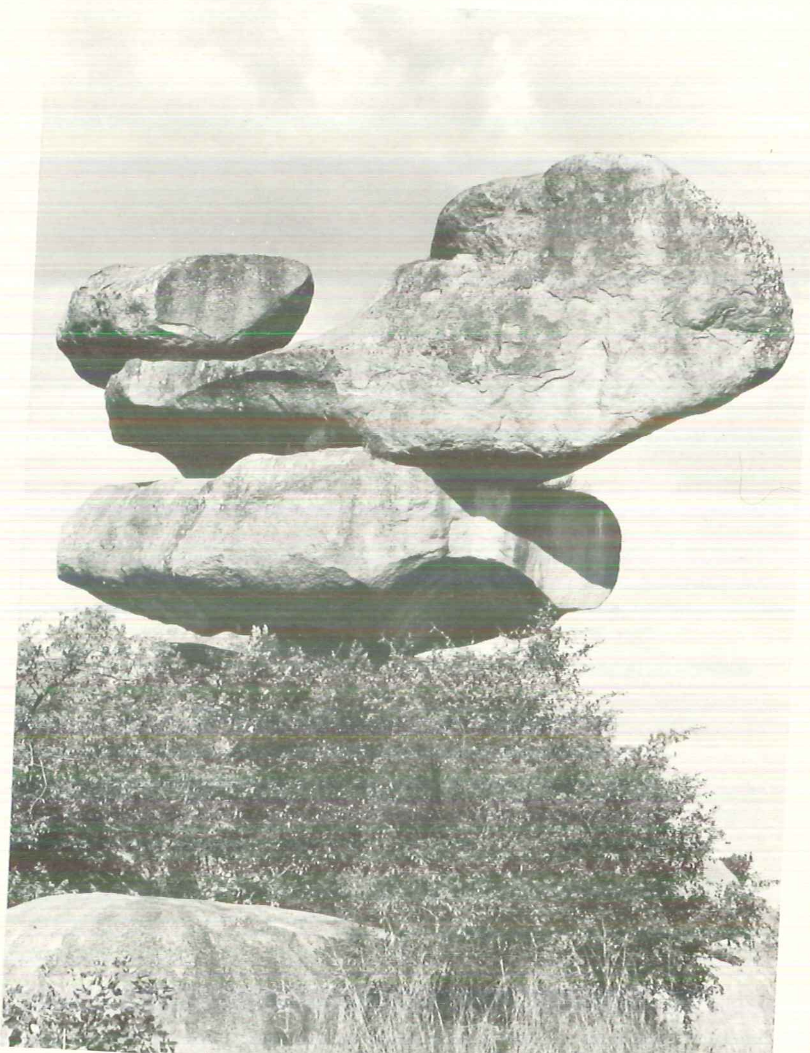
As a rule the older rocks retain more evidence of mixed composition and are more clearly banded and gneissic, whereas the younger ones are homogenous and massive.

The greater proportion of the metallic mineralization of the Basement Complex is bound up with the intrusion of these gneisses and granites into the greenstone belts and is always found within the belts or in the immediately surrounding granitic country. The direct connection between the younger granites and the tin, tantalum and lithium in granitic pegmatites is clearly demonstrated in the Mtoko, Victoria, Salisbury and other schist belts. Equally though less obviously older and younger granites have digested great quantities of invaded greenstones and concentrated their rarer metal content to be injected as hydrothermal ore bodies. Most of the gold deposits in the country are of this nature, and the gold which is always accompanied by silver may have associated copper, lead, zinc, arsenic, antimony and other metals.

The Older Gneiss Complex

These gneisses occur throughout the craton and occupy rather less than half of the granitic terrain. The complex is particularly well developed in the south-west and central parts where large areas are underlain by a variety of gneisses. It also outcrops extensively between the villages of Headlands and Mtoko but otherwise in the north and north-east is only exposed intermittently between large sheets and batholiths of younger granites.

PLATE III



BALANCING ROCKS. Granite outcrops near Salisbury.

The rocks are variously foliated or banded grey gneisses and darker coloured migmatites, all of which are of tonalitic composition. They all contain cross-cutting and conformable veins of aplite and quartz, often in great profusion. Although the topographic expression tends to vary, the gneisses usually occupy the low ground in which there are scattered flat pavements, low rounded hog-back ridges and small rocky hills.

Within the complex and forming an integral part of it are large relatively homogeneous areas of only weakly foliated gneiss derived from the heterogeneous varieties by partial fusion. Contacts are gradational and remobilization to the extent of auto-intrusion has not been recorded. Several bodies of differing lithology and age may be present in any one area.

As mentioned previously, xenoliths of ultramafic rocks such as serpentinite and magnesian schists, and banded ironstone are found commonly in the gneisses especially in the immediate environs of the gold belts where they conform with the gneissic foliation. These rocks resist assimilation whereas greenstone xenoliths have a much greater tendency to become diffused and nebulous. Areas well away from the main schist belts do, in isolated instances, contain a profusion of xenoliths in migmatitic gneiss. They clearly represent remnants or keels of schist belts which have been invaded and almost completely assimilated.

It is believed that the Older Gneiss Complex has suffered widespread refusion and mobilization after serving as a basement for greenstone belt deposition and that only very rarely is the original sedimentary unconformity preserved. The only known case is at Shabani where the basal members of the Upper Bulawayan undoubtedly have this relationship with gneiss dated at 3 500 Ma. While there is no certainty about the primary origin of the gneisses it seems probable that they are almost exclusively orthogneisses. If paragneisses are a component of the complex they must be very rare as very few have been distinguished with any confidence.

Younger Granites

Emplacement of this suite of granitic rocks came at a late stage in the consolidation of the Basement Complex. It is dated at approximately 2 650 Ma and has equivalents of similar age in many Archaean terrains throughout the world.

The intrusions are essentially homogeneous, medium- to coarse-grained and usually equigranular, although porphyritic varieties are by no means rare. These contain large tabular crystals of microcline formed late in the crystallization history. The rocks are more potassic on average than the older gneisses and there are indications that porphyritic texture develops when the magma has incorporated more than usual amounts of invaded country rock.

Compositionally most of the Younger Granites are adamellites and they form vast sheets and batholiths in the central and eastern parts of the country. Typical mode of occurrence of the granodiorites and tonalites is as smaller stocks in more direct association with the schist belts on which they have marked metamorphic and sometimes metasomatic effects. Contacts are sharp and clear cut, distinctly transgressing all pre-existing structures. The association of the granodiorite and tonalite stocks with the major gold deposits of the country leaves little doubt that there is a close genetic relationship.

Felsites and Porphyries

These rocks form hypabyssal intrusions such as dykes, sills and small stocks. They are fine-grained and are of granitic composition, and consist of a mosaic of quartz and feldspar with subsidiary micas and other minerals. The porphyries contain, in addition, phenocrysts or metacrysts of quartz, feldspar or both that attain dimensions up to 3 or 4 mm. Most of the bodies are undoubtedly of magmatic origin but there are many places where metasomatic generation of intrusive porphyries may clearly be demonstrated.

In the extreme north-east of the country the porphyry dykes are probably of late- or post-Karoo age and in the lower Sabi Valley swarms of porphyry dykes are related to late-Karoo igneous activity.

The larger, irregular bodies distributed throughout the greenstone belts of the Basement Complex are of much greater age and some of them are probably related to the felsic lavas and pyroclasts of the Bulawayan Group. Apart from frequently containing disseminated pyrite, they are unmineralized but their close association with clusters of important gold mines must be more than coincidental.

MINERALIZATION OF THE BASEMENT COMPLEX

The greenstone belts, consisting of the Sebakwian, Bulawayan and Shamvaian groups plus ultramafic complexes and the immediately associated granitic rocks contain the major portion of the country's mineral wealth.

Of a primary nature are the asbestos and chrome deposits, within ultramafic complexes and for the most part confined to the southern part of the country. The nickel occurrences are of wider distribution but are also contained in or associated with differentiated igneous intrusions. Iron ore, limestone and other sedimentary deposits are in the same category, in the sense that although they may have been modified by intrusions and other agencies they have not necessarily been dependant on hydrothermal emanations from granitic intrusions for their formation.

On the other hand gold deposits with accompanying metals such as copper and tungsten, and the pegmatite metals, tin, tantalum and lithium are, with few exceptions, of hydrothermal origin and are directly related to intrusion of the granites.

In the following account, gold mineralization is treated first, followed by other metals and minerals of prime importance to the economy and then those of lesser value in alphabetical order thereafter.

Gold

In view of its importance to the development of Rhodesia, a brief historical outline of gold mining is included. The early European hunters and explorers, Carl Mauch, Henry Hartley and Thomas Baines observed the abundance of "Ancient Workings" and brought them to the attention of the outside world. Who the "Ancients" were is still problematical but there has hardly been a gold mine of any consequence in the country which was not sited on one of their workings.

The first mining company, formed in 1863, operated unsucessfully in the Tati Concession, now in Botswana, and soon became defunct. In 1889 a Royal Charter was granted to the British South Africa Company, conferring exclusive mineral rights. The charter was not revoked until 1923 when the rights passed, on payment, to the then Government of Southern Rhodesia. The mineral rights remain vested in Government and are administrated under the Mines and Minerals Act [*Chapter 165*].

Regular gold production commenced at the Cotopaxi and Dickens mines in Victoria District in 1894, but it was not until the early 1900's that the industry got into stride. By World War I gold output had risen to 900 000 Troy ounces per annum, an amount again attained during the early part of World War II, after which it declined to some 500 000 ounces per annum and has remained at about this level since. Total production to the present exceeds 40 million ounces, most of which has come from the 10 to 20 larger mines operating at any one time. There have been some 50 of these larger mines each with an annual production exceeding 10 000 ounces of gold, but records show that more than 4 000 smaller gold deposits have been developed during the past 80 years. In this country, as in many others, operation of gold mines has brought in the revenue to provide a primary infra-structure and so pave the way for base metal exploitation and industrial development.

It was for a long time believed that the source of gold and associated mineralization, in Archaean granite-greenstone terrain, lay in the intrusive granites themselves and that emplacement as quartzose veins and replacement bodies in the invaded country rocks occurred as a late phase in the crystallization history of the granites. In 1951, A. M. Macgregor published a paper entitled "The Primary Source of Gold" in which he concluded that its origin was in the invaded greenstones and not in the granite. He suggested that the gold and other metals were released by migmatitic extraction from large blocks of greenstones which had sunk into the invading granites by a process of magmatic stoping. On assimilation in the granite the heavy metal content of the greenstones was concentrated in some manner, later to be injected in the form of aqueous solutions containing carbon dioxide, sulphur, possibly alumina and other constituents. These views were based on the study of the chemistry and mineralogy of very many epigenetic gold deposits and the observation that where granites intrude into older granites ore deposits are not found whereas where they intrude into greenstone belts such deposits are an almost invariable consequence. Strength had been added to these views by the application, in recent years, of neutron activation techniques of analysis which permit confident determination of heavy metal content of rocks with an accuracy of parts per billion. Analyses of this type have shown that the intrinsic heavy metal content of basic greenstones is several times greater than that of acid rocks such as granite. Investigations in Canada during the last decade more precisely define the source of gold and associated sulphide mineralization. Rather than being evenly distributed throughout the greenstones it tends to occur in syngenetic form in banded ironstones and as strata-bound deposits of metallic sulphides. It is postulated that gold and other metals in the ironstones were chemically precipitated along with cherty silica and iron in a submarine environment and that the massive sulphides are of fumarolic origin in a like environment as a final phase of extrusion of basaltic lavas.

Several classification schemes have been proposed for the gold orebodies in Rhodesia but essentially, virtually all the gold production has come from hydrothermal lodes. Fossil placers, like those of the Witwatersrand, are not known in the country although in some areas the ancient conglomerates have been well explored for gold mineralization in this form. Alluvial gold in river beds and terraces has been very actively sought in scores of rivers since the end of the last century, most particularly the Angwa, Mazoe and Ruenya rivers, but the reward has been minimal.

The important hydrothermal lodes may be divided into two categories, namely quartz veins and sulphide replacement or impregnation deposits. Quartz veins, the predominant type, consist of gold and minor amounts of metal sulphides such as pyrite, galena and sphalerite injected into pre-existing fault or joint fractures. The sulphide replacements contain very little quartz; the silica content being of the dark cherty or chalcedonic type, and pyrite, pyrrhotite, arsenopyrite, chalcopyrite and stibnite in various combinations are major components. Injected into shear zones, ingress was less facile and replacement of country rocks more extensive. Because of the lack or paucity of quartz the replacement deposits or schist orebodies, as they become known, were overlooked by early prospectors and miners. All gradations between quartz veins and massive sulphide lodes occur, giving rise to banded reefs of tabular form. Where the quartz occurs as a ramification of veinlets or the sulphide replacement is incomplete, so that ore and contained host rock must be mined together, the deposit is classified as a stockwork. The attitude of the majority of lodes is vertical or steep-dipping but flat-dipping reefs are no rarity and at Makaha horizontal quartz veins have been mined.

All rock types of the Sebakwian, Bulawayan and Shamvaian groups as well as the marginal and stock granites and in some instances the intrusive felsites and porphyries contain gold deposits. Most are in the basaltic and andesitic greenstones of the Bulawayan Group, because of their preponderance. However, relationship to the granite rather than any other factor is the vital control of the formation of the ore deposits. This is admirably demonstrated in a linear zone along the western margin of the Rhodesdale batholith. Here, from Que Que to Eiffel Flats, such mines as the Gaika, Globe and Phoenix, Piper Moss, Sherwood Starr, Kanyemba and Cam and Motor occur in a variety of lithological settings, in a belt a kilometre or two wide, along the granite contact and together account for nearly a quarter of the country's entire gold production. An example of concentric distribution of gold reefs around an intrusion and arrangement transverse to the stratigraphy of the country rocks, is provided by a group of mines north-west of Gatooma. Among them are the Golden Valley, Patchway, Big Ben and Glasgow mines which form a cluster in the basaltic greenstones around the Whitewaters tonalite stock, dipping flatly away from it.

Numerous small deposits and several larger ones are associated with banded ironstones and enthusiastic application of the Canadian model has led to statements implying that much of Rhodesia's gold production is derived from syngenetic ore in these ironstones and further that the country's sulphide replacements or impregnations are in reality stratiform deposits of associated volcanic cycles. There is little support for this view as structural rather than stratigraphic control has quite clearly been the prevailing factor in thousands of the mines. Furthermore a recent extensive exploration programme which involved the continuous sampling of more than 400 km of banded ironstone strike and some 100 000 gold assays showed the ironstone to have anomalously high gold and other heavy metal content albeit well below economic limit, but also proved that ore grade occurs only in structural traps, where the ironstone has acted competently under stress to be shattered and provide ideal conditions for permeation of ore fluids.

The schedule (Table I) gives the production of 20 of the larger mines up until the end of 1965 and illustrates the great variability of the mines in respect of size and their geology and mineralization. Shape and pitch of oreshoots are other variables. As a rule of thumb it may be said that the depth extent of the average orebody is of the order of twice its surface strike but there are extreme departures from this rule. The Mickey Mine near Mount Darwin had a strike of 10 metres and was mined down incline to a depth of 260 metres whereas the Surprise Mine at Selukwe had a strike of more than a kilometre and petered out at a depth of only 60 metres. The Fred reef at Filabusi was stoped over a strike of 400 metres near surface. This had doubled by the 15th level, thereafter diminishing to the 31st level at a vertical depth of 1 000 metres. The numerous oreshoots pitched west in the plane of the reef at an angle of 60 degrees. The control of oreshoot

Table I
SCHEDULE OF LARGE GOLD MINES

Mine	District	Geology and mineralization	Production (troy ounces)
Cam and Motor	Gatooma	Large shear zone containing several quartz veins converging at depth in greenstones and meta-sediments. Mineralized with pyrite, stibnite, arsenopyrite and sphalerite. Mined to 2 000 metres	4 536 845
Globe & Phoenix	Que Que	Several quartz veins in talc-carbonate rock and granitic gneiss with pyrite, arsenopyrite and stibnite	3 717 588
Shamva	Shamva	Large low-grade ore-bodies with discrete high-grade ore-shoots partly controlled by fractures, in reworked felsic tuff. Pyrite and sphalerite	1 493 480
Rezende	Umtali	Shear zone with quartz veins in greenstone and quartz-diorite. Mineralized with pyrite, pyrrhotite and galena	1 360 038
Lonely	Bubi	Quartz vein with sphalerite, galena and chalcopyrite in serpentinized high-magnesium basalts. Unique in being partly oxidized to 900 metres	1 146 417
Wanderer	Selukwe	Pyrite mineralization in crush zone containing quartz veins in phyllite between banded ironstone and conglomerate beds. Some ore in wall rocks	1 048 407
Gaika	Que Que	Several quartz veins with stibnite and arsenopyrite in talc-carbonate rock. Auriferous pyrite in propylitized mafic intrusions. Rich free gold in shears in massive talc rock	669 281
Dalny	Gatooma	Pyritic, arsenical, quartzose shear zone of considerable strike length in andesitic lavas and pyroclasts	652 799
Golden Valley	Gatooma	Quartz vein with pyrite, galena and scheelite along contact between basaltic greenstone and felsite	640 962
Giant	Hartley	Pyrite mineralization in chlorite schist associated with banded ironstone, talc-carbonate rock and talc schist. Fault terminated at 200 metres below surface	618 861
Tebekwe	Selukwe	Quartz veins in granitized metasediments of the Mont D'or Formation mineralized with pyrite, pyrrhotite, chalcopyrite and molybdenite	616 351
Fred	Filabusi	Banded and lenticular, quartz vein with arsenical mineralization in sheared epidiorite	569 070
Connemara	Gwelo	Pyrite and pyrrhotite mineralization in banded ironstone	530 500
Eldorado	Sinoia	Two narrow deep ore-shoots with pyrite mineralization in sheared conglomerate of the Shamvaian Group	492 211
Sherwood Starr	Que Que	Pipe-like ore-body of jaspilite, probably a faulted fold nose. Pyrite and arsenopyrite mineralization forming a stockwork	470 621
Arcturus	Salisbury	Fractures mineralized by quartz, pyrite and arsenopyrite in epidiorite. The large shear zone has several *en echelon* ore-bodies disposed obliquely	467 328
Muriel	Banket	Five lenticular quartz veins *en echelon* in hornblende schist. Mineralized by pyrite, pyrrhotite and chalcopyrite. Important copper production	386 825
Mazoe Group	Mazoe	Quartz veins with pyrite in a granite stock intruding into metasomatized mafic and felsic volcanic rocks of porphyroidal aspect	381 177
Falcon	Umvuma	Quartz vein with pyrite, pyrrhotite and chalcopyrite in chloritic schist. 34 320 tons of copper has been produced from the mine	368 586
Antelope	Matobo	Parallel shear zones in actinolite schist and serpentinite containing quartz and mineralized with pyrrhotite, pyrite and magnetite. Ore zone is intruded by late barren pegmatites	307 405

attitude and pattern is generally structural, determined by fold flexures, the anticinal portions of which are more favourably mineralized. The Renco Mine, in charnockitic granulites, in the south-east of the country is an extreme example. Cymoid loop structures are a common feature of the antimonial gold reefs north-west of Que Que and fracture intersections in conjugate systems play an important role in some areas. Although blocky competent rocks provide a more favourable environment for mineralization than incompetent schists, it seems that host rock chemistry exercises little influence and it is probable that drop in temperature of the ore-bearing solutions is of prime importance.

Ore mineral assemblages range from the simple gold-pyrite quartz reef to the more complex ones consisting of various combinations of pyrite, arsenopyrite, galena, scheelite, pyrrhotite, chalcopyrite, sphalerite, stibnite and rarely molybdenite and tellurides in that general order of frequency. Mineralization may be simple or multiphase with early phases tending to be arsenical and late phases antimonial. All phases are not necessarily auriferous and gold is frequently of late precipitation. Tungsten copper, arsenic and antimony are by-products at a number of mines and silver is always an important constituent of the gold bullion although it has only been recorded in the form of argentite from mines in the Lower Gwelo area.

Wall-rock alteration may be intense or virtually imperceptible. It is best displayed in the greenstones as a propylitic alteration to a yellowish assemblage of chlorite, epidote, zoisite, sericite and carbonate minerals. Actinolite schist wall-rocks often develop biotite adjacent to the orebody and sericitization of felsic wall-rocks is commonly observed.

Constant characteristics of practically all of the orebodies are that they strike parallel to the schistosity of the immediately enclosing host rocks and that they have a surface zone of secondary enrichment. This extends to the water table at a depth of about 30 metres and within it the tenor of the ore is often many times greater than that of the primary or sulphide zone. It is also less refractory from the point of view of metallurgical extraction. In the oxide zone, too, the oreshoot pattern has usually been obscured by chemical and mechanical rearrangment of the mineralization although indications may remain as fluting or striation of the hanging and foot-walls.

Payability limit is now approximately 5 grams of gold per tonne. This accords closely with the 3 dwt per short ton value which was regarded as the cut-off figure 30 years ago and shows that mining costs have now reached a similar balance with the currently enhanced gold price. Total average of the country's mines has not been calculated but the recovery of 11,15 grams per tonne achieved from milling of 12,5 million tonnes of ore at the Cam and Motor Mine is probably above the average grade.

SILVER

This metal is not mined on its own account. Most of the production, amounting to nearly ten million ounces, has come as a by-product from gold mining. Production records show that the average fineness of the declared gold output has been a little more than 800, so the silver content of the bullion has been of the order of 20 per cent. This varies from district to district and in the Umtali-Penhalonga area the silver content is greater, due to argentiferous galena being a prominent component of the gold ore. At the Osage Mine in Lower Gwelo, argentite has been identified in the ore and the resulting bullion has a much reduced fineness.

ASBESTOS

All asbestos production in Rhodesia has been of the chrysotile variety, essentially of cross-fibre type, and in consequence has been obtained from orebodies in igneous rocks of ultramafic composition. Crocidolite or blue asbestos and amosite, occurring in banded iron-stones in South Africa, and other asbestiform amphiboles are not known except as rarities of academic interest.

With the exception of the Ethel Mine deposit, in a transgressive fault zone in the Great Dyke north of Mtoroshanga, all of the country's asbestos ore occurs in a belt stretching south-west from Mashaba through the Shabani-Belingwe Schist Belt to Gwanda. The host rocks are serpentinized portions of large, differentiated peridotite intrusions which invade the schist belts and the surrounding granitic gneisses alike. They appear to be of post-Sebakwian and intra-Bulawayan age.

The formation of cross-fibre chrysotile is dependent on the host serpentinites having been subjected to deformational stress which produced tensional conditions under which massive serpentinite is recrystallized into acicular chrysotile. It is believed that elevation of temperature and possibly the addition of fluids are necessary to facilitate the conversion and that in the area under consideration age relationships are such that the Younger Granites could have provided both.

The largest properties are the Shabanie Mine, and the Gaths and King mines at Mashaba where asbestos formation is closely related to thrust planes. Others of note are the Vanguard Mine at Belingwe, Pangani Mine at Filabusi and the Thornwood Mine at Gwanda. Several of these are large operations by any standard and the country's production has exceeded three million tons of fibre.

Chromite

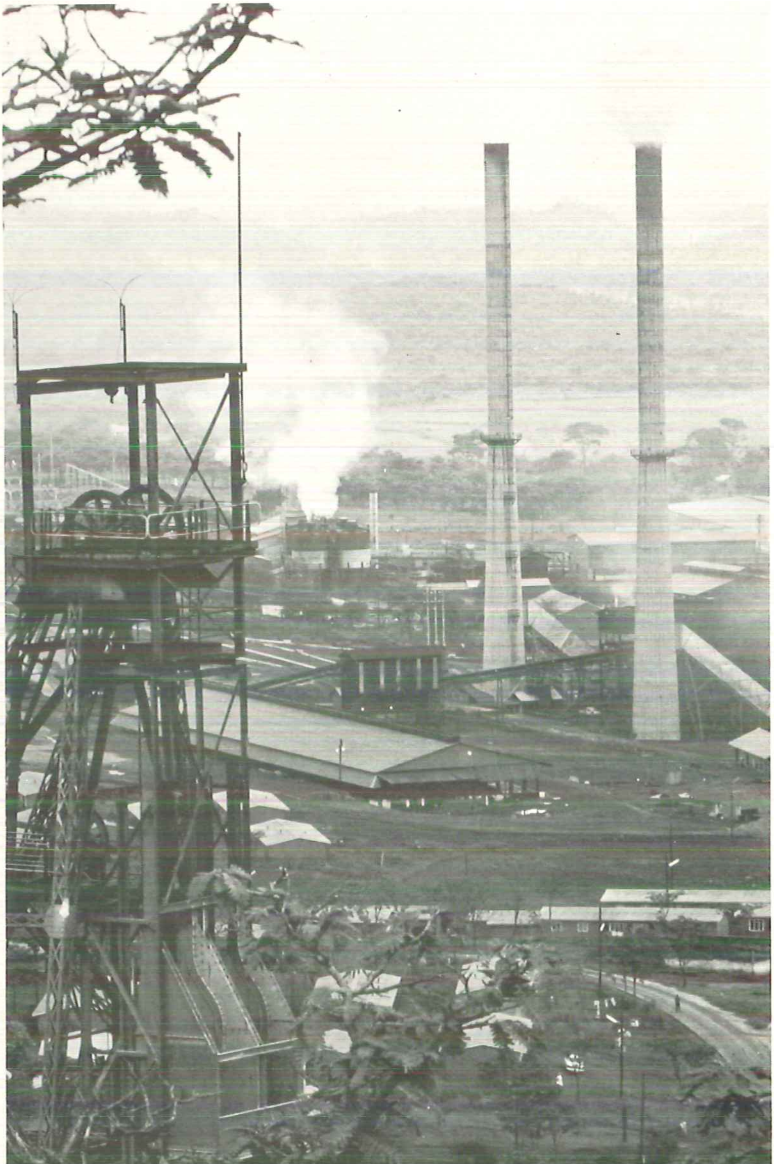
Chrome ore in the Basement Complex, sometimes referred to as off-Dyke chromite, is located in the same general area as the asbestos deposits of the country although it is more restricted to the environs of Selukwe and Mashaba, the former particularly. It also occurs in ultramafic complexes but in those of greater age which have undergone more severe tectonic distortion. Originally as stratiform layers, the chromite has been squeezed into favourable structural environments in which it forms large and small, lenticular, pod-like orebodies. One of the lenses has been proved to have the dimensions of 600 by 140 by 20 metres, very unlike the thin regular cumulate seams of the Great Dyke.

The most important locality is at Selukwe where high-grade metallurgical ore has been mined from carbonated and silicified serpentinite and magnesian schists of an ultramafic complex which is a component of the Selukwe nappe, thrust from the south in Sebakwian times.

Exploitation commenced in 1906 and at one time there were no less than 130 separate bodies being worked at surface. Mining has now, in places, exceeded a depth of 450 metres. Chrome-bearing rocks underlie an area of 60 km² but the better chrome is in the wedge-shaped area measuring 3 km by 9 km around the Selukwe township. Total production has exceeded eleven million tons of chrome and the several inter-connected mines of Selukwe area have been the mainstay of the Rhodesian chrome industry for more than 60 years.

Sweeping round from Selukwe towards Mashaba are trains of small ultramafic inclusions in the older gneisses. These contain chromite lenses and in rare instances chromite occurs enveloped in walls of granitic gneiss, a seemingly anomalous geological situation. The train is interrupted by a tonalite intrusion but continues in reduced form to the south

PLATE IV



TROJAN NICKEL MINE, near Bindura.

of Mashaba. In the Mashaba belt layered chromite ore has been exploited at the Prince Mine in a small ultramafic sequence now considered to be of Sebakwian age.

An interesting association at this mine is that of good quality, dark green nephrite jade partially veined by pink thulite. The minerals occur in xenoliths of metamorphosed serpentinite within an aplite intrusion and the jade is characteristically speckled with minute chromite grains.

Related chromite deposits of Sebakwian affinity are present as massive deposits along the margin of the granulite zone of the Limpopo Mobile Belt, south of Buhwa and as small pods at Filabusi and east of Shabani.

NICKEL

The nickel deposits of the country are widely distributed along a strip of terrain that cuts obliquely across many geological features bearing no apparent structural relationship to any of them. It trends south-west from Madziwa Mine, 30 km north of Shamva, through Empress Mine, west of Gatooma and through Shangani to Epoch Mine at Filabusi. This is a distance of 500 km.

Unlike the chrome and asbestos deposits of the Basement Complex all nickel deposits do not have a constant geological environment although the presence of serpentinite as lava flows with spinifex-textured basalts and contemporaneous hypabyssal feeder channels is common to those other than the Madziwa and Empress properties.

These serpentinite occurrences, namely the Epoch, Shangani, Damba, Hunters Road, Perseverance and Trojan orebodies, have been emplaced into the lower and upper parts of the Upper Bulawayan succession where these have been defined. This contains highly magnesian basalts, cherts and in some cases, dacites. Mineralization is in the form of both massive and disseminated pyrrhotite and pentlandite with very little chalcopyrite so that the nickel: copper ratio may be as much as 15 : 1. Platinum group metals are also present in small quantity.

The Madziwa orebody contains sulphide segregations in differentiated rocks of gabbroic type emplaced into older granitic gneisses and the Empress deposit is similar but the gabbro, now amphibolitized, has intruded into a thick pile of andesites of Upper Bulawayan age, themselves intruded by the Sesombi and other smaller, young tonalite stocks.

Chalcopyrite is a prominent ore mineral and the nickel: copper ratio in these is of the order of 1:1.

Six of the properties mentioned have been in operation for a number of years and they make a large contribution to the country's mineral production.

Iron Ore

Each of the country's schist belts contains tens of kilometres of banded ironstone which outcrops as ridges with steep, scree-covered slopes, and in aggregate there must be well over a thousand kilometres of strike of ironstone with a metallic iron content of 30 to 40 per cent or more. In the Mwanesi Range, 100 km south of Salisbury, it has been calculated that 20 000 million tons of hematite-bearing jaspilite are exposed above general ground level.

However, material classified as ore must contain 55 per cent or better of the metal and there are only three localities in the country where important reserves of this quality are known. These are at Buhwa in the south, at Que Que in the Midlands and at the southern end of the aforementioned Mwanesi Range, and in each of these the ironstone is dominantly jaspilitic in character. At Que Que there is sporadic distribution of manganese in small amounts.

The enrichment of the primary sediment into material of ore grade is considered to be largely due to meteoric agencies that have been more effective in zones of greater tectonic disturbance. In consequence ore is not generally expected to extend much below current water table. Recent investigations at Buhwa have shown that there are additional factors of importance there. These are probably due to the ironstones being situated along the northern margin of the Limpopo Metamorphic Belt and it has become evident that the ore-forming processs were certainly in large part hypogene. It follows that orebodies need not necessarily outcrop and that reserves may be larger than previously believed.

Limestone

Lenticular beds of limestone are present in practically all of the schist belts of the country. They often lie in close conformity with banded ironstones at various stratigraphic horizons within the Bulawayan basaltic greenstone sequences. The deposits are often small and are frequently both siliceous and magnesian so that they do not warrant exploitation for cement manufacture or metallurgical purposes although they may be worked for agricultural lime. Important exceptions are the Sternblick deposits near Salisbury and the Colleen Bawn occurrence east of Gwanda which supply the cement industry. The Early Worm deposit near Concession, composed of very pure and coarsely crystalline calcite, is of metallurgical grade as are parts of the Lambourne limestone near Hartley and that at Risco. A much larger deposit, known as the Three Baobabs, is remotely located 140 km north-east of Salisbury. Preliminary investigations indicate zones of high quality material.

All of these are believed to be chemical sediments, thermally metamorphosed and recrystallized in varying degree due to granitic intrusion. But it has been suggested that some of the smaller and more contorted occurrences may owe their origin to accumulations of calcite, derived from vesicles in the encompassing basalts, that has flowed under tectonic stress into the noses of folds.

ANTIMONY

As stibnite, antimony is a very common associate of gold mineralization in the Midlands area. The Cam and Motor Mine at Gatooma, the Globe and Phoenix and Indarama mines of Que Que area and the Gothic Mine at Lower Gwelo are examples. Over the years there has been a considerable production of stibnite concentrates but in many of the mines antimony, like bismuth, has proved to be a metallurgical embarrassment. There has recently been renewed interest in antimony production and stibnite, not associated with gold, has been exploited from the Glovers Farm deposits at Umniati and from two localities at Shabani.

ARSENIC

Quantities of arsenious oxide are produced from the Government Roasting Plant at Que Que. This is derived from the treatment of gold-bearing arsenopyrite concentrates from mines throughout the country.

BISMUTH

All of the common bismuth minerals have been recorded in the country but the prospects of bismuth mining are not good and production to 1965 totalled only 19 tonnes of ore and concentrates. Small quantities of the metal are of widespread occurrence in auriferous quartz veins in the greenstone belts, especially in the Midlands, but are of no value and lead to metallurgical difficulties in gold extraction. In this situation molybdenum, lead, antimony and tungsten are commonly associated with bismuth.

Bismuth minerals, most usually the carbonate, are found in pegmatites, notably along the northern margin of the Salisbury Schist Belt, at Filabusi, at Bikita and also cutting the Proterozoic sediments in the Miami area.

Attempts have been made to mine bismuth as a by-product of scheelite mining at the Sydkom Mine, Filabusi, from quartz veins in greenstones in the vicinity of Hunters Road and from quartz lenses in actinolite schist at the Alison Claims near Fort Victoria, but with no success.

BARYTES

In Rhodesia barytes or barite is of minor economic importance although 19 different deposits are scattered throughout the country, most of them within the schist belts. The Dodge Mine south of Shamva is the single current producer and only three other properties, the Argosy near Que Que and the Dick and Staff claims south of Bulawayo have been worked in the past. Combined total output has been less than 20 000 tonnes. At the Dodge Mine the barite occurs in disconnected lenses striking north-east and dipping steeply north within limestones and phyllites of Bulawayan age. There is no associated lead or zinc mineralization. By contrast the Argosy deposit, a series of small parallel quartz veins cross-cutting the country andesites, contains barite and lead minerals.

COPPER

There have been three major copper producers among the auriferous hydrothermal lodes of the Basement Complex. At Umvuma, the Falcon-Athens strike extends for 1 500 metres and was mined at the western end to a depth of 500 metres. The average tenor of the two million tonnes of ore that were mined was 5,6 g/t of gold and 1,6 per cent of copper, as chalcopyrite. The Muriel Mine, at the eastern end of the Banket Schist Belt, is a current producer of both metals, and the Inyati Mine, 130 km east-south-east of Salisbury, is in granitic gneiss terrain well away from the main schist belts, but the strong vertical quartz veins are associated with epidiorite dykes or inclusions and intrusions of younger granite. Fresh dolerite sheets have caused much loss of ground at the property.

A few years ago several small copper deposits were worked for their oxide ore, in most cases apparently oxidized remnants of partly eroded supergene zones. The ore, consisting chiefly of malachite and azurite, was acid-leached and precipitated on iron scrap to be marketed as copper cement. The Skipper Mine, 30 km west of Que Que and where the copper carbonates occurred in a shear zone in andesitic agglomerates, was a profitable venture of this nature. There were others at Fort Victoria and in Lower Gwelo.

Corundum

Crystal corundum has been worked at several localities distributed throughout the craton, and there has been a small production but none of the material has proved to be of gem quality. The usually flat, hexagonal crystals are associated with small granitic pegmatities that have presumably been desilicated by intrusion into or incorporation of ultramafic xenoliths in the old gneisses.

Of most unusual character and of more economic importance are the nine known deposits of corundum granulite. The rock has been marketed under the name of boulder corundum. The deposits are located in the Mazoe-Concession, Wedza, Umvuma, Gatooma, Shangani and Belingwe schist belts. They occur in close association with banded ironstone and serpentinite within the Bulawayan greenstone succession and in practically all localities intrusive granite or dolerite dykes outcrop in close proximity.

The granulite is a very hard and heavy rock which is extremely fine-grained and of grey to coppery red colour. It is composed of minute corundum grains ranging between 0,1 mm and 0,2 mm in diameter, which is of the ruby variety and which constitutes 60 per cent or more of the mass. Accessories always present are fuchsite mica and rutile. Diaspore and various alumino-silicates may be present as well.

At one time derivation was attributed to thermal metamorphism of bauxite by intrusive granite or dolerite, but in view of the belief that anoxygenic conditions prevailed in Bulawayan times this seems unlikely. More probably the primary sediment was an aluminous tuff interbedded with ferruginous cherts and ultramafic lavas. Chromium derived from the latter would explain the presence of fuchsite mica and the ruby colour of the corundum.

Production of this granulite has been surprisingly large and in 1965 accounted for 80 per cent of the world output, excluding that of the U.S.S.R. It is of interest to record that in quarrying, normal drilling practice had to be replaced by oxy-acetylene cutting.

Iron Pyrite

Pyrite, used in the manufacture of sulphuric acid, is mined at the Iron Duke Mine near Mazoe and was for many years supplied to the Zambian Copper Belt. The ore is a massive sulphide layer of volcanogenic origin in felsic volcanic rocks of Bulawayan age which form the Iron Mask Range. Gossanous deposits such as that at the Mazoe Dam wall are derived by oxidation from massive sulphides and are present sporadically all along the range. Gold content is minimal. Massive pyrite bodies are known in many of the country's gold mines, examples being the Golden Kopje Mine in banded ironstone near Sinoia and the Kanyemba Mine at Umsweswe, south of Gatooma.

Lead-Zinc

Following the line of thought that the andesitic, dacitic and more felsic members of the Bulawayan Group might be expected to contain lead-zinc deposits of volcanogenic nature, many areas of these rocks have been subjected to exploration exercises using geochemical, geophysical and follow-up techniques. Up to the present they have not been successful. The only deposit of any significance is that at the Cactus Mine in dacitic greenstones, south of Que Que, which has not proved to be viable. The massive ore which consists of a complex of sulphides, including mercury is so severely faulted that its original form cannot be deciphered. Quartz veins carrying gold and the same sulphides are present in the vicinity as are small pod-like bodies of massive pyrite and chalcopyrite.

Although galena is a very common mineral in hydrothermal reefs throughout the Basement Complex it is only in the Penhalonga Valley of the Umtali Gold Belt that it occurs in sufficient quantity to justify collection as a by-product of gold mining. In the past there was an output of several thousand tonnes, principally from the Penhalonga and Old West mines. Several other mines of the area have been re-examined for lead content without resulting exploitation.

Mercury

Cinnabar is known to occur on Richmond Farm near Battlefields and also at the Pilgrim Claims 70 km north-north-east of Bulawayo. At both localities there are minute cinnabar crystals in quartz-carbonate veinlets and on joint planes of the host rocks. These are carbonated basaltic greenstones of Bulawayan age and it has been regarded as somewhat surprising that mercury should have remained in rocks of such great age. In consequence it was postulated that the Pilgrim Claims deposit was related to the Formona granite stock, at the time considered to be very much younger than the Archaean granites of the area. Both deposits are of very low grade. Persistent reports of native mercury from a mine in the Mazoe area proved to be due to spillage of amalgum mercury having worked its way into a reef channel.

Molybdenum

Molybdenite is a relatively common mineral but is sparingly distributed in the hydrothermal veins of the Basement Complex and has not been found in economic quantity. It occurs associated with scheelite in auriferous quartz veins at Southampton Mine, north-west of Umtali and in similar environment in many other gold belts. East of Banket and north-west of Gwelo so called "buck quartz" veins in granite are molybdenite-bearing. Weak mineralization is known too in concentric aplite dykes, in the periphery and surrounding country rocks of the Chirwa granitic dome at the eastern end of the Makaha Schist Belt. The only occurrence with apparent promise is that covered by the Gigantic Claims near Selukwe. It has been investigated by several mining organizations but has so far failed to reveal economic potential. Molybdenite flakes and smears on joint planes together with pyrite, pyrrhotite and chalcopyrite are present with quartz veinlets in large bodies of aplite which are believed to represent granitized greywackes of the Sebakwian Mont d'Or Formation.

Tungsten

In the Basement Complex, tungsten in the form of scheelite has two distinct modes of occurrence. It is distributed throughout the country in gold-bearing quartz veins; the Filabusi Schist Belt being a particularly favourable province. In Gatooma area the large and rich Golden Valley Mine has produced scheelite as a by-product for more than 30 years. At Bindura metallogenic zoning is a feature at the R.A.N. gold mine. Here the scheelite content of the gold reef increases markedly as the vein passes westwards out of metasedimentary wall rocks into the granitic stock.

The other mode of occurrence is in skarns of which the Beardmore Mine at the eastern end of the Fort Victoria Schist Belt is an important example. The orebody cross-cuts the country greenstones and consists of a coarse aggregate of epidote, garnet, vesuvianite, actinolite, quartz, calcite and scheelite. Deposits of like nature are present in the Odzi belt as well. At Mazoe there is the calc-silicate association at the Scheelite King Mine, the country's largest producer, and at Alton, Plum and other claims where granite has intruded calcareous sediments.

The Essexvale wolfram deposits, first discovered in 1904, must be regarded as a third type. Here quartz veins and stockworks have the unusual combination of wolframite with a little scheelite together with fluorite.

Uranium

Despite diligent search by prospectors uranium deposits with economic potential have not been discovered in the country. Many of the pegmatites, both in the Basement Complex and in the Proterozoic terrains are weakly radioactive due to partial replacement of tantalo-columbite by uranium oxide but never in any significant degree. Production of ore for experimental purposes has been recorded from the Cripmore Claims, 20 km south of Umtali. Here 300 tonnes grading 0,3 per cent U_3O_8 were taken from a mineralized fault zone that cuts through granite and a dolerite sill. The uranium, as pitchblende, forms little discontinous veinlets and is accompanied by quartz, hematite and copper, lead and zinc sulphides. Another small deposit, 45 km south of Umtali, and in the same geological environment, was examined by diamond drilling in 1957 also with unfavourable results. Discovery of radioactivity in Shamvaian conglomerate in the Fort Victoria area caused excitement but on examination proved to be due to minute quantities of detrital cheralite, a variety of monazite that contains uranium and thorium.

Pegmatite Minerals

The distribution of economic pegmatite minerals in the Archaean craton is closely linked with the younger granites of adamellitic composition which were emplaced about 2 650 Ma ago. They tend to be concentrated in the Mtoko, Salisbury-Shamva, Umtali-Odzi and Victoria districts. There are pegmatites in other areas but with the exception of the emerald producers they are of little consequence. Furthermore practically all pegmatites of economic value are intrusive into the greenstone or schist belts, those enclosed within the granitic rocks being of little or no value.

The shape of the pegmatities varies from flat, irregular sheet-like bodies to vertical dykes. Some have regular zones in which the economic minerals are preferentially located and others are a complex mixture of quartz, feldspar and mica. The economic minerals contained are beryl, tantalo-columbite, microlite, simpsonite, cassiterite and lithium minerals. Economic sheet mica and semi-precious varieties of beryl and topaz are rarely found in the pegmatites of the craton.

Beryllium and tantalum-bearing pegmatities occur in the small remnant greenstone belts flanking the northern margin of the Mtoko batholith. Many of these were essentially beryl producers but the largest, at Benson Mine, was a major source of microlite. Tantalite from Mtoko area almost always has a high tantalum content. Tin-bearing pegmatites containing small quantities of lithium and tantalum minerals are common to the north and east of Salisbury and those at Shamva are similar. At Odzi, greisens and zoned pegmatites do contain tantalite but the main production from this area has been beryl. In almost all of these, the economic mineralization is located in the fine-grained albite or clevelandite zone or in the lepidolite greisen.

Along the northern margin of the Fort Victoria belt to the northeast of the town, beryllium-bearing pegmatites intruding serpentinites have given rise to occurrences of the precious varieties of chrome-bearing beryl and chrysoberyl known as emerald and alexandrite respectively. The source of the small but necessary chrome content is in the ultramafic serpentinite which is usually converted into biotite-tremolite schist. The famous Sandawana emeralds occur at the Zeus Claims on the southern margin of the Mweza belt in Belingwe District, in a similar geological setting. Emeralds are also known at other localities in the Mweza belt and south of Filabusi.

The Bikita Tin Field at the eastern end of the Fort Victoria Greenstone Belt was so named because that mineral was the first to be discovered but the production of lithium minerals particularly, together with beryl and tantalite has far exceeded that of cassiterite. The main Bikita pegmatite is a massive, layered, sheet-like body containing great tonnages of the lithium minerals, petalite, lepidolite, spodumene, amblygonite, eucryptite and the caesium silicate, pollucite. It is one of the world's major sources of these minerals.

THE GREAT DYKE AND SATELLITES

This structure is in reality not a dyke at all but is composed of four elongated lopolithic complexes preserved by faulting in a graben of major dimensions. It is a geological phenomenon and is unique in that it, alone among the world's larger ultramafic complexes, contains high grade metallurgical chromite. It strikes north-north-east for 540 km centrally across Rhodesia and varies in width between 3 km and 11 km. For the most part the Dyke is a positive topographic feature, but only spectacularly so in the northern third of its length where it forms the Umvukwe Range of mountains in which the heavily wooded pyroxenite ridges contrast strongly with the barren, grassy, serpentinite terrain. In the extreme south it terminates in a smooth curve but towards the northern end the overall straight character is lost, and beyond a dextral fault gap the Dyke is bent into an S-curve finally trending east along the Zambezi Escarpment. In this section the rocks are intensly faulted and it has been suggested that the structure was strongly folded into its present shape during one or other of the tectono-thermal episodes of the Zambezi Metamorphic Belt. However, as the rocks are neither foliated nor discernibly metamorphosed or metasomatized there is little support for this contention.

Age of emplacement of the Great Dyke has been well established at about 2 500 Ma ago by radiometric and palaeomagnetic methods. It is therefore considerably older than the Bushveld Igneous Complex, with which it was formerly correlated and with which it has much in common although it is chemically more magnesian.

In each of the four lopolithic complexes there is an overall gradation from the gabbroic rocks, gabbro, norite and anorthosite forming a centrally disposed capping at the top through to the ultramafic base of the intrusion as far as it has been probed. In each of them too, the gradation within the ultramafic sequence is not regular but is made up of cyclically repeated units. An idealised unit would contain basal dunite with a cumulate chrome seam in the lower part, overlain by olivine rocks that contain progressively more pyroxene upwards to be topped by a thick orthopyroxene layer composed almost exclusively of enstatite. The pyroxenite layer is not always present and in the largest, or Hartley Complex, 11 chrome seams are known but only 7 pyroxenite bands have been distinguished. Another feature of note is that down to the second pyroxenite in all four complexes the sequence is remarkably similar but lower down there is great disparity. Slumping of the

PLATE V

THE GREAT DYKE: Northern part of the Hartley Complex.

layers has produced a synclinal structure of the pseudo-stratification in each lopolith so that the layers dip gently from the margins to the central axes, the axes themselves being doubly plunging, even more gently, from the ends to central points beneath the gabbroic cappings. Gravimetric surveys have disclosed the largest gravity anomalies ever published over similar narrow widths of any continent and their interpretation suggests a slowly tapering and very deep linear core with a specific gravity of 3,3. The Hartley cross-section shows the Dyke to be symmetrical and funnel-shaped with the walls becoming increasingly steep with depth.

The Dyke is flanked by granitic rocks for the greater part of its length and its metamorphic effects are not markedly evident, but in places the invaded granite has developed pyroxene and has been thermally hardened so that it outcrops as castle koppies right adjacent to the Dyke. Engulfed inclusions from schist belts traversed, occurring in the Hartley area particularly as roof pendants, provide better evidence of thermal metamorphism in the form of greenstones converted into mafic hornfels or granulite and there are several occurrences of vein-like bodies of acid granophyre representing inclusions of siliceous sediments or lavas.

Deep drilling and mine workings have shown that the ultramafic rocks are almost invariably serpentinized to a depth of 300 metres or more below surface throughout the entire extent of the Dyke. It is believed that this is due to metoric agencies and in this connection the presence of methane, encountered in boreholes north of Darwendale and in the deeper mine workings at Mtoroshanga, is a phenomenon of interest and concern in mining operations. One of the boreholes intersected gas under pressure at a depth of 500 metres below surface. It ignited and was expelled for several days accompanied by a hydrous froth of sodium sulphate. Previously attributed to the downward percolation from the marshy eastern flanks of the Umvukwe Range, a most unlikely process in view of the low density of methane, an explanation is now believed to be found in the chemistry of the serpentinization reaction, which is probably continuing to this day. The reaction is intensely reducing and under certain circumstances nascent hydrogen is evolved which in the absence of oxygen reacts with carbonates or carbon dioxide to produce methane and graphite. This being so, vast quantities must have evolved and escaped to the atmosphere, but trapped pockets remain a danger.

Mineralization

The immense mineral wealth of the Great Dyke is in its chrome ore resources and the platinum metals horizon. There has been chrysotile asbestos production and magnesite has been exploited at the southern end in the Wedza ·Complex. Along both flanks of the northern most or Musengezi Complex there are very extensive semi-lateritized serpentinite deposits, at an altitude of 1 500 metres, containing one per cent or more of nickel which will with advancing metallurgical techniques have great future potential.

Apart from removal by erosion and fault displacements, chrome seams occur continuously throughout the entire extent of the four complexes. The number of seams known in each complex, from north to south respectively, is 7, 11, 7 and 6 and there may be others that have not been discovered although this is not likely because drilling penetrated 560 metres below No. 6 seam of the Wedza Complex and disclosed dunite with an abnormally high content of disseminated chromite but no additional seam. The chromitite layers may exceed 30 cm in width but the general average is of the order of 10 cm. Taking 6 km as the average width of the complexes and using the other dimesions quoted, the potential chromite resources of the Great Dyke are a staggering 10 000 million tonnes. In 1960 an ore reserve of 326 million tons in the seams then being mined was known and the industry has expanded greatly since that time. These calculations do not take into account the disseminated inter-seam chromite which has been successfully exploited from eluvial soil concentrations in the northern part of the Hartley Complex. In regard to quality, the chromite shows a progressive increase in chromic oxide content and chromium/iron ratio downwards reaching maxima of some 60 per cent and a ratio of 4:1 but the untreated ore from the two upper seams averages 47 per cent chromic oxide and has a ratio of 2,2 : 1.

The platinoid metals horizon, too, is continuous in all four complexes but the gabbroic rocks are of lesser extent than the ultramafic members. Nevertheless reserves are vast; they occur as a one metre thick layer, determined by assay cut-off, in the uppermost or No. 1 pyroxenite band between 30 and 50 metres below the base of the norite. Copper and nickel content are of the order of 0,25 per cent each and there are between 3 and 5 g/t of combined platinum and palladium finely disseminated in the base metal sulphides. The ore zone is very similar

Plate VI: Chrome seam in the Great Dyke, Van ad Mine.

to the Merensky Reef of the Bushveld Igneous Complex. It is being mined in the Wedza Complex and has been extensively explored in the Hartley Complex.

It might seem surprising that so large a mass of serpentinite as that represented by the Great Dyke has not had a significant chrysotile asbestos production. The reason is undoubtedly due to a general absence of structural deformation. There is one area where structural conditions were favourable and in this the Ethel Mine supported an operation that had produced 40 000 tonnes of high grade fibre by the end of 1965. Magnesite formation has been even more restricted and must have depended on processes no longer operative, as weathering and sepentinization now produce calcium carbonate as veins in the mine workings.

SATELLITES

The Umvimeela Dyke on the west and the East Dyke are remarkably persistent intrusions of quartz gabbro up to 250 metres wide which run nearly parallel to the Great Dyke for its entire length, diverging slightly from it southwards. On the basis of structural association and petrography they almost certainly represent the final phase of Great Dyke magmatic activity. Slightly off-set to the south-east of the Wedza Comlex and continuing for 80 km through granitic terrain well into the Limpopo Mobile Belt are several dyke swarms cogenetic with the Great Dyke. They are composed of melanorite and melagabbro and like the southern extremities of the Umvimeela and East dykes they have not been affected by the metamorphic and tectonic activity of the Limpopo belt.

The Chewore Complex in the Zambezi Valley, 130 km north-west of the northern end of the Great Dyke, is also believed to be genetically related although there is no discernible structural connection. This complex is intruded into charnockitic gneisses and is partly overlain by arenaceous sediments of Upper Karoo age. It is composed of partly serpentinized picrite and harzburgite together with pyroxenite and norite and although chromitite seams were noted they did not appear to warrant development at the time of the preliminary investigation of the area.

A most unsúal differentiated, layered intrusion is that which cuts Shamvaian lavas and sediments along the Hunyani River, 50 km north of Banket. Its age has not been established but again a genetic relationship with the Great Dyke seems probable. There is a 60-metre thick capping of cumberlandite, a rock composed of approximately equal proportions of olivine (FO_{65}) and titaniferous magnetite, which apparently rests horizontally on troctolite, consisting of similarly iron-rich olivine and labradorite feldspar. A limited drilling exercise indicated that the structure is more complicated than anticipated and revealed that the magnetite has a low vanadium content but no other mineralization of economic potential was located.

THE LIMPOPO MOBILE BELT

The Limpopo Mobile Belt is an extensive east-north-east-trending tract of high-grade metamorphic rocks that lies between the Rhodesian and Kaapvaal cratons. It is approximately 600 km long by 300 km wide, emerging from beneath a relatively undisturbed sequence of Umkondo and Karoo cover in the Sabi Valley and continuing across the southern portion of Rhodesia into Botswana where it apparently terminates beneath the Kalahari Sands. It may be subdivided into a central zone, with north-trending structures, which lies between northern and southern marginal zones that have east-north-east trends. In Rhodesia only the *Northern Marginal Zone* and the northern part of the *Central Zone* are represented and much of the junction between the two is obscured by down-faulted Karoo sediments and lavas. The Northern Marginal Zone is further subdivided into a northern granulite subzone, characterized by metamorphism of granulite facies which here affects rocks of the Rhodesian Basement Complex, and a linear zone that has suffered intense shear deformation and retrograde metamorphism. Both structural and metamorphic effects of the belt are evident at reduced intensity in the craton northwards of the diffuse granulite boundary which is a contact of decreasing metamorphic grade, local shearing and granite intrusion.

Until recently it was believed that the Limpopo Mobile Belt, in Rhodesia, consisted essentially of the 3 500 to 2 650 Ma granites and Archaean schist belt components, characteristic of the craton, highly metamorphosed and so granulated that they resembled paragneisses; and that infolded with them, as remnant outliers, in the Beitbridge area particularly, were magnetite quartzites, other metasediments, granulites and amphibolites of the Messina Formation. This formation, extensively developed south of the Limpopo River, was regarded as a much younger, highly metamorphosed and deformed equivalent of one or other of several epeiric basin deposits of Proterozoic age known to the south.

Investigations during the last decade have revealed a completely different picture. The cratonic Basement Complex components prove to be present only within the Northern Marginal Zone. An intensely flow-folded cover sequence, now classified as the Beitbridge Group, occupies the greater portion of the whole area. Its basement for the most part is revealed as rare inliers of the Macuville Group of South Africa which has an indicated age of 3 850 Ma. Layered anorthositic intrusions into the Beitbridge Group have been dated at circa 3 220 Ma. An age of 2 930± 120 Ma is attributed to the granulites of the Northern Marginal Zone and the Bulai granitic gneiss emplacement at 2 690 ± 60 Ma is regarded as representing the main Limpopo tectono-thermal event. Major activity ceased before the emplacement of the Great Dyke although a thermal event at about 2 000 Ma, not accompanied by obvious metamorphism or deformation, is indicated at many localities.

All of the evidence points to a unique situation in which the normal Archaean granite-greenstone assemblage, formed and modified over a period of some 900 Ma, lies in direct association with a completely different, but equally Archaean, assemblage formed and modified during much the same time span. Tectono-thermal activity in each ceased effectively some 2 600 Ma ago since when both have merely undergone uplift and erosion.

NORTHERN MARGINAL ZONE

Greenschist facies of metamorphism prevails in the cratonic rocks immediately north of the Limpopo Belt although Limpopo structural effects may be discerned in the form of strong east-north-easterly trends. At the craton margin the greenstones are converted into amphibolites, tightly folded along this regional trend. Proceeding south, granulite facies obtains over a width of some 40 km before it retrogresses within the linear zone, which at its widest is of the same order and which contains several extensive, parallel shears. Mineralogical changes in the granulite zone include the production of pink to honey-brown colour in the feldspars of the tonalitic gneisses and the appearance of bluish quartz. Enderbitic and charnockitic gneisses also make their appearance, rare in the west but commonly towards the east. The basaltic greenstones become pyroxene-bearing granulites containing variable proportions of plagioclase, hornblende, other amphiboles and in some instances cordierite and sapphirine. The ironstones are recrystallized to grunerite-magnetite quartzites. All are strongly drawn out to occur as tightly folded inclusion-like streaks and lenses within the quartzo-feldspathic gneisses. Some of these measure only a few metres across whereas others form long ridges as much as 2 km wide. In the country south of the Buhwa-Mweza Schist Belt deformed remnants of one of several differentiated ultramafic intrusions known in the area are preserved as chromite-bearing serpentinite with associated anorthosites. Potash-rich gneisses within the granulite zone are chemically so similar to the nearby Chibi and Zimbabwe batholiths that there is probably a genetic relationship with them and with the later pods and sheets of coarsely porphyritic granite along the craton margin.

The southern boundary of the granulites is characterized by an abrupt topographic transition from hilly country to flat lowveld. This marks the situation of the linear or cataclastic zone where metamorphic grade is reduced to amphibolite facies and where the most northerly outcrops of garnetiferous leuco-paragneisses and other metasediments of the Beitbridge Group are first encountered. They are intimately intermingled with the orthogneisses, charnockitic gneisses and amphibolites of cratonic origin and are all aligned on the same trend. In consequence, especially where there is lack of outcrop continuity, it has not been possible to determine whether certain of the ironstones, amphibolites and granulites are representative of a greenstone assemblage or of the Beitbridge Group; their lithology is common to both.

In regard to structure, as previously stated, the predominant feature throughout the Northern Marginal Zone is a persistent east-north-easterly foliation. As this invariably dips south, isoclinal folding is strongly suggested. Plastic deformation of this period has led to extreme attenuation, boudinaging and refolding of fold limbs and a later deformation about north-westerly axes has sporadically produced assymetric domes and basins, albeit of a tenuous nature. Major dextral shearing, characterized in several areas by flaser gneisses, is seemingly always associated with reduction in metamorphic grade and the latest activity to leave a marked impression was brittle fracture, related to intrusion of the Great Dyke, which resulted in a set of faults often occupied with mafic dykes.

CENTRAL ZONE

Although not well exposed, the Central Zone of the mobile belt occupies a considerable tract of country immediately north of the down-faulted belt of Karoo basalts and sediments of south-eastern Rhodesia. However, its main development and characteristic tectonic style are best displayed in the large rhomb-shaped area bounded on the north by these Karoo rocks and on the south by the Limpopo River.

Other than the few inliers of ancient gneisses of the basement Macuville Group and intrusions of Bulai Gneiss and Ultramafic Complexes, all present in the more dissected country approaching the Limpopo River, the entire terrain is occupied by formations assigned to the Beitbridge Group. This group has been classified into a widespread Diti Formation overlain by an infolded sequence known as the Nulli Formation which is equivalent, in part, to the Messina Subgroup of South Africa.

Gneisses constituting the *Macuville Group* have been recognised both east and west of Beitbridge township as small isolated inliers often associated with the Bulai Gneiss. They are banded, migmatitic and often nebulitic grey rocks, variably of dioritic, tonalitic, granodoritic or enderbitic composition and characteristically contain little or no garnet. The foliation of these gneisses is transgressed by deformed bands of mafic granulite interpreted as representing early doleritic dykes. The *Diti Formation*, which occupies the greater part of the whole area, consists predominantly of banded garnetiferous biotite gneisses which may contain as much as 70 per cent of these minerals but more usually have appreciable amounts of microcline perthite, plagioclase and quartz as well and may be quite pale coloured. There are also rare lenses composed entirely of garnet and biotite with barrel-shaped corundum crystals and intergrown sillimanite. Interbedded with these are the leucogneisses which are much better exposed, consist essentially of quartz and feldspar, and often have trains of garnets possibly delineating bedding planes. Thin horizons of massive quartzite, magnetite quartzite and calc-silicate rocks are intercalated throughout the succession and there is a dolomitic marble member that contains serpentinized ophicalcite. A distinctive orange-brown weathered surface of the so-called Singelele Gneiss, a garnetiferous biotite feldspar paragneiss of granitic aspect, enables it to be traced as a separate horizon near the top of the formation. Also towards the top of the formation are grunerite-bearing magnetite quartzites with associated biotite-cordierite gneiss. Most of the overlying *Nulli Formation*, which forms a prominent range of hills of the same name, consists of a variety of massive and granular sillimanite-bearing quartzites and beds of diopside-bearing calc-silicate rocks. Both formations are cut by sills and dykes of mafic composition now granulite and amphibolite.

Two major types of syntectonic *Ultramafic Complexes* have been intruded into the Beitbridge Group. Serpentinite and metapyroxenite form interbands and pods associated with magnetite quartzite horizons and occur as large oval plugs in the noses of folds. East of Beitbridge layered meta-anorthosite complexes strike northwards across the Limpopo River from South Africa and have been traced for more than 50 km to beyond Marungudzi. They consist of sheets up to 400 metres thick of banded mesocratic and medium-grained, anorthite-hornblende granulites, the more hornblende-rich varieties of which are better exposed. A local occurrence of interest within the anorthosites is an inclusion containing large crystals of kornerupine in association with corundum, sillimanite, sapphirine, cordierite and gedrite. The syntectonic *Bulai Gneiss,* considered to have formed by anatexis from gneisses of the Macuville Group, occupies an area of 200 km² immediately north-west of Beitbridge as several lobes with north-north-easterly alignment. It varies in composition from grey tonalite to porphyroblastic granodiorite and is surrounded by a charnockitic halo.

The complex *tectonic history* of the Central Zone commenced with the obscure folding and metamorphism of the Macuville Group prior to deposition of the Beitbridge cover sequence in which it is possible to distinguish four major deformational events. The first led to the production of recumbent isoclinal folds with easterly axes and was accompanied by a metamorphic phase, of kyanite-granulite grade, during which the ultramafic complexes were emplaced. A long period of quiescence was followed by a phase that led to upright isolcinal folds about north-easterly to north-north-easterly axes. Attendant metamorphism of sillimanite-granulite grade progressed locally to anatexis of the basement and intrusion of the Bulai Gneiss. Thereafter intensity of metamorphism declined through the final phase of deformation which resulted in north-west-trending, upright cylindrical folds that have given rise to the open dome and basin structures reflected in the present topography.

Economic mineralization of significance in the Northern Marginal Zone is restricted to occurrences of chromite within a serpentinite complex south of the Buhwa Mountain and intricately folded gold mineralization in enderbites at the Renco Mine north of Bangala Dam. Search for copper-nickel mineralization has been largely unsuccessful although small deposits associated with mafic granulites are known and several geophysical anomalies discovered during exploration exercises proved to be massive pyrite-pyrrhotite bodies not otherwise mineralized. Large magnetite resources at Manyoka and Mongula, in the extreme east, may warrant future exploitation in conjunction with coal from adjacent Karoo fields.

The Central Zone contains numerous copper showings apparently confined to epidotized breccia shears but none has proved to be encouraging. Magnesite, as stockworks in serpentinite, has been extensively worked at the Pande Mine. Metamorphic minerals produced on a small scale include garnet and crystal corundum, and epidotized Bulai Gneiss finds a market as the semi-precious gemstone, unakite. Sillimanite schists near Gwabe in the west have attracted attention and weak uranium mineralization associated with small pegmatites near Beitbridge aroused interest in the past.

THE ZAMBEZI METAMORPHIC BELT

This northern metamorphic belt extends for some 900 km in Rhodesia from Wankie in the west, through Kariba to beyond Nyamapanda in the north-east. The complex zone of high-grade metamorphic rocks occurs along the northern margin of the relatively undisturbed Rhodesian craton and in much of the western part is obscured by considerably younger unmetamorphosed cover rocks. Between Kariba and a point north-east of Mount Darwin exposure of the belt is terminated on the north by the Zambezi Escarpment Fault and only the Chewore gneiss inliers protrude through Karoo cover in the mid-Zambezi Valley.

The zone is not a regular mobile belt in the same sense as the Limpopo Belt and, although several charnockitic hot spots have been located, the grade of metamorphism is generally lower. It is also far more complex in that it contains many more lithological units that often strike across the general trend, and as a whole has experienced a longer and more involved history of metamorphism and structural deformation up to the latest or Miami metamorphic event, 400 to 650 Ma ago.

For descriptive purposes division is made into western, central and eastern sections. The western section is exposed as several gneiss and schist inliers centred on the villages of Dett and Kamativi. These rocks pass north-eastwards beneath Karoo and Sijarira cover sequences for some 150 km before emerging in the Matusadona Range, south of Kariba. This section, unlike the remainder of the belt, has not been affected by the circa 500 Ma Miami metamorphic event. The central section comprises the area between Kariba and the Angwa River and involves several refoliated lithological elements which include the northern extremities of the Piriwiri, Deweras and Lomagundi groups and the younger Makuti Group of Katangan age as well as a number of post-Basement Complex but pre-Piriwiri pelitic paragneiss formations. The eastern section continues eastwards from the Angwa River to the Mozambique Border where it merges with the Mozambique belt having an inter-relationship that has not yet been satisfactorily resolved but may well be represented by a syntaxis in which east-trending Rushinga and other formations are infolded with north-trending elements of the Umkondo Group.

WESTERN SECTION

Precambrian schists and gneisses of the Zambezi Metamorphic Belt are exposed in the west of Rhodesia as inliers within relatively undisturbed Sijarira, Karoo and Kalahari cover. The Dett-Kamativi inlier, which is the largest, trends north-eastwards for a distance of about 150 km bounded to the north by Karoo sediments and blanketed in the south by aeolian Kalahari sands. It consists of granitic gneiss recognisably intrusive into four north-east-trending belts of highly deformed and metamorphosed sediments, namely the Kamativi, Tshontanda, Inyantue and Malaputese formations.

Two stratigraphic domains have been established in the *Malaputese Formation*. In its western part arcuate domes of pink, granitic paragneiss are mantled by tightly folded mafic granulites, metapelites and quartzites and in the eastern domain a thick succession of hornblende-andesine amphibolites overlies metapelites in a series of quartzite enclosed synforms. The mafic rocks are interpreted as metamorphosed extrusive basalts within thinly bedded volcanogenic sediments and tuffs.

The *Kamativi* and *Tshontanda* formations are composed almost entirely of garnetiferous mica schists intimately veined and infolded with garnet-tourmaline-mica pegmatites. The pegmatites which range in size from mere wisps to large sheet-like bodies over 30 metres thick were emplaced mostly during the main granitic episode. Garnetiferous sillimanite- and cordierite-bearing gneisses, regarded as the high-grade parents from which the schists were derived, are locally preserved in parts of the Tshontanda belt.

The V-shaped *Inyantue Formation* merges with the schists of the Kamativi belt in the north and extends beneath the Kalahari sands in the south. It is composed of garnetiferous sillimanite-cordierite gneiss and migmatite with intercalations of calc-silicate rock, graphitic schists, biotite-hypersthene granulite, quartzite and talc-chlorite schist.

The *granitic gneisses* are usually medium-grained, weakly foliated, nebulitic rocks of granodiorite or adamellite composition. Along zones of deformation they become strongly foliated and have blasto-mylonitic fabric. Numerous sedimentary inclusions range in size from a few centimetres to bodies more than a kilometre long. Near the larger of these and adjacent to the main schist belts the gneisses are usually biotite-rich and migmatitic, with many inclusions and schlieren. The contacts are transgressive and recognisably intrusive.

Upper amphibolite to granulite facies metamorphism is the earliest recognisable thermal event of the area. A later, retrograde, greenschist to lower amphibolite grade of metamorphism accompanied intrusion of the granitic rocks and the emplacement of numerous pegmatite swarms in the linear belts. Granitic rocks from the Kamativi area have an average Rb-Sr age of 2150 $\pm$ 100 Ma and the tin bearing pegmatites a Rb-Sr age of 990 $\pm$ 15 Ma.

Three fold phases are evident from the regional and small-scale structures in the Malaputese Formation. The initial intense deformation accompanied the early high-grade metamorphism and produced north-east-trending isoclinal folds and local large-scale recumbent structures in the south-east of the inlier. Granite intrusion probably preceded the second fold episode which formed more open north-west-trending structures. Tight, third phase folds deformed both the granites and the meta-sediments producing structures often coaxial with those of the first phase.

Economic Mineralization. The Dett-Kamativi inlier contains the only known deposits of economic value in this western sector of the Zambezi belt. Large flat-dipping sheets of lithium-tin pegmatite are being mined at Kamativi, Lutope and Kapata in the Kamativi Formation. Swarms of smaller steep-dipping tin pegmatites occur sporadically throughout the belt, becoming larger and more abundant in the main tin-mining centres. These economic pegmatites post-date and are apparently unrelated to the garnet-tourmaline-mica pegmatites. Stockworks of wolfram-tourmaline quartz veins, some carrying copper suphides, have been located in the narrower stretches of the Kamativi and Tshontanda belts. It is probable that these veins are a late hydrothermal phase of the tin pegmatites. Significant copper has been exploited at the Gwaai River Mine. Mica has been won from late stage cross-cutting tourmaline pegmatites in the Tshontanda belt and argentiferous galena occurs in quartz veins within the Inyantue Formation. Fluorite in siliceous veins is found within faults in the granitic gneiss usually adjacent to outcrops of Karoo sediments.

CENTRAL SECTION

North-east-trending gneisses emerge from beneath cover rocks to form the Matusadona Range south of Kariba and continue into the central section of the metamorphic belt. It is significant that no proven remnants of the Rhodesian Basement Complex are exposed in this area although numerous such inclusions were noted in the post-Piriwiri granodiorite of the southern Urungwe district, itself possibly a remobilized Basement granite. The *Urungwe Paragneiss* forms the local basement over a wide area north and west of Karoi and is overlain to the east by north-trending *Lomagundi and Deweras* groups. The central part is covered to large extent by schists and gneisses of the *Piriwiri Group* which also overlie and are infolded with various post-Basement micaceous gneisses recognised as the *Chiroti, Chipisa, Kariba and Chitumbi* paragneiss formations. The late-Precambrian *Makuti Group* occupies the country along the Zambezi Escarpment between Kariba and Makuti and has been correlated across the Zambezi River with the Katangan of southern Zambia. This Makuti Group is a thick succession of meta-sediments consisting of a largely pelitic basal Tsororo Formation and an upper Vuti Formation comprising pink, feldspathic paragneiss, micaceous and aluminous schists, quartzites, calc-silicate rocks and conformable amphibolites of igneous origin. With the exception of the Deweras, Lomagundi and Makuti groups all of the foregoing have been subjected to varying degrees of permeation by fluids of granitic composition and are extremely variable in texture and composition. They are usually migmatitic gneisses rich in biotite with common infolded calc-silicate resisters. The early Proterozoic formations distinguished as overlying the Urungwe Paragneiss are all remarkably similar but have been locally named. The Chiroti Paragneiss of the south Urungwe district may be granitic or a strongly foliated biotite gneiss frequently porphyroblastic. The Chipisa Paragneiss occurs to the south and east of Kariba and forms a monotonous series of well foliated biotite gneisses whereas the Kariba Paragneiss although similar contains infolded sillimanite quartzite. The Chitumbi Paragneiss present west of the Shamrocke Mine is also a well foliated biotite-rich variety. The Piriwiri Group, covering a large part of the area under consideration, is also in part permeated and granitized; is intruded by the Urungwe and Miami granites and in the Nyaodza Valley displays hot spots of plagioclase charnockite. The Deweras and Lomagundi groups elevated to amphibolite grade north-west of the Shamrocke Mine and converted into meta-arkoses, coarsely crystalline dolomite, tremolite marble, quartzite, micaceous and graphitic schists and amphibolite have not been so permeated nor has the Makuti Group except at its extreme base.

With all these formations, several of similar lithology, that have been subjected to tectono-thermal influences since earliest geological times the structures of the area are understandably extremely complex. South of the Zambezi Metamorphic Belt namely, in this area, generally below the 17°S latitude, the Piriwiri rocks have been folded on northerly axes and converted into phyllites of low greenschist facies or, in the aureole of the Urungwe granodiorite, into garnetiferous biotite schists. This is attributed to an episode termed the Magondi orogeny for which an age of circa 2 000 Ma seems to be appropriate although age determination exercises have been few and the results contradictory. As these Piriwiri schists also occur infolded with metasomatized Chiroti paragneisses in the Urungwe west area an earlier metamorphic event must have been responsible for the elevation of the Chiroti pelites to paragneisses. Its age is not known and it may have been polyphase but it was presumably Archaean. Indeed several remnant Archaean imprints, in one instance of the order of 3 000 Ma, have been detected even within the sphere of influence of the Miami metamorphism which itself is confidently dated in the range 400 to 650 Ma.

North of latitude 17°S any Magondi effects that may have been present have not been distinguished within the zones of much higher metamorphic grade and more intense deformation resulting from the circa 800 Ma Katangan event and the Miami event, the latter particularly, as the strong north-westerly trends of the Katangan orogeny leave little impression beyond the southern outcrop margin of the Makuti Group. In view of this it is surprising that the final metasomatic phase of the Miami event has effectively failed to penetrate into the Makuti Group although all the older surrounding formations are extensively intruded by pegmatites.

Within the Makuti Group, in the vicinity of Gota Gota, greenschist facies prevails but proceeding south and east zones of staurolite-kyanite, kyanite-almandine and sillimanite-almandine fan out progressively. Similarly but in the complementary directional sense the Piriwiri phyllites pass from greenschist facies, some 20 km south-east of Miami, through zones of staurolite-kyanite and sillimanite-almandine sub-facies to granulites culminating in the formation of the enderbitic derivatives along the junction between the two fronts in the Nyaodza and Rukomeshe valleys. It is pertinent to record too that the isograds in the southern area frequently trend strongly oblique to the formational strike and furthermore that the oft repeated statement to the effect that metamorphic grade rises progressively from south to north approaching the Zambezi Valley, is not strictly correct.

Mineralization. The location of economic mica pegmatites within sillimanite-bearing host rocks is a clear example of the metamorphic control of the formation of book-mica oreshoots which are located on the hanging and foot-walls of pegmatite dykes. Many of these have been mined to vertical depths exceeding 100 metres and have produced very high quality ruby mica. Zoning is a common feature of the pegmatites and instances of composite intrusions are recorded. Most of the deposits contain beryl and tantalo-columbite mineralization as well and in several, late pneumatolytic action has led to kaolinization of the feldspar and provided conditions favourable for the growth of beryl, topaz and tourmaline of gem quality. Tungsten in the form of wolframite is being mined from late-phase quartz veins extending beyond the feldspathic phase of the pegmatite intrusions in the country east of Karoi and in the Urungwe west field. Tin is exploited from a belt of concordant pegmatites in garnetiferous mica schists associated with two cupolas of Miami granite. Graphite deposits within the Piriwiri Group improve in quality with increasing metamorphic grade and are mined in the Urungwe east area. Kyanite pseudomorphing chiastolite has been exploited from deposits near the Angwa River, east-north-east of Miami but as far as is known the sillimanite schists do not attain a sufficiently high degree of purity to warrant mining, Muscovite quartzites of the Makuti Group form good flagstones and are extensively quarried in the Kariba area. The copper mineralization at the Shamrocke Mine in the Lomagundi Group and that interstratified in the Makuti paragneisses ante-date the metamorphisms but have been tectonically modified.

EASTERN SECTION

Between the Angwa and Hunyani rivers the country is not well known. However prominent early-Proterozoic biotite and hornblende paragneisses, variably migmatized, are here described as the *Escarpment Gneisses.* They rest on granitic rocks of the craton, have a strong easterly grain and occupy the greater part of the country. Several major shear zones, one approaching a kilometre in width, traverse the area and terminate against the Zambezi Escarpment Fault. They represent a prolongation of the Deka Fault system so well developed in the Wankie District, 500 km to the south-west.

The adjoining Sipolilo area, stretching from the Hunyani River to the Great Dyke provides the most westerly example of undisputed involvement of elements of the Rhodesian Basement Complex in the high grade metamorphic belt. Greenstones of the *Basaltic Formation* of the *Bulawayan Group* are converted into mixed biotite and amphibole schists and gneisses as are the metagreywackes of the *Shamvaian Group* whereas the meta-arkoses become granitic paragneisses. Profuse *lit-par-lit* injection and incomplete metasomatic transformation have resulted in there being a most heterogeneous assemblage of gneisses containing lenticular calc-silicate resisters and penetrated by stocks of granite. There is a pronounced westerly metamorphic foliation almost at right angles to the northerly strike of the Sipolilo Schist Belt of the craton. The transition from low greenschist facies of the cratonic area to amphibolite grade is relatively rapid becoming particularly marked some 15 km south of the Escarpment Fault. The age of the tectono-thermal activity responsible for the transformation can only be bracketed as post-Shamvaian and pre-Great Dyke, at 2 500 Ma, on the assumption that the Great Dyke would have retained evidence of metasomatism and migmatization, at least in its mafic horizons, had it been emplaced prior to this metamorphic event. Continuing to the east, the Darwin, Swiswamoyo, Benson and Makaha schist belts, as additional examples, occur along the southern margin of the high grade metamorphic zone and are affected to lesser degree than the Sipolilo belt although they are amphibolitized and drawn into the migmatitic gneisses in their northern parts. North of Chirwa Hill mafic schists, biotite gneiss, calc-silicate rocks and quartzites, within the staurolite-kyanite sub-facies of regional metamorphism are believed to be extensions of the Makaha Schist Belt but it is not always possible to distinguish such assemblages from early-Proterozoic paragneiss formations when they have been folded together and have been migmatized. The *Escarpment Gneisses* of the Tondongwe area, in the west, are one of these early-Proterozoic formations, so too are the *Mazoe Schists* which are lithologically very similar to the Kariba Paragneiss. Further east the *Nyamvu Schists and Gneisses*, consisting of a folded sequence of biotite and migmatitic gneisses with associated kyanite schists apparently equate to the Mazoe Schists and may be equivalent to the Barue Formation in Mozambique.

The gneissic complex of the metamorphic belt, with its occasional porphyritic granite stocks, isolated charnockitic hot spots and epidioritized mafic intrusions is so complexly folded and migmatized that it has, up to the present, defied separation into Archaean and Proterozoic elements except those enumerated and in those instances where the rocks may be traced back to their lowly metamorphosed equivalents in the schist belts of the craton. Dating of the activity as well is problematical for although results of analyses of several samples from the Sipolilo, Benson and Chirwa areas fall in the range 2 250 to 2 500 Ma the whole area is strongly overprinted by the Miami event and the Katangan event has not been revealed at all, possibly because most of the samples were taken in areas containing strong pegmatitic influence.

The much younger middle to late-Precambrian sequences resting on and variably folded with this migmatitic basement are the *Umkondo Group*, sporadically developed in the extreme east, the *Kahire Group* forming part of the Mavuradonha Range and the *Rushinga Group* which occupies a strip of country 15 km wide stretching for 150 km from north of Mount Darwin to Nyamapanda on the eastern border of Rhodesia. The oldest of these, the Mozambique Facies of the Umkondo Group, in northern Inyanga District consists of basal orthoquartzite with phyllites and micaceous schists containing chloritoid. An outlier preserved around the Chirwa Dome is composed of quartzite, diopside-bearing calc-silicate rock and staurolite-kyanite schist with interstratified amphibolite and is the most northerly known occurrence of Umkondo rocks in the country. The Kahire Group comprises various feldspathic, garnetiferous and hornblendic gneisses together with amphibolite and dolomitic marble. A well developed basal conglomerate has been noted at several places along the Mavuradonha Range. This sequence has a persistent easterly strike and dips at moderate angles to the south. Its relationship with the migmatitic gneisses and the Rushinga metasediments has not been satisfactorily established. It seems likely that the narrow strip of picrophengite schists and granulites north of Sipolilo may be related. The Rushinga Group has almost identical lithology to the Makuti Group of the central section of the Zambezi Metamorphic Belt and bears a similar relationship to the underlying migmatitic gneisses except that the pegmatitic phase has penetrated more deeply into the basal beds of the former. Correlation, however, is probable. North of Mount Darwin the basal pelitic sediments of the Rushinga Group, among them kyanite and sillimanite schists and muscovite quartzite, are overlain by a thin but persistent dolomite bed in turn followed by a thick pink meta-arkose.

Other than in the extreme west interbedded amphibolites are not common. East of Rusambo there are small modifications and a basal conglomerate has been recognised. Prevalent dome and basin structures of the area are believed to be largely due to local thickening of competent members. In addition to the many doleritic and feldspar porphyry dykes that traverse the country in this north-eastern area two irregular ring intrusions of carbonatite type penetrate the Kahire Group at Nanuta Hill and Gungwa. The enclosing gneisses are scapolitized and contain apatite and magnetite.

Economic Mineralization. Despite the occurrence of a great variety of metamorphic minerals in the area under consideration economic production has been small. Deposits of kyanite, with considerable potential, mica, coarsely crystalline dolomite and glitterstone have been exploited and sillimanite, corundum, amazonite and wollastonite warrant further investigation. Some of the corundum in pegmatoid lenses approaches gem quality ruby and sapphire. The kyanite deposits that have been mined are in two categories. At the Ky Mine and in Inyanga North, residual concentration of a member of the Nyamvu Schists has formed valuable eluvial deposits and at the Prylin Mine very large tonnages of kyanite are present in an assymetrical synclinal basin of pelitic schists of the younger Rushinga Group. High quality mica at the Idol Mine represents one of the few examples of pegmatite intrusion into the Rushinga metasediments. Exploration exercises within rocks of the Kahire Group at Nanuta Hill have indicated millions of tons of low grade but potential copper ore, and in the same area magnetite deposits have an appreciable vanadium content. Significant lead, zinc and copper mineralization is known within the Nyamvu Schists south of Chirwa Hill and occurrences of molybdenite have received attention. Scheelite at Ball Mine, tantalum in the form of microlite at Benson Mine and many small beryl and gold deposits, although within the high grade metamorphic zone, belong more properly to the Basement Complex mineralization.

THE PIRIWIRI, DEWERAS AND LOMAGUNDI GROUPS

An arcuate belt of folded sedimentary rocks of contrasting bulk lithologies occurs in the north-west of the country, stretching in a north-north-easterly direction from the Umniati River, west of Gatooma, to the Zambezi Escarpment. These rocks were originally grouped together in a loosely defined Lomagundi System but are now subdivided into a

Deweras Group, in the east, comprising arkoses, greywackes, argillites and basaltic lavas, unconformably overlain by a Lomagundi Group consisting of quartzites, slates and greywackes with a basal orthoquartzite-carbonate association and adjoined on the west by an extensive Piriwiri Group composed mainly of phyllites and greywackes.

The lithological groupings of these rocks have been defined several times during the piecemeal mapping of the belt, and the Piriwiri and Deweras have been referred to both as separate entities and as series and formations of the original embracing Lomagundi System. Accounts of the chequered history of the classifications which evolved are contained in the many departmental publications on the subject.

Recent completion of regional mapping of the belt, which has involved the tracing of the lithological and structural units, together with the adoption of a loose lithostratigraphic system of nomenclature has resulted in the establishment of the three separate groups referred to. They are composed of variously named formations which possess certain distinctive or combinations of distinctive features, possibly of a genetic character, and are subdivided into members themselves of distinct lithological character.

The exact inter-relationships of the groups are imperfectly known for throughout most of the belt normal stratigraphic relationships are obscured by folding and thrusting, and there is an almost total absence of exposure in the critical areas. The uncertainty which has been termed the "Lomagundi Puzzle" is compounded by high-grade metamorphism in the north and a cover of Lower Karoo and eluvial deposits in the south.

The Deweras Group is regarded as having been deposited in a graben formed by fracture of the eastern margin of the Piriwiri basin after which further subsidence and marine incursion led to the differentiated sedimentation of the Lomagundi Group in a series of axially adjoining basins along the same general northerly trend.

South of latitude 17°S the groups display no evidence of having been affected by the circa 500 Ma Miami metamorphism. Nevertheless the radiometric age determinations made have been inconclusive in attributing absolute or even relative ages to the three groups. Galena from the Copper Queen Mine in the Piriwiri Group gave a result of 2 250±32 Ma and a lead age from a prospect in Lomagundi dolomite is recorded at

1 980±33 Ma. Whole rock, K-Ar ages from Lomagundi slates and Piriwiri phyllites range between 1 655 Ma and 1 975 Ma. Furthermore the Urungwe porphyritic granodiorite intrusive into the Piriwiri with the production of a thermal aureole, has a whole rock Rb-Sr age of 2 180±130 Ma whereas its biotite age is only 833±40 Ma. Numerous explanations for these diversities have been offered but the picture remains obscure other than to say that the groups are of early Proterozoic age and were only mildly metamorphosed where not involved in the Miami event, which is described in the chapter dealing with the Zambezi Metamorphic Belt.

PIRIWIRI GROUP

Piriwiri Series was the name given by Molyneux in 1919 to a monotonous succession of phyllitic rocks forming a belt 50 km wide in the country west of Sinoia. In the west they pass unconformably under Karoo or Sijarira red beds cover or have been intruded by the Urungwe granodiorites. Beyond this granitic core they are recognised as remnants, at higher metamorphic grade, infolded with various older paragneiss formations in the Zambezi Metamorphic Belt; here with north-easterly rather than north-north-easterly strike and extending as far west as the Wankie District where they occur as the tin-bearing schist belts of the Kamativi-Dett inlier.

Although Molyneux recorded younging from west to east of the Kanyaga, Chidomo Sandstone and Graphitic divisions which he distinguished in his series and which are throughout in faulted contact with the west-dipping Striped Slates of the Lomagundi System, he nevertheless placed them as the uppermost members of that system. This practice has been followed by many subsequent workers in the field and the Piriwiri has been described as the deep water or flysch facies coeval with a miogeosynclinal or shelf facies assemblage of dolomites, orthoquartzites and slates to the east.

Essentially the Piriwiri Group, as it is now named, consists of phyllites, greywackes, black graphitic and ferruginous slates, cherty quartzites, other subordinate argillaceous and arenaceous members plus rare volcanics. In areas of higher metamorphic grade calc-silicate rocks are present but their parent type has not been recognised elsewhere. Structural analysis around and east of the Copper Queen Mine led to the distinguishing of four phases of deformation. These and the accompanying metamorphism were termed, perhaps rather extravagantly, the

Magondi orogeny. The practical result was folding of the group principally on north-north-easterly axes curving north and eventually north-north-west and the impression of a strong, usually vertical, regional foliation often coincident with the bedding which has led to the sculpting of strikingly linear terrain unmistakable on aerial photographs and contrasting strongly with the photo-expression of the Deweras and Lomagundi groups.

In the thermal aureole of the Urungwe granite, Piriwiri rocks have been converted into garnetiferous mica schists and micaceous quartzites and in the Miami area, by the much later, circa 500 Ma metamorphism, progressively to sillimanite schists and gneisses, but for the greater part low greenschist facies prevails.

Many attempts have been made at stratigraphic subdivision, often based on the proportion of various constituent varieties and the presence or absence of impersistent volcanic members. For instance along the Umfuli River section, three divisions have been erected on somewhat tenous grounds. An Umfuli Formation comprises phyllites and greywackes with minor interbedded cherty quartzites and grits plus, in the south, graphitic and pyritiferous slates at the base. The Chenjiri Formation, also consisting of phyllites and greywackes, is characterized by thin beds of tuff, chert and pyritiferous slate, and thicker beds of micaceous quartzite are prominent. Thirdly, the Copper Queen Formation has predominant phyllites identical to those of the other formations but lacks interbedded chert and tuff. Additionally it contains the contact aureole of the Copper Queen and King domes where hornfelses, skarns and amphibolites, probably of Basement Complex origin, are circumscribed by garnetiferous mica schists and micaceous quartzites. Due to thinning out of members and subtle lateral facies changes, such subdivisions can seldom be sustained beyond local map boundaries. As a consequence in the most recent analysis it has been necessary to revert to a two-fold division namely a *Kanyaga Formation* equating largely to Molyneux' division of the same name and composed of phyllites, greywackes and micaceous quartzites with a very fine, silty, buff to pinkish soil cover and a *Chitena Formation* with prominent graphitic phyllites, cherts and black ferruginous slates. Both are penetrated by sodic diatremes and contain thin beds and lenses of agglomerate, tuff and associated narrow, cherty albitite dykes.

As previously stated opinion regarding the relationship between the Piriwiri and Lomagundi groups has been contentious. For more than 220 km of strike the exact contact is nowhere displayed. Its approximate position is usually marked by a topographic break and the appearance of graphitic schists. However, there are numerous factors which although not individually conclusive, strongly indicate that Lomagundi deposition post-dated the formation of the Piriwiri Group. Among these are different folding styles; the almost ubiquitous presence of concordant white quartz veins in the Piriwiri absent from the adjacent Lomagundi Striped Slates; the generally higher metamorphic grade of the former; and the occurrence within the Piriwiri Group only of Basement Complex type of hydrothermal gold mineralization, as at D Troop Mine, copper-lead-zinc mineralization at the Copper Queen Mine and low grade copper-gold mineralization in association with quartz-siderite veins that characterizes the so-named old Piriwiri mineral belt.

In addition to those described there are three other categories of *mineralization* within the group. In the zones of higher metamorphic grade intrusions of pegmatite are common and many have been mined for their tin, tantalum and beryl content. Late phase quartz veins have produced wolframite and several of the pegmatites contain beryl, topaz and tourmaline of gem quality formed as the result of late pneumatolytic processes. High-grade book or sheet mica once the basis of a flourishing industry has deteriorated into scrap recovery for ground mica production. The mica-bearing pegmatites are demonstrably confined to sillimanite grade terrain which also contains deposits of kyanite, sillimanite and graphite ore. Manganese often in association with flat-dipping quartz veins within graphitic phyllites is characteristic for long stretches of the contact zone between the Piriwiri and Lomagundi groups where thrusting is suspected.

DEWERAS GROUP

The Deweras Group is seen as a deposit of medium- to coarse-grained unworked sediments of a continental environment. Alluvial fans situated along the fault-bounded margins of crystalline massifs are considered to have distributed the sediments into intermontane troughs with finer grained and sometimes calcareous varieties being the product of evaporative conditions in temporary basins of water along the axes of the troughs. The bounding faults, as well as controlling uplift of the provenance, probably acted as channels up which tholeiitic magma was introduced.

The group was, in 1936, first defined in the Lower Umfuli area to the north-west of Hartley where it was regarded as an uppermost series of the Basement Complex although separated by major unconformity from all older formations. Traced southwards beyond the Umniati River into the Mafungabusi area, it became apparent that it had a much greater affinity with the overlying Lomagundi Group albeit here too with distinct unconformity. Proceeding north the Deweras passes underneath the Lomagundi for some 40 km to emerge as an antiformal exposure 10 km wide flanked by hills of Lomagundi dolomite and quartzite which extend nearly to Mangula Mine. North beyond the mine there is a swing in strike from north to north-northwest and the arkosic rocks, heavily intruded by dolerite, continue as a belt some 5 km wide to the Zambezi Escarpment. They rest on granite, in the main unconformably but with intrusive relationship adjacent to Mangula Mine and dip west below the Lomagundi dolomite, quartzite and slate which are succeeded by the Piriwiri Group, in this area, all apparently conformably.

South of the Umfuli River exposure is relatively good and although the rocks have been involved in two major episodes of deformation accompanied by thrusting and extensive faulting, bedding dips are flat to moderate and it has been possible to divide the sequence with confidence into three formations. A *Lower Arenaceous Formation*, sporadically developed, attains a maximum thickness of 150 metres. Grey-green to reddish brown grits, arkoses and thin shales are subordinate to a distinctive basal conglomerate with Basement Complex-derived clasts of tonalite, porphyry, quartz, chert and lavas. This is unconformably overlain by the *Volcanic Formation* as much as 1000 metres thick in places and composed of flows of amygdaloidal tholeiitic lava generally green or purplish in colour and often strongly epidotized. The flows, which provide evidence of gravity differentiation, are often separated from one another by thin impersistent mud seams. In scattered localities agglomerates occur at the top of this succession. The very thick *Upper Arenaceous Formation* rests with a fossil lateritic base upon reddened and spheroidally weathered lava. It is composed of greywackes of variable lithology and containing a chaotic boulder bed, followed by an argillite member with reddish shales and thin dolomite horizons; in turn capped by considerable thicknesses of medium- to coarse-grained, cross-bedded arkoses. The formation is grey-brown in the lower parts becoming paler and pink in the upper parts.

Although there is no reason to believe that conditions of sedimentation were much different in the section northwards of the latitude of

Sinoia, no similar division of the group into formations and members is possible. For the most part metamorphic grade remains low but it is suspected that deformation, principally on north to north-west-striking axes, is very much more intense. The terrain is little dissected and natural outcrops are rare. Except in the vicinity of some of the copper mines, where silicification has rendered the rocks more resistant to weathering, there are only small outcrops often several kilometres apart and separated by fine, pale sandy soil. On the basis of these few exposures the group is believed to consist of a great thickness of pink arkoses representing an ill-defined Upper Arenaceous Formation with sporadically developed boulder and pebble beds. In the mine workings shales, argillites, chloritic schists and carbonated chloritic arkoses feature as well but presumably are not representative. The Volcanic Formation is known only from diamond drill core and small inliers of sheared amygdaloids with reddish clay soil cover in the environs of Shackleton Mine. Other than in the Silverside Mine outlier of possibly overthrust, sheared chloritic lavas underlying equally strongly sheared, arenaceous, feldspathic sediments, at the northern extremity of the Hunyani Escarpment, it has not been recognised further north. Indeed it appears that north of Shackleton Mine sills of dolerite, representing a deeper erosional level, replace the Volcanic Formation. Dolerite becomes more prominent within the group proceeding northwards until some 20 km north of Mangula, on entering the zone of higher metamorphic grade, it becomes amphibolitized and constitutes nearly half of the area of outcrop. The arkosic rocks of this zone are paler, harder and finer grained than usual and nearing the Zambezi Escarpment have been converted into feldspathic paragneisses.

The arkoses of this ill-defined Upper Arenaceous Formation are the host-rocks of the important copper *mineralization* which characterizes the group. It has been described variously as syngenetic, hydrothermal and strata-bound. It exhibits elements of each. If of biogenic origin, a popular modern concept, it presumably moved from a shaly or calcareous depositional environment into the more sandy one in which it is found and there became influenced by some thermal agency of concentration which led to cross-cutting relationships, alkali metasomatism and injection of pegmatite veinlets. Deposits currently being exploited are at the Mangula, Avondale, Shackleton and Angwa mines. The Silverside orebody is a hydrothermal quartz-carbonate lode. Exploration in the very much better exposed Upper Arenaceous Formation of the southern area, between the Umfuli and Umniati rivers, has not disclosed orebodies of any consequence. Apart from copper with by-product silver and gold, uranium of academic interest at Mangula Mine and several small quartz veins that have been exploited for gold, the Deweras Group is apparently devoid of metallic mineralization.

LOMAGUNDI GROUP

Outcrops of the Lomagundi Group extend from the Umniati River in the south to the Zambezi Escarpment 250 km away. For the entire distance its quartzites, dolomites and slates are in close association with arkosic rocks and in the south with basaltic lavas as well, of the Deweras Group. In the Nyamandhlovu District, 180 km south-west of the most southerly outcrop of the main belt, a borehole drilled through Kalahari Sand and Karoo cover passed, at a depth of 425 metres, into a succession of dolomites, quartzitic dolomites and dolomitic schists, with quartz-sericite and graphitic schist intercalations, more than 400 metres thick. Being on the direct strike extension and on the basis of characteristic carbon isotope ratios there is little doubt that this occurrence represents an isolated basin of Lomagundi sedimentation.

On account of the close parallelism of outcrop the Lomagundi and Deweras have in past classifications frequently been grouped together despite strongly contrasting lithologies and not taking fully into consideration the major unconformity between them which is clearly displayed in the Umniati River area although, due to more intense folding and thrusting, this becomes less readily discernible as one proceeds north along strike.

Between the Umniati and Umfuli rivers division of the group into three formations has been effected, but the uppermost or Sakurgwe Formation dies out at the latter river and has not been recognised elsewhere; so that generally only two divisions persist as is illustrated in the tabulation:—

Sinoia Area Northwards		*Magondi-Mafungabusi Area*
	Argillaceous Division	
		Sakurgwe Formation
		Greywacke + 600 m
Striped Slate Formation		*Nyagari Formation*
Striped slates		Argillites
Mountain Sandstone	+ 500 m	Striped slates + 600 m
Black slates		

Arenaceous Division

Sinoia Caves Formation		*Mcheka Formation*
Dolomite	+ 300 m	Main dolomite 0−400 m
Quartzites, with pockmarked variety and thin dolomite	+ 600 m	Upper quartzite ± 1 000 m
		Pocked quartzite 0−200 m
		Lower quartzite 0−300 m
		Basal dolomite 0−300 m
Schistose basal conglomerate ± 30 m		Basal conglomerate 0−75 m

There is a conglomerate or coarse grit basal to the *Arenaceous division* both in the northern and southern areas. In the latter it is seldom deformed and is characterized by jaspilite and vein quartz clasts often in a dolomitic matrix. In the former, along the Hunyani Escarpment the basal bed is usually scree-covered but where exposed is always a strongly deformed schistose grit with appreciable sericite and chlorite content, completely drawn out rock clasts and rare rounded quartz pebbles. It is mylonitic in character supporting the view that the Lomagundi has been thrust over the Deweras or Basement Complex along much of their contact.

The quartzites of the formation are generally pure and fine-grained. At surface they are sugary and white in colour where not locally iron-stained. Fresh exposures in cuttings and quarries are hard, almost glassy and white, grey or pinkish in colour. These quartzites are thickly developed to form the imposing Mcheka-wa-ka-sungabeta Range and the Hunyani Escarpment. A pock-marked variety of unusual appearance, believed to afford a bedding marker may not be such as it apparently transgresses to near the base of the formation in the extreme south-west. Additionally to dolomites, thin grits and sandy shales are interbedded with the quartzites but they, like the dolomites, are seldom exposed except on steep slopes. All along the eastern edge of the Lomagundi belt bedding dips average between 30 degrees and 40 degrees to the west with small local reversals and practically all of the rocks, the argillaceous ones particularly, have a near vertical, schistose foliation trending parallel to bedding strike.

Stromatolitic and calc-arenite structures in the dolomite, suggesting a shallow-water evaporitic environment, are well-preserved in the country southwards of Sinoia. These features are less apparent elsewhere. The calcareous rocks are very fine-grained, white, pink, grey or buff in colour with darker weathered skin, the roughness of which increases with degree of silicification, brecciation and cherty interlamination. In the Sinoia Caves area a 10 metre thick bed of pure, pale pink dolomite occurs near the base of the succession and an upper band 300 metres thick containing a bed of coarse, grey argillaceous grit is at the top, dipping directly beneath the Striped Slate Formation. Due to lack of exposure it is seldom that such bands may be traced more than a few kilometres along strike.

This expression of a little contorted, relatively regular sedimentary sequence is not repeated along the anticlinal limbs of the Arenaceous Formation which arch over the Deweras Group of the Umboe Valley between the Alaska and Norah mines and in the country to the north. The quartzites, dolomites, minor grits and shales here have undergone such severe tectonic distortion, coupled with brecciation and silicification, that they are inextricably intermingled and so attenuated that the outcrop width of the whole formation is often reduced to less than 500 metres. The west-dipping belt from Mangula to beyond Shamrocke Mine is similarly attenuated and north of the mine the sediments are largely replaced by interstratified dolerite now converted into amphibolite. The dolomites in this area have been changed into coarse-grained marble and quartz-tremolite rock, the argillaceous beds into garnetiferous biotite schists and the quartzites coarsely recrystallized. The only other sector where metamorphic grade of the Lomagundi rocks rises above low greenschist facies is some 15 km south of Mangula where late-stage folding has depressed the formation into an oblique synclinal belt with north-easterly axis and in which the dolomite has been thermally metamorphosed to massive tremolite rock by a large underlying mafic intrusion.

The *Argillaceous division*, usually referred to as the Striped Slates, comprises the Nyagari and Sakurgwe formations in the southern third of the area, the Zhonzi Formation in the centre and again the Nyagari Formation in the far north. In the south this last provides evidence of unconformable relationships with Mcheka dolomites and quartzites. It consists there of striped slates, argillites, minor beds of andesitic lava, tuff and agglomerate and occasional lenses of dark, carbonaceous dolomite. The equivalent Zhonzi Formation has been divided into black basal shales overlain by striped slates. The prominent but lenticular Mountain Sandstone, an impure grey quartzite, is interbedded near the top of the black shales. The Sakurgwe Formation, a monotonous sequence of fine-grained, unbedded greywacke and minor argillite is known only from the large synclinorium, of which it forms the uppermost unit, centred on the river of the same name.

Mineralization of the Lomagundi Group is lean compared with that of the underlying Piriwiri and Deweras groups. The only known primary occurrence of importance is the copper deposit at the Shamrocke Mine which lies within rocks occupying the stratigraphic position of the Mcheka or Sinoia Caves formations. In this area of high grade metamorphism the equivalents of the dolomite and quartzite are overlain by calcareous graphitic schists which contain complexly folded beds of meta-arkose, a lithological sequence differing considerably from the norm. Copper as chalcopyrite is disseminated in the meta-arkose. Other copper deposits, of secondary nature, which have been mined in severely faulted zones within the Lomagundi dolomite in the Alaska Mine area were almost certainly derived from adjacent Deweras arkose. Meagre lead mineralization and small hydrothermal gold veins are known but do not warrant exploitation.

However, the dolomites are good aquifers and locally provide sufficient water supplies for irrigation. In addition, though frequently siliceous, they contain unlimited amounts of pure material suitable for aggregate, for building and ornamental purposes and are a source of ground and burnt lime for agricultural use. Within the Striped Slates there are several localities where the coincidence of bedding and metamorphic foliation have resulted in the formation of slate which is quarried for many building purposes too but does not cleave finely enough to be of roofing quality.

Volcanic Centres. Several assemblages of highly carbonated vent agglomerate with subordinate crystal tuffs, fine-grained bedded tuffs and pyritiferous felsite are irregularly located in a north-east-striking zone over a distance of some 60 km and with one exception within phyllites of the Piriwiri Group. The exception is the most northerly or Nyamakari Centre, due south of D Troop Mine, where the country rocks appear to be Lomagundi slates but where field relations are obscure. Each occurrence occupies an area of one to two square kilometres. In some instances the tuffs and felsites are intercalated with the phyllites but in others the agglomerates, containing fragments of tuff, felsite and other country rocks in addition to obviously foreign blocks, are apparently intrusive and post-date the deformation of the phyllites.

Chemical analyses of the felsites, ultra-fine-grained rocks of cherty aspect, show them to be almost pure albitites and the fragmental rocks as well are highly sodic and contain large proportions of magnesium carbonate. Although never directly associated, it is clear that the hydrothermal veins of quartz with iron-magnesium carbonate of the area, which contain low-grade copper and gold mineralization, are genetically related to the volcanic activity.

THE UMKONDO GROUP

The Umkondo Group is a thick sedimentary succession uncomformably deposited upon granites and gneisses of the Archaean Basement Complex and on the eastern part of the Limpopo Mobile Belt.

Since they were first described by Brackenbury in 1906, the rocks have been referred to by many different names amongst which are Frontier System (1920), Sabi System (1920), Spungabera Series (1924), Umkondo System (1924), Gairezi Series (1957) and Manica Series (1963). The name Umkondo System, agreed on as a composite term to include all the various elements in 1964, was subsequently changed to Umkondo Group to comply with recommended Precambrian lithostratigraphic terminology.

The sediments form the Eastern Highlands and Chimanimani Mountains along the eastern border of Rhodesia and the Gairezi-Barue Highlands in Western Mozambique. The continuation of these rocks was thought to extend farther north into the Rukori Range and the Mount Darwin area of Rhodesia but the sediments of this area are now known to belong to the Rushinga Group, of considerably lesser age.

The Umkondo Group can be subdivided into two distinct suites: a western succession of five formations of virtually flat-lying, shallow-water, dominantly argillaceous and arenaceous sediments and three formations of deformed and metamorphosed, deeper-water quartzites and pelites lying to the east. The former, almost wholly restricted to Rhodesia is best developed in the Chipinga-Lower Sabi area in the south with smaller occurrences at Inyanga, Ruangwe Range and Chirwa Dome in the north. The deformed sediments which occur mainly in Mozambique can be traced northwards from the Statonga Ranges and Chimanimani Mountains in the south, through a series of outliers in the Bandula region into the Gairezi-Barue Highlands.

There has been great controversy about the relationship between the two suites. The deformed Gairezi Series of the Inyanga area was considered to be older than the flat-lying Umkondo System to the west. In the south the Frontier Series of the Chimanimani Mountains which had been equated with the Gairezi Series was regarded as either the lowest member of the Umkondo System or its deformed and metamorphosed equivalent. It was further suggested that the Umkondo and Gairezi rocks were deposited contemporaneously and differed in appearance due to a combination of facies change and degree of metamorphism. The two components were referred to as the Inyanga and Gairezi facies of the Umkondo Group. Recent investigations have upheld the validity of the two facies concept and furthermore have demonstrated that they overlap and interfinger due to a lateral shift of their common boundary during sedimentation. As an expansion of the nomenclature to embrace the entire extent of these rocks the term Rhodesia Facies of the Umkondo Group has been introduced for the western flat-lying sediments, and the Mozambique Facies for the deformed sediments to the east as illustrated below.

Rhodesia Facies		Mozambique Facies	
South	North (Inyanga Facies)	North (Gairezi Facies)	South
Volcanics			
Upper Argillaceous Formation	Upper Argillaceous Formation	Upper Pelitic Schist Formation	
Arenaceous Formation	Arenaceous Formation }	Lower Pelitic Schist Formation	
Lower Argillaceous Formation	Lower Argillaceous Formation }		
Calcareous Formation	Calcareous Formation		
	Basal Formation	Basal Formation	Basal Formation (Frontier Series)

RHODESIA FACIES

The succession attains a maximum thickness exceeding 3 650 metres in the south compared with 200 metres at Inyanga. The basal sediments in the north are restricted to thin horizons of dominantly fine-grained arenite, but no Basal Formation as such has been recorded from the Chipinga-Lower Sabi area in the south. However, in the Middle Sabi Valley, the fine-grained, cherty, calc-hornfelses and minor intercalated limestones, typical of the Calcareous Formation throughout, are underlain by a series of arkoses, dolomites, siltstones and quartzites, but these were considered to be part of the Calcareous Formation. Eastwards from here the calcareous rocks decrease in thickness and interfinger with shales, phyllites and ferruginous arenites which comprise the Lower Argillaceous Formation. In the vicinity of the Chimanimani Mountains these sediments may rest directly on the Basal Formation of the Mozambique Facies, a similar relationship to that observed in the Gairezi Highlands.

The Arenaceous Formation, 760 to 900 metres thick in the south, thins to less than 75 metres at Inyanga. This monotonous sequence of fine-grained, grey, feldspathic quartzites contains abundant shale intercalations in the north, but few in the south. These arenites pass upwards into phyllites and argillites comprising the Upper Argillaceous Formation in which interbeds of pale, feldspathic sandstone reach thicknesses of 60 to 90 metres. In the Middle Sabi Valley at least 200 metres of basic andesite, agglomerate and tuff cap the succession.

MOZAMBIQUE FACIES

The sugary, white orthoquartzites and intercalated chlorite schists, typical of the Basal Formation of the Mozambique Facies, attain their maximum thinkness of 2 040 metres south of Musapa Gap in the Chimanimani Mountains. The chlorite schists wedge out northwards and orthoquartzite, greatly reduced in thickness, is the major constituent of the basal sediments in the Bandula region. Impersistent lenses of orthoquartzite along the south-west margin of the Gairezi-Barue Highlands become interbedded with grey siltstone and quartz-mica schists farther north. These siltstones represent the most easterly extent of the Inyanga Facies.

Although two distinct pelitic schist assemblages, representing variable conditions of deposition, have been recorded from the Gairezi Facies, no such distinction has been made by Mozambique geologists. These schists, comprising the bulk of the sediments of the Gairezi-Barue Highlands and Bandula area, are absent from the Chimanimani Mountains. The Lower Pelitic Schist Formation, composed dominantly of quartz-muscovite schist, quartzite and phyllite, is characterized by numerous lenses and thin horizons of epidote- and tremolite-bearing calc-hornfels. The schists of the Upper Pelitic Schist Formation are more ferruginous and contain abundant chloritoid. Calc-hornfelses are rare whereas tremolitic limestones and ferruginous quartzites are common.

Deposition

The fine-grained sediments of the Calcareous Formation, a thin but extremely persistent horizon, were deposited on a flat peneplained surface in a restricted lagoonal environment. Eastwards these calcareous sediments thin and lens out in part against a beach sand barrier marking the western limits of a deeper water, higher energy depository.

The lagoon, with its minor algal colonies persisted throughout the deposition of the muddly Lower Argillaceous Formation. The Arenaceous Formation marks the onset of a braided deltaic system prograding into the lagoonal basin and resulted in a meandering stream system built out across the delta, with shallow streams cut into a flat, alluvial plain.

In the east, depositional conditions were more chaotic, as shown by the great variety of sedimentary types of the two Pelitic Schist formations of the Gairezi Facies. Numerous, impersistent lenses of well-bedded calc-hornfels, containing structures resembling stromatolites, and a decreased volume of pure quartzites indicate that there were periods of deposition into shallow water.

Structure and Metamorphism

Thick quartz dolerite sills are numerous in the Calcareous and Lower Argillaceous formations, with fewer and thinner sheets intrusive into the other formations of both the Rhodesia and Mozambique Facies. The sills were intruded after sedimentation was complete but before the onset of the first deformation.

Palaeomagnetically, the Precambrian dolerites of eastern Rhodesia form two distinct groups, indicating two distinct magmatic episodes. One group, intruding the Precambrian Shield, is termed the Mashonaland Dolerites and the other, associated with the Umkondo sediments is known as the Umkondo Dolerites. The pole of the latter corresponds well with those obtained from post-Waterberg diabases and from a 1 700 Ma diabase sill cutting the Premier Mine kimberlite. This age is close to a maximum K-Ar age of 1 785 ± 80 Ma for a hornfels from the Chipinga area and represents the minimum age of the Umkondo Group. The maximum age is more difficult to establish. At Inyanga, Umkondo sediments apparently unconformably overlie a thin sill of porphyritic dolerite, typical of the Mashonaland Dolerite group, samples of which give a Rb-Sr age of 1 850 ± 20 Ma.

Much of the Umkondo Group has been affected by the 400 to 650 Ma tectono-thermal event, termed the Mozambique Metamorphic Event, the western limit of which more or less coincides with the boundary between the two facies. The eastern parts of the Rhodesia Facies are only slightly affected, but the Mozambique Facies shows well-defined zones of easterly-increasing metamorphic grade. Chlorite, garnet, staurolite, kyanite and sillimanite isograds have been recognised over a strike distance of 500 km. The western part of the Rhodesia Facies in the south is comparatively undeformed except for very broad low amplitude folds which plunge to the south. The succession is block-faulted with large down-throws to the south.

The deformation of the adjacent Mozambique Facies is characterized by a series of north-trending, asymmetrical folds in which the long limbs dip gently to the east and the shorter, attenuated western limbs are steeply inclined and often overturned. In the Chimanimani Mountains the deformation is intense, with recumbent folds and tectonic slices thrust westwards over the comparatively undeformed sediments.

Mineralization

The only known mineralization of economic interest in the Umkondo Group occurs in sediments of the Rhodesia Facies of the Middle Sabi Valley. At the Umkondo Mine copper ore bodies are located within a sequence of alternating shales and quartzites lying towards the top of an horizon stratigraphically equivalent to part of the Upper Argillaceous Formation. Here in the shales and siltstones, chalcopyrite and bornite occur as nodules and in thin horizons parallel to the bedding or as cross-cutting veins and minute stringers. The sulphides in the quartzites occur either as fine-grained interstitial disseminations or as nodules. Copper has in part replaced stratiform pyrite mineralization. Its source has not been established but it may have percolated down from the lavas which formerly covered the sediments.

Chalcocite, with minor amounts of bornite, chalcopyrite, covellite and native copper, is often concentrated in the vesicular portion of the basic andesites as well as in the agglomerates and the tuffaceous siltstones. Disseminated chalcopyrite, not uncommon in the altered dolerites, also occurs sporadically in thermally metamorphosed sediments adjacent to dolerite instrusions.

THE WATERBERG GROUP

An occurrence of red beds overlies the paragneisses of the Limpopo Mobile Belt and dips flatly beneath the basal beds of the Karoo System in a small area some 35 km west-north-west of Beitbridge. The total extent is less than 2 km^2 and the thickness of the succession is no more than 50 metres. It would appear that prior to deposition of the overlying Fulton's Drift Mudstone, the basal Karoo member of the area, the red beds were protected from erosion by a resistant quartzite ridge within the paragneisses.

In the main, the succession consists of a variety of ferruginous sandstones and greywackes, ranging in colour from a light brown-yellow to a deep purple. Generally the rocks are poorly sorted and exhibit few sedimentary structures. Intercalated with these arenites are thin horizons of siltstone, chert and fine-grained tuff. Subsequent to deposition, east-north-east-trending dolerite dykes, some of which may be of Waterberg age, have been intruded and gentle folding on north-easterly axes has taken place.

On the basis of this deformation, and the lithological similarity to sediments of the nearby Soutpansberg Range in South Africa the small outlier is tentavely correlated with the Waterberg Group.

DOLERITIC INTRUSIONS

The conduits that fed the vast outpourings of mafic lava which formed the Archaean schist belts leave little evidence other than as penecontemporaneous intrusions of doleritic greenstones that are distinquished in the underground workings of some of the larger gold mines. In the Mashaba-Shabani area there are epidiorite dykes probably representing the feeder channels of the greenstones of the area. Fresh dolerites of great age, too, are known. These ante-date the Great Dyke and are composed of little altered pyroxene and feldspar whereas many dykes of lesser age are composed of metadolerite or epidiorite, so that it is clear that degree of alteration is no safe criterion of age.

Terminology in common usage classifies a rock as dolerite if it is fresh or only incipiently altered deuterically. It may be aphanitic or range in grain-size up to 3 mm or more. It is frequently ophitic but not necessarily so. In consequence there is no real petrographic distinction between dolerite and gabbro. The term diabase is not used. Metadolerites have uralitized pyroxene and saussuritized feldspar but retain primary texture. When this is destroyed and the rock consists of uralitic amphibole and epidotized feldspar it is known as epidiorite. Recrystallization produces high grade epidiorites composed of complex blue-green hornblende and albite which are equivalent mineralogically to the amphibolites of regional metamorphism.

On the basis of such characteristics coupled with field relationships and small mineralogical differences it has been possible to distinguish three or four ages of mafic intrusions in most craton areas that have been studied in detail. As the intruded rocks are almost invariably components of the Basement Complex without younger cover these ages are relative only and no upper limit can be established. West of the Great Dyke, however, between Chakari and Mtoroshanga there is a major dyke that may be a little more precisely defined. It also illustrates some of the petrographic features described and is the youngest of the mafic intrusions distinguished in the area. At its south-western extremity it is a narrow, fresh, ophitic dolerite dyke that invades lavas and sediments of Deweras age. It strikes north-east for 130 km and in its middle section, due west of Banket, is a body 100 metres wide with a chilled basaltic selvage and a core of granular fabric composed chiefly of pigeonitic pyroxene and labradorite as 1 - 2 mm crystals. Among the Proterozoic formations, the widely developed Piriwiri Group is practically devoid of mafic intrusions but by contrast the Deweras Group, especially in the Mangula region and northwards, is heavily invaded by sills of metadolerite and small dykes of younger fresh pyritic dolerite. On the evidence of extensive conversion of Lomagundi dolomite into quartz-tremolite rock, in the country south of Norah Mine, it may be inferred that they post-date the Lomagundi Group as well.

All of the foregoing although of local importance are insignificant in comparison with the numerous intrusions comprising the *Mashonaland Dolerite* and *Umkondo Dolerite* suites. Dykes, sheets and sills of generally fresh dolerite occur in profusion in the north-eastern quarter of the country from west of the Great Dyke to the Mozambique border. Their area of outcrop is in excess of 10 000 km^2 and as many of the undulating sheets in the granite country and sills intruded into the Umkondo sediments are as much as 300 metres thick, the volume of magma involved was immense and must have approached in order of magnitude that of ultramafic type responsible for the emplacement of the Great Dyke. Both suites are of tholeiitic affinity and analyses display normative quartz. There are small differences in their chemistry but lithologically the rocks are indistinguishable. Division into two suites followed Rb-Sr age determination analyses of feldspar from Mashonaland dolerite, revealing an age of 1 850 ± 20 Ma which was supported by palaeomagnetic data; and a lesser age of circa 1 700 Ma was obtained by similar investigation of Umkondo dolerite.

The dolerites are predominantly fine- to medium-grained but some are coarse-grained and porphyritic varieties are present. The occurrence of dark coloured, granular dolerites in the lower portions of Mashonaland sills and pale ophitic rock in the upper parts points to a degree of gravity differentiation and many of the rocks contain proportions of orthopyroxene and olivine in addition to pigeonite and labradorite, although extremes such as picrites and melanorites are rare. No such differentiation has been discerned in the many Umkondo dolerite sills that have been studied in the Inyanga area. A feature shared by both suites, however, is the incorporation, in the upper parts of the larger sills, of invaded host rock material which has been assimilated to form mafic granophyres.

A very long period followed during which there is no recorded igneous activity until the injection of sills into the Makuti and Rushinga sediments of Katangan age. These are confined to the Zambezi Metamorphic Belt and the intrusions have been converted into amphibolites in the country between Kariba and Makuti although some, north of Miami and in the Mount Darwin area, have partially resisted metamorphism and are described as olivine-bearing metadolerites and gabbros. A further long period of quiescence lasted until the outbreak of basaltic fissure eruptions of Jurassic age in upper Karoo times. East-trending dolerite dyke swarms of this period are a very notable feature of the geology of the Sabi-Limpopo Basin but dykes are absent or very rare in the Zambezi Basin coalfields.

Economic Considerations. Although doleritic intrusions exercise structural control, sometimes of an adverse nature, in many of the country's mines, there are no known examples of directly associated metallic mineralization of more than academic interest. With regard to the large Mashonaland sills it is quite possible that they may contain immiscible sulphide segregations of pyrrhotite, pentlandite and chalcopyrite in a manner analogous to the Insizwa deposits of Pondoland in Transkei. It is believed that the sills were emplaced along pre-existing, gently undulating fractures and that zones of maximum magmatic differentiation could be expected to coincide with synclinal troughs. If so they are likely to be difficult exploration targets because it is probable that the troughs are not likely to be exposed at present erosion level.

From the agricultural point of view the larger dolerite masses, especially those in granitic terrain, are of great value. They weather to form fertile, deep red, clayey soil suitable for crops other than tobacco which is grown on the granitic sandveld. Additionally basins of decomposition and contact zones are favourable locations for underground water in the crystalline basement.

In the Mtoko area several dolerite sheets to the north and east of the township are composed of rock a little darker in colour and more even-textured than normal. This has been extensively quarried and is marketed world-wide as ornamental and monumental stone under the name "black granite". The better quality material is hypersthene-bearing and the labradorite feldspar has a translucent brown stain, known as thermal clouding. These in conjunction impart the desired even dark colour to the polished slabs.

THE TENGWE RIVER GROUP

Situated in the Urungwe District, 80 km to the south-east of Kariba, is a succession composed mainly of calcareous sediments and ortho-quartzites which form what may be regarded as the superstructure of a very large klippe derived from a now eroded orogen, located to the north, and emplaced by gravity slide into the northern marginal part of the basin of Sijarira red beds. It seems that these red beds may well represent a molasse accumulation, the provenance of which was partly the rising orogenic belt to the north. Further it is probable that the Sijarira Group had not been fully consolidated at the time of emplacement of the klippe judging by the minimal disruption of its fringe sediments along the northern margin of the basin as contrasted with the intensely folded nature of those immediately ahead of the southern or frontal edge of the allochthon.

Historically, mention is made of the presence in this area of lime-stones, dolomites and quartzites in reconnaissance reports written during the early decades of the century. These were then believed to form part of a loosely defined Lomagundi System. In the late 1950's the area was systematically mapped and the succession shown to consist of a sporadically developed thin basal arkose, resting on Archaean meta-arkoses and granite, followed by a *Calcareous Formation*, some 200 metres thick with basally disposed limestone and marls overlain by dolomite. This in turn is overlain by the 300 metre-thick *Orthoquartzite Formation* which contains shaly intercalations. The group is at a low-grade of metamorphism, is in the main gently folded but has been subjected to considerable deformation in several north-north-east-trending zones spaced a few kilometres apart and which are now the drainage channels occupied by major streams of the region. Towards the west the group is unconformably overlain by tillites and other fluvio-glacial beds.

Correlation with the distant Katangan of north Zambia and Zaire was considered, but there was insufficient evidence to warrant disturbing the time-honoured link with the then more precisely defined Lomagundi Group developed little more than 50 km away to the east and consisting of a lithologically almost identical succession of calcareous sediments and orthoquartzites. However, if the glacial beds were to be incorporated in the Tengwe River Group and equated to the Kundulungu tillites much strength would be added to a correlation with the Katangan. This was indeed suggested but what the postulate failed to take into consideration is the marked unconformity between the Tengwe River formations and the overlying glacial beds, a major hiatus which suggests that these particular tillites, although somewhat tectonically disturbed in part, more properly represent a montane remnant of the much later Dwyka glaciation of Permian age.

In the absence of palaeontological evidence and radiometric dating no further advance was made until recently when Dr. M. Schidlowski and his co-workers at the Max Planck Institute, in the course of a world-wide investigation of the $\delta^{13}C$ values of sedimentary carbonate rocks, demonstrated that the Lomagundi dolomite facies represents the largest isotopically anomalous province ever recorded which is evidence of an exceptional depositional environment, a characteristic not shared with the Tengwe River carbonate rocks.

The most probable solution to the stratigraphic position of this thrust-isolated group now seems to rest on the hypothesis that it represents the miogeosynclinal phase of an orogenic cycle, the early formations of which are preserved as the Makuti Group of paragneisses, other high-grade metasediments and amphibolites in the Zambezi Valley east of Kariba. Syntectonic metamorphism of the Makuti Group is reliably established in the 800-850 Ma range. The Tengwe River

Group would be somewhat younger but as it was not influenced by this metamorphism and was spatially beyond the range of the 400-650 Ma Miami metamorphism no greater precision is possible.

A small school of thought holds that the white orthoquartzites and dolomites of the Tengwe River Group should more properly be included in the Sijarira Group. There is little to commend this view for apart from other considerations the term Sijarira has been applied exclusively to the red beds sequence of the Zambezi Valley since it was defined 75 years ago.

Economically the group has to the present not yielded any mineral output of value. However the basal limestones of the Calcareous Formation undoubtedly represent the greatest reserves of good quality limestone in the country but are too remotely situated for current exploitation. They have been quarried on a very small scale as a source of marble. The promise of lead, zinc and copper deposits has been indicated by exploration exercises and large areas are held under mining title for these metals, largely in the limestone and dolomite terrain.

THE SIJARIRA GROUP

In post-Lomagundi times there is a complete dearth in Rhodesia's sedimentary record of a duration approaching 1 000 Ma until the Katangan orogenic cycle commenced, in what is now the Zambezi Valley, and produced the successions preserved there as the highly deformed and metamorphosed Makuti and Rushinga groups. To the south in the continental area erosion continued and all cover was stripped down to a basement of Archaean and early Proterozoic gneisses and granites before Sijarira sedimentation was initiated in the Eocambrian. This group of red beds occurs in a long strip of country stretching south-west from the Urungwe area into Wankie District. As the basal members of the succession are quite locally derived, it seems probable that the original extent of the basin was not much greater laterally than the present area occupied. The Sijarira Group is unfossiliferous and is not metamorphosed. It is only very gently folded about north-easterly axes except in close proximity to large scale fault dislocations.

The term Sijarira was first used by Molyneux in 1903 for beds that form the core of a plateau in the then Sebungwe District. The plateau is 100 km long and 30 km wide and is bounded by fault scarps on north and south-eastern sides, which converge north-eastwards as the surface rises gently. The surface has the form of a gentle trough surmounted by a few peaks, among which are Chisarira, which gives its name to the south-eastern scarp and the higher peak Tundazi above the majestic northern scarp. The latter is built of about 300 metres of hard sandstone containing thin beds of pebbles and numerous flattened shale pellets. Where not faulted these rest on gneissic basement and are overlain by sandy shales of Lower Karoo age.

Recent, more detailed investigations of the Chisarira horst have revealed a greater thickness of sediments. They have been divided into three lithological sub-groups comprising nine formations with an aggregate thickness of approximately 650 metres. In the Kamativi-Lubimbi area there is a reduction to about 150 metres of the same quartzitic sandstones, grits, flagstones and maroon shales; further west at Wankie they are only patchily developed as thin cappings on the gneisses or as fault-bounded inliers surrounded by Karoo sediments. North-eastwards of the Chisarira Plateau there is another major development of the group astride the Sanyati River. The northern third of this occurrence is overlain by a very large klippe composed of ancient meta-arkoses capped by white quartzite, dolomite and limestone, of the Tengwe River Group, thrust into position from the north; but the Sijarira sediments are well exposed in the Sanyati Valley. Here the thickness measured was 600 metres of shales, quartzitic sandstones and feldspathic grits with basal arkose, interformational conglomerates and rare thin intercalations of dolomite and beach sand ironstone. They have been classified into four stages or formations and the basal beds, characteristically maroon coloured, rest uncomformably on a planed surface of granite or mica schists of the Piriwiri Group. Higher up in the succession maroon colour is less prominent and many of the sandstones and grits are hard, compact, grey-brown rocks with conchoidal fracture and a tendency to spheroidal weathering.

In the past there have been many attempts at correlation of the Sijarira Group with other formations within the country and beyond its borders. These were based on lithology, succession and unmetamorphosed condition; and the popular equivalents were the Umkondo, the Kundulungu of northern Zambia and the Waterberg of South Africa, particularly the last. Now with some support given by palaeomagnetic investigation for an age of about 600 Ma it seems likely that the Sijarira Group may be structurally an extension of one of several red bed successions of South West Africa that trends north-eastwards beneath the Kalahari Sand in Botswana.

Prospecting of silicified, post-Sijarira fault zones in the Wankie District has disclosed weak copper, lead and uranium mineralization with accompanying iron pyrite and fluorite. Of these only the flourite has warranted exploitation on a small scale. In the Urungwe area extensive geological exploration exercises aimed at strata-bound mineralization were similarly unsuccessful and only defined weak copper occurrences, also associated with faulting.

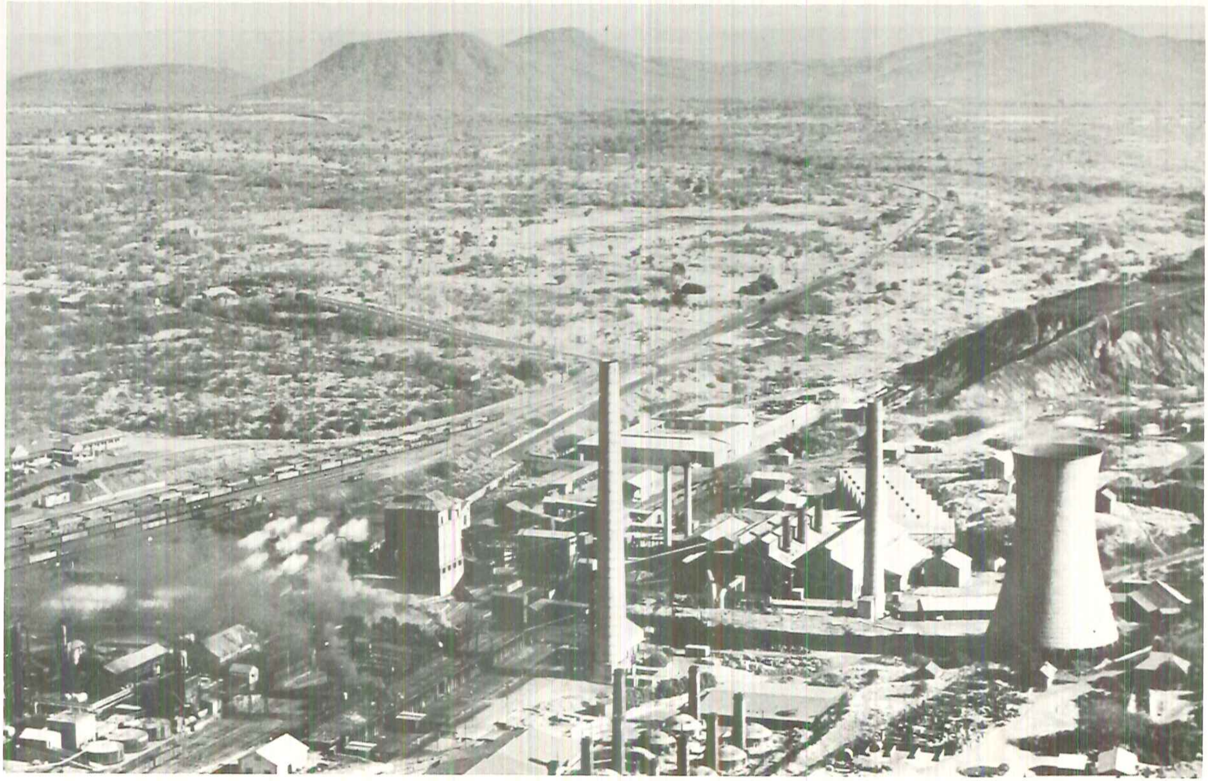
THE KAROO SYSTEM

Severe tectonic disturbance and widespread metamorphic activity, in the extreme north of the country, followed the Sijarira period but erosion presumably held sway for some 300 Ma as there is no preserved record of any sedimentary deposition until the Karoo era was initiated in late Carboniferous to early Permian times. Sedimentation continued throughout the Permian and Triassic to be brought to a close by vast fissure eruptions of mafic lava in the Lower Jurassic. The three-fold division of the Karoo System into Permian, Triassic and Jurassic, which is largely an overall lithological division as well, has been adopted on the geological map of the country for clarity of display but in describing the system the more precise Southern African terminology with its divisions into Dwyka, Ecca, Beaufort and Stormberg series and local sub-divisions, as illustrated in Table II, is preferred.

There were two main areas of deposition, to the north-west and south-east respectvely of the major watershed which trended north-east centrally across the country and is believed to have been parallel to but some 80 km south-east of the present watershed. They are the Zambezi and Sabi-Limpopo basins and each contained subsidiary basins of deposition in which there are variations of lithology and succession so that there is no absolute certainty that identical lithological units separated from one another, and named on the basis of their lithology and succession, are synchronous although palynological studies are now adding much more confidence to correlation than was previously possible.

The pre-Karoo land surface was an uneven one probably resembling the present day topography with small hills and ridges near the divide rising above a generally flat rolling terrain. Palaeomagnetic investigations have established that, in the late Palaeozoic, Southern Africa was

PLATE VII



LOWER KAROO LANDSCAPE, No. 1 Colliery, Wankie.

TABLE II

KAROO SUCCESSIONS

EUROPEAN TIME EQUIVALENTS	RHODESIA: MIDDLE ZAMBEZI BASIN: WANKIE-SEBUNGWE		MIDDLE ZAMBEZI BASIN: LUBIMBI-LUSULU	SABI REGION: NORTHERN LIMB or SABI VALLEY	SABI REGION: SOUTHWESTERN LIMB	MAZUNGA BASIN (TULI)	SOUTH AFRICAN EQUIVALENTS		
LOWER JURASSIC	BATOKA BASALT (with interbedded sandstone at the base)		—	BASALT	BASALT	BASALT	Drakensberg Volcanics Stage	STORMBERG SERIES	UPPER KAROO
TRIASSIC	FOREST SANDSTONE		—	AEOLIAN SANDSTONE		FOREST SANDSTONE	Upper Red Beds Sub-stage (Red Beds Stage)	STORMBERG SERIES	UPPER KAROO
	PEBBLY ARKOSE		—	SANDOTA PEBBLY GRIT	—	—	(Red Beds Stage)	STORMBERG SERIES	UPPER KAROO
	FINE RED MARLEY SANDSTONE		—	BOND GREYWACKE UNIT		RED BEDS	(Red Beds Stage)	STORMBERG SERIES	UPPER KAROO
	RIPPLE MARKED FLAGS		RIPPLE MARKED FLAGS	BOND GREYWACKE UNIT		RED BEDS	Molteno Stage	STORMBERG SERIES	UPPER KAROO
	ESCARPMENT GRIT		ESCARPMENT GRIT	BOND GREYWACKE UNIT		ESCARPMENT GRIT	Upper Stage	BEAUFORT SERIES	UPPER KAROO
	unconformity at basin margins			uncomformity at basin margins			Upper Stage	BEAUFORT SERIES	
	MADUMABISA MUDSTONE: UPPER	K^5 e + f	UPPER MADUMABISA MUDSTONE	MKURURWE ALTERNATION UNIT		FULTONS DRIFT MUDSTONES	Middle Stage	BEAUFORT SERIES	LOWER KAROO
PERMIAN	MADUMABISA MUDSTONE: MIDDLE	K^5 c + d	MIDDLE MADUMABISA MUDSTONE	MKURURWE ALTERNATION UNIT		FULTONS DRIFT MUDSTONES	Lower Stage	BEAUFORT SERIES	LOWER KAROO
	MADUMABISA MUDSTONE: LOWER, COAL	K^5 a + b	ALTERNATIONS GROUP (clastic wedges in grey mudstone)	MARARE CARBONACEOUS MUDSTONE (± intervening grit); MARARE COALY SHALE	BENDEZI COAL SEAM	FULTONS DRIFT MUDSTONES	Upper Stage	ECCA SERIES	LOWER KAROO
				MKWASINE GRITS AND INTERCALATED SHALE BANDS	MAULONGWE COALY-SHALE HORIZON	FULTONS DRIFT MUDSTONES	Upper Stage	ECCA SERIES	LOWER KAROO
	UPPER WANKIE SANDSTONE	K^4	UPPER WANKIE SANDSTONE			FULTONS DRIFT MUDSTONES	Middle Stage	ECCA SERIES	LOWER KAROO
	BLACK SHALE + No. 1 SEAM	K^2	BLACK SHALE (with clastic wedges)	DENDERA COALY-SHALE HORIZON; SANGWE GRITS		FULTONS DRIFT MUDSTONES	Middle Stage	ECCA SERIES	LOWER KAROO
	WANKIE MAIN COAL SEAM		WANKIE MAIN SEAM	MKUSHWE SHALY-COAL SEAM		FULTONS DRIFT MUDSTONES	Lower Stage	ECCA SERIES	LOWER KAROO
	LOWER WANKIE SANDSTONE	K^1	LOWER WANKIE SANDSTONE	LOWER MKUSHWE SANDSTONE		± SANDSTONE	Lower Stage	ECCA SERIES	LOWER KAROO
CARBONIFEROUS	GLACIAL BEDS	K^0	GLACIAL BEDS	CHOMPIMBI GLACIOGENE SEDIMENTS. LEVANGA TILLITE		GLACIAL BEDS	DWYKA SERIES		LOWER KAROO

positioned in the high latitudes and was covered by a continental ice sheet. Melting of this ice sheet gave rise to the deposition of tillites and other glacial beds of Dwyka age, probably a little later in Rhodesia than in South Africa. They filled the hollows in the pre-Karoo floor, levelling it to present an even surface, across which shallow, fresh water flooding, in Ecca times, provided conditions ideal for the growth of coal-forming plant life. Establishment of estuarine conditions terminated coal formation and further slumping of the basin led to the accumulation, in Beaufort times, of thick successions of argillaceous sediments. Sedimentation eventually surpassed slumping and shallow water arenaceous beds of Stormberg age filled the basins and transgressed across to the watershed. As the climate became warmer and the land more arid, aeolian sands covered wide areas of the country and continued to form and become interbedded with the early lava flows. Outliers of these sandstones and lavas remain along the present watershed well exposed in the Charter District between Beatrice and Enkeldoorn.

The Karoo succession of Rhodesia, with a maximum development of rather less than 3 500 metres of lavas and sediments, is much attenuated in comparison with the accumulation of nearly three times this thickness in the major epeiric basin of the Cape Province in South Africa, particularly in respect of the Dwyka and Ecca series. Nevertheless it occupies a large area, some 15 per cent of the country, and contains extensive and valuable coal measures.

The areas of Karoo deposition north of the central divide consist of the very well known Middle Zambezi Basin which contains the Wankie and other coalfields and extends from Victoria Falls to Kariba township; and the Lower Zambezi Basin which continues due east from there to Mozambique. This latter is a trough, 60 km wide, bounded on north and south by faulted escarpments of Precambrian gneisses. The greater part is a flat expanse of arenaceous, Triassic sediments with two outliers of basalt and one small occurrence of Lower Karoo beds containing coal and resting along the southern margin of a Precambrian gneissic horst at Msambansova. Younger sediments have been discovered in several localities and are assigned to the Upper Jurassic on the grounds of containing bones of a gigantic dinosaur, but the entire area has not been thoroughly investigated and details of the geology are relatively unknown.

In the south-eastern part of the country, Karoo rocks are of much more restricted occurrence being represented by a large expanse of lavas narrowly rimmed by sedimentary rocks which are only thinly developed and are in many sectors faulted down into the underlying gneisses. Much of the lava succession is limburgitic in composition in contrast to the basaltic nature of that of the northern province. The indications are that there were several depositories, smaller than those of the Zambezi Valley and that they were filled with more locally derived detritus and did not coalesce until Upper Karoo times. Very good exposures of glacially striated pavements, of Dwyka age, have been found in the trough extending north up the Sabi Valley and partially covered by Sabi alluvium and along the limb that trends south-west from it.

DWYKA GLACIATION

The presence of glacial beds has now been established at the base of the sequence in practically all Karoo areas in the country and, in several, glacial striations of the floor rocks are an interesting feature. The deposits consist of chaotic gravels and boulder beds deposited in irregularities in the pre-Karoo floor, plus reworked tills and in many instances accumulations of varved. clays with drop stones. The nature and size of the erratics and their degree of rounding is very variable. At Mafungabusi a thickness of 100 metres of these deposits has been measured and 101 metres of glacial beds were intersected in a borehole on the Matabola Flats, 50 km north-east of Lubimbi. North-west of Bulawayo, on the evidence of three boreholes drilled at Sawmills, Tjolotjo and in the Insuza Valley, the palaeoslope dips northwards at 3 degrees and the glacial beds composed of 8 metres of tillite and a veneer of varved mudstones at Tjolotjo have thickened to 58 metres at Insuza. Banded fissile grey shales considered to be varved clays are developed at Wankie and Entuba. As long ago as 1951, tillites and varved shales were recorded from the valleys of the Sengwa and Sanyati rivers. In the Limpopo Valley, the Tuli Coalfield now known as the Mazunga area, provides evidence of Dwyka glaciation in many boreholes; there are no significant outcrops. One borehole has 24 metres of glacial rocks resting on the basement and 9 metres, which is closer to the average thickness, is disclosed in another. In the Sabi Valley the tillite varies between one and 11 metres and the overlying glacial sediments between 15 and 90 metres.

At Somabula, along the watershed south-west of Gwelo, basal diamondiferous gravels, the only source of the country's small production of these gem stones, were together with overlying sandstones assigned to the Triassic. The most prominent heavy mineral in the gravels is staurolite which is extremely rare except in the mica schists of Karoi area, 300 km to the north. As transport by rivers seemed to be out the question, transport by glaciers was invoked to explain the presence of staurolite, thus implying Dwyka age for the basal gravels. Halfway between Karoi and Somabula, in the Mafungabusi area, Dwyka tillite rests on striated pavements showing the direction of ice movement to have been from the south-south-east and the heavy mineral suite from these gravels lacks staurolite and is quite different from that at Somabula. The question is therefore open once more and the source of the diamonds and the staurolite remains an enigma.

The age of the Dwyka series is generally placed at Upper Carboniferous to Lower Permian but this is in conflict with palaeomagnetic data which plot a Lower Carboniferous position on the Palaeozoic polar wander curve for Africa. This problem too remains unresolved but interglacial shales intersected in the Matabola borehole do provide some palaeontological evidence in support of the lesser age. This is fully described in Bulletin 70 of this series which contains comprehensive descriptions of the palaeontology and palynology of the Karoo System of Rhodesia. The interglacial shales disclosed the wing of a distinctive paraplectopteron insect related to *Hadentomum* of the North American Upper Carboniferous. Additionally miospore populations indicate that these late Dwyka shales are either uppermost Carboniferous or lowermost Permian.

MIDDLE ZAMBEZI BASIN

Lower Karoo

With the rocketing oil price and the resultant realization of a pending energy crisis a spate of exploration exercises commenced, under Special Grants and Exclusive Prospecting Orders in the country in 1974. Both known and previously untested fields have since been very thoroughly examined for their coal potential with a view to possible export and suitablity as feedstock for oil generation. A vast amount of new information has consequently accumulated regarding the Karoo System. Much of this remains of a confidential nature and whilst many new stratigraphic schemes with local nomenclature have been erected for the different areas, they have not been sufficiently well collated to allow an authoritative correlation from area to area. The succession of the Wankie Coalfield, still regarded as the type area, is set out below and may be taken to represent an average stratigraphic column for the Lower Karoo, Approximate thicknesses are given in metres.

Madumabisa Mudstones	Upper	180	Beaufort Series
	Middle	240	
	Lower	120	Ecca Series
Upper Wankie Sandstone		30	
Fireclay (Wankie only)		25	
Black Shale and Coal Group		70	
Lower Wankie Sandstone		60	
Glacial Beds		100	Dwyka Series

DWYKA SERIES. At Wankie the Lower Wankie Sandstone, consisting of coarse and fine white sandstone, overlies varved shale. A lithologically similar sandstone at Lubimbi, below the coal measures, contains shards and thin seams of coal. At Tjolotjo and Insuza, borehole intersections showed the stratigraphic equivalent to be mudstone and siltstone respectively. These variations suggest differing distances from the shoreline of the lake into which the fluvioglacial sediments were deposited and although the Lower Wankie Sandstone has in the past always been regarded as the base of the Ecca Series and as a consistent marker horizon, this may not necessarily be so. In some sections the white sandstone below the coal measures may be of Dwyka age and in others absent altogether.

ECCA SERIES. The uneven nature of the pre-Karoo floor has been demonstrated at Wankie by drilling which encountered gneissic highs against which the coal measures are cut out. Further evidence to the uneven topography at the commencement of Ecca sedimentation is found at Marowa Coalfield, 70 km south of Kariba, where conglomerates are interbedded with the coal seams.

Accepting Dwyka age for the white sandstone, where present, the base of the Ecca Series becomes the Black Shale and Coal Group which consists of carbonaceous mudstones and shales with coal seams and rare thin intercalated sandstones.

Southern African coals of this age are considered to have accumulated in peri-glacial or tundra environments. Fan deposits, stable shelf fluvial plain and graben lake deposits have been recognised. The lowermost seam in the Lubimbi Coalfield, associated with sandstone and shale of glacial origin, represents the fan type, accumulated in a glacial valley. The coal is dull and torbanitic. Overlying seams are of alternating bright and dull coal of the stable shelf, fluvial plain type, which constitute the majority of the seams in the country. In the Sabi-Limpopo areas the graben type is represented as well. The environment was one of cold peat swamps in quiet water between delta distributaries. Plant debris deposited under acid reducing conditions with uninhibited humification of organic matter would have given rise to the bright coals, whereas nearer the distributaries where the fresh water inflow was charged with allochthonous organic and inorganic debris, dull coals would have formed. Coal quality shows considerable variation even in one and the same seam and being of Gondwana association, ash content is always relatively high compared with northern hemisphere coals.

In spite of having the best shales to be found in the whole Lower Karoo, the Black Shale and Coal Group is disappointingly lacking in good macrofossils. But some material in which *Gangamopteris* is quite as abundant as *Glossopteris*, both with large fronds, has been discovered at Wankie and in the Sengwa Valley. This flora is typically Ecca and the large size indicates a low position in the series but is not absolutely definitive.

Eastwards from Wankie the sandstone tends to predominate over the shales, and upwards in the succession the fireclay grades into a white micaceous sandstone, the Upper Wankie Sandstone. This is a coarse, often gritty sandstone which, though of variable thickness, has been recognised in many parts of the Middle Zambezi Valley. It contains a single shale band, only a few centimetres thick, which has become world renowned for its assemblage of *Glossopteris* flora, specimens of which have been very widely distributed.

The Madumabisa Mudstones which attain a thickness of 540 metres overlie the Upper Wankie Sandstone. The bottom 120 metres consist of dark grey shales and mudstones with thin coal horizons, limestone and sandstone beds. At Lubimbi these were termed the Alternations Group but now, following recent work, new formational names have been introduced. Palaeontological evidence points to an Upper Ecca age, whereas the middle and upper mudstones belong to the Beaufort Series. Some of the earliest fossil discoveries were made in the Lower Madumabisa Mudstones. Remains of the fossil fish, *Acrolepis molyneuxi* now renamed *Namaichthys* were found at the confluence of the Busi and Sengwa rivers and while *Glossopteris* flora still flourished *Gangamopteris* had died out.

BEAUFORT SERIES. This commenced with the deposition of 240 metres of the Middle Madumabisa Mudstones which are grey in colour and calcareous near the base with nodules up to a metre in diameter. Deposition appears to have coincided with warming of the climate and change in environment from lakes to pools and swamps. Alkaline conditions prevailed and deposition of calcareous sediments led to the preservation of vertebrate remains, molluscan shells and woody plants. The assemblage is by far the most diverse of any in the Rhodesian Karoo. Included are *Glossopteris*, for the last time and *Taeniopteris*, for the first time. Additionally there are insects, phyllopods, ostracods, lamellibranchs, gastropods, fish, amphibia and reptiles. The upper horizons of the Middle Madumabisa Mudstones are representative of the *Endothiodon* zone.

The Upper Madumabisa Mudstones consist of a lower succession of unbedded khaki-coloured mudstones with numerous calcareous nodules, and an upper part of well-bedded grey and green siltstones and mudstones. With the exception of ribbed plant stems all the fossils are of animal remains and it would appear that plant growth had reached its lowest ebb. On the basis of uniform fine grain of the sediment, it has been suggested that much of it could be wind-blown loess in which water played some part.

Upper Karoo

There is no measurable angular discordance beween the Lower and Upper Karoo although the unconformity is widespread and well marked by a transgressive conglomerate. The Upper Karoo rocks outcrop extensively in the Middle Zambezi Basin and underlie particularly in all of the Zambezi Valley along the northern border of the country. They are almost the sole representatives of the Karoo System downstream from Kariba Gorge. Total thickness has been estimated to be some 3 000 metres but this has not been satisfactorily demonstrated.

STORMBERG SERIES. This is characterized by red beds and aeolian sandstones, indicative of a desert environment, capped by basaltic lavas. The thickness, in metres, of the various divisions in the better known parts of the Middle Zambezi Valley is listed below:

Basalt with basal sandstone	300
Forest Sandstone	610
Pebbly Arkose	140
Fine Red Marly Sandstone	70
Ripple-marked Flags (Molteno) (stage) Escarpment Grit	0-1200

The basal Escarpment Grit, never more than 20 metres thick, is ill-sorted, coarse-grained and contains water-worn pebbles of quartzite and angular fragments of Basement Complex rocks such as jaspilite. It grades upwards through a fine-grained sandstone into the Ripple-marked Flags. These are alternating maroon and grey mudstones and flags. In addition to covering large areas of the Zambezi Basin, fossil evidence suggests that the red sandstones overlying the diamondiferous gravels at Somabula on the watershed are of Molteno age. Fossil remains are sparse but a characteristic *Dichroidium* flora has been recorded. The Fine Red Sandstone consists of generally unfossiliferous, fine-grained sandstones alternating with siltstone. Colour is red to purple and the rocks are to some degree calcareous.

The eroded surface at the base of the Pebbly Arkose is marked in places by a thin bed containing hardened fragments of underlying sandstone. Above is a coarse grit with isolated pebble bands, passing upwards into sandstone. The overlapping of Upper Karoo across Lower Karoo is well demonstrated by the Pebbly Arkose. It is more resistent than the underlying sandstones and remnants have been found above the Molteno Stage at Somabula and around Featherstone, 80 km south of Salisbury. The formation is characterized by the presence of fossil wood.

The Forest Sandstone is essentially of desert derivation but does contain basal beds of sub-aqueously deposited, pale sandstone passing up into white sandstone and ultimately aeolian sandstone. This last exhibits dune bedding and is reddish in colour due to iron oxide coating on the rounded wind-blown grains. Immediately below the basalt there is evidence of intense silicification. In many places, such as near Bulawayo, where it is known as the Nyamandhlovu Sandstone, this red sandstone rests directly on the Basement Complex. The reptile *Massospondylus* is a zonal index for the formation and remains have been found near Bulawayo, at Gokwe, Mana Pools and at the confluence of the Angwa and Zambezi rivers.

SABI-LIMPOPO BASIN

This southern area contains a very much lesser development of the Karoo System than the northern area, and well over 90 per cent, in plan, consists of basalt with a thin rim of sediments often in faulted contact with the basement of gneisses and granulites.

The Lower Karoo is affected by rapid facies changes, variations in thickness and condensing of the succession. Nevertheless there are coal seams of economic potential although block faulting is a problem and, unlike the Wankie area, dolerite intrusions have a very disruptive effect in some sections. Fossils are scarce and correlation with other Karoo provinces are uncertain.

Lower Karoo

DWYKA SERIES. Glacial beds are not well represented to the north and west of Beitbridge and owing to their gritty and feldspathic nature are often difficult to distinguish, in the bore core, from underlying weathered gneisses. Outcrops of fluvioglacial rocks have been observed in the lower reaches of the Bubye River and, as has been stated earlier a large amount of evidence of their presence has now been accumulated in the lower Sabi area where, for instance, the Mkushwe coal seam is separated from glacial beds by a 7 metre thickness of medium to coarse white sandstone very like the Lower Wankie Sandstone.

ECCA SERIES. In the Bubye Coalfield the succession consists of 112 metres of alternating grits, carbonaceous shales and coal seams overlain by beds believed to be of Lower Beaufort age, as listed:—

Red mudstone	105	Lower Beaufort
Mudstone, grit, coaly shale	77	
Grit	22	Ecca
Grit, carbonaceous shale	29	
Coal and shale (main coal horizon)	4	
Grit, coal, carbonaceous shale	45	
Conglomerate, gritty shales	12	

The Ecca succession is thinner and more sandy in the east and preservation of fossils is poor but meagre *Glossopteris* flora suggest that the period of coal formation was contemporaneous with that of the Zambezi Basin. Recent work at the Massabi Coalfield west of Beitbridge has disclosed 60 metres of so-named Fulton's Drift Mudstones which are coal-bearing and in the light of present knowledge represent a greaty condensed Ecca-Beaufort sequence. In the Sabi Valley, in the northern limb of the basin, about 210 metres of rapidly accumulated, alternating arenaceous and argillaceous sediments were laid down in a graben during Lower Karoo times. The general absence of coaly horizons points to an unfavourable environment for the accumulation of organic debris but to the south, in the Mkushwe field, conditions were quieter and coal with associated shales was the result. Boulders of Umkondo quartzite in deltaic sediments and the overlap of the higher beds onto the quartzites indicate that throughout Karoo sedimentation the Melsetter area to the east was exposed high ground.

Boreholes in the Sabi Valley passed through 30 to 40 metres of grits lying above the coal seams, and at Massabi 10 metres of arenaceous rocks occupy a similar stratigraphic position. These beds may be the equivalent of the Upper Wankie Sandstone. Whether the 180-metre thick succession of fine-grained sandstones with alternating grey mudstones and siltstones, occurring 15 km north of Mkushwe Coalfield and which are often calcareous, are related to the Lower Madumabisa Mudstones is not known.

BEAUFORT SERIES. Because of the condensed successions, facies changes, lenticular nature of the beds and paucity of palaeontological record, there is little assured information regarding Karoo sedimentation in the Sabi-Limpopo Basin during this period of time. The Lower Beaufort is thought to be represented by the grits and carbonaceous shale bands above the Dendera seam in the Mkushwe Coalfield and at Bubye, the red mudstones and grits with coaly shales apparently have the same stratigraphic poisition.

UPPER KAROO

Whenever Upper Karoo beds remain overlying the Lower Karoo succession they do so unconformably, and as is the case in the Zambezi Basin these upper sandstones transgress across onto Basement gneisses or other old formations.

STORMBERG SERIES. The basal Escarpment Grit has been recognised to the north-west of Beitbridge but the most prominent member of the Moleno Stage is the Red Beds. In the Sabi Valley a conglomerate also marks the base of the series. The Red Beds of the Mazunga area are a widespread sequence, 300 metres thick and composed of fine-grained sandstones, marls and mudstones of reddish or purple colour and contain scattered pebbles and calcareous nodules. Contact with the Escarpment Grits is seldom exposed but appears to be conformable as does that with the overlying Forest Sandstone. In the Sabi Valley thickness reaches 530 metres, with siltstones predominating. An anomalous feature is the presence of a layer of volcanic rocks, or so it has been said. They are described as a 10-metre thick band, near the base, composed of flow-banded hornblende latites. They are very much more probably a greywacke member derived from degradation of Umkondo Basalt terrain. At the top of the sedimentary portion of the Stormberg Series is the Forest or Cave Sandstone. It is widespread throughout the Sabi-Limpopo Basin, is between 70 and 160 metres thick and consists of white to brownish, dune-bedded, feldspathic sandstones which build the only prominent topographic features of Karoo sediments in the area. This too is the only one of the Upper Karoo formations that may be confidently correlated with its namesake in the Zambezi Basin.

COALFIELDS

The only area in the country that has been exploited for its coal resources is that known as the reduced *Wankie Coal Concession* area. Within it is Wankie Township which is 300 km, on rail, north-west of Bulawayo. The concession is approximately 160 km² in extent. No. 1 Colliery commenced production here in 1903 to be followed by Nos. 2, 3 and 4 collieries. They have been well able to supply the country's needs despite the disastrous methane-initiated, coal dust explosion in 1972 which cost 427 lives and forced the closure of No. 2 Colliery.

Mining depth varies between 60 and 150 metres and will increase westwards but a large proportion of the field is open-castable. An isopachyte map of the concession area shows the main coal seam to vary between 2 and 11 metres in thickness, averaging between 7 and 8 metres.

The bottom part of the seam has excellent coking properties and its ash content is as low as 5 to 7 per cent. Phosphorus content too is low but the recorded mean value of sulphur is approximately 1,3 per cent. The seam deteriorates in all respects upwards except sulphur content which decreases. A proximate analysis of average run of mine coal, for saleable purposes is quoted as:—

Volatiles	23,77 per cent.
Fixed carbon	65,70 per cent.
Ash	9,77 per cent.
Moisture	0,76 per cent.
Calorific value	31,4 Mj/kg

The resources of the Concession and adjacent areas, as published in 1960, have been classified into *total coal* which is all carbonaceous sediment containing less than 30 per cent of ash: *good quality coal*, which averages less than 12,8 per cent ash, an empirically derived value: and *extractable coal* which equates to ore reserves. In arriving at the ore reserve, 15 per cent is deducted from the good quality coal value for bad or faulted ground and 50 per cent of the remainder is classified as mineable under the pillar and stall methods employed. The resulting figures, converted into metric tonnes, are listed below:—

	Total Coal	*Good Quality Coal*	*Ore Reserves*
Colliery Concession .	910 000 000	750 000 000	320 000 000
Buffer Zone	420 000 000	320 000 000	135 000 000
Messina Area . . .	300 000 000	85 000 000	35 000 000
Entuba	370 000 000	115 000 000	50 000 000
	2 000 000 000	1 270 000 000	540 000 000

Re-examination of the *Entuba* field, currently in progress, shows that the main coal seam, underlying 6 km² of ground, is 11 metres thick and corresponds to the Wankie Main Seam. Earlier tonnage estimates have been confirmed in greater detail and subdivision into different grades of coal is being made. West of Wankie Colliery Concession, the Buffer and Messina areas now known as the Western Area have been reassessed. The western portion occupies 30 km², with coal outcrop in the far west, and can be open-cast. A reserve of high ash coal suitable for a thermal power station has been calculated at 650 million tonnes. The eastern portion occupying 50 km² contains a similar tonnage but of much better quality coal.

In 1959, after an 80 km² area at *Lubimbi* had been probed by 66 boreholes, it was calculated that 20 million tonnes of good coal and 50 million tonnes with an ash content averaging 18,6 per cent were present. An exercise carried out by the Lurgi Company at Frankfurt proved the material to be eminently suitable for gasification and it was calculated that the reserves were ample to feed an oil-from-coal industry sufficient for the country's needs for 50 years, based on the market situation at the time. Commencing in October 1973, the Industrial Development Corporation has been re-drilling the entire Lubimbi field. North of the Shangani River, an open pit coal and bituminous shale reserve of 543 million tonnes with a maximum overburden of 80 metres has been established. South of the river to Dahlia on the main road, five open-cast blocks are estimated to contain 192 million tonnes of usable coal. A sixth, fault uplifted block, immediately south of Dahlia, has 100 million tonnes of coal body overlain by 146 million tonnes of over-burden. Along the entire strike, scout holes drilled down dip to the south-east indicate astronomical tonnages of coal and associated bitu-minous shale.

The *Lusulu* area is 80 km north-east of Lubimbi. Here high volatile steam coal with negligible coking properties underlies 70 km² of country, a quarter of which could be mined by open-cast methods.

Further to the north-east, at the end of the Chisarira horst, active exploration of the *Sengwa Coalfield* has been under way for the last five years. An average seam width of 10 metres has been determined and a provisional estimate of 200 million tonnes of extractable coal containing less than 20 per cent ash has been made. The coal is of lower rank than that at Wankie and is non-coking but its average sulphur content at 0,6 per cent. and phosphorus at 0,02 per cent. are very favourable features. Other fields in this generally remote area are known as *Marowa, Bari, Kaonga* and *Sessami* where artesian water may be a problem.

At the southern end of the country, coal was discovered in the Mazunga area on the east bank of the Umzingwani River in 1895, and this locality and the nearby Singwesi and Massabi areas, collectively known as the *Tuli Coalfield*, have received desultory attention for years. The coal seams are very narrow, have high ash content and are dislocated by faulting and dolerite intrusions. For the greater part, beneath basalt cover, they are probably beyond economic mining depth. Marginal areas that have been examined in the past few years indicate reserves of some 30 million tonnes of coal that could be beneficiated to produce good quality, low sulphur coking coal.

The *Bubye* field, 100 km downstream on the north bank of the Limpopo River, has in like manner been disrupted by faulting and dyke and sill intrusions. The reserve estimates of saleable coking coal are of the order of 15 million tonnes.

Coal occurrences in the Sabi Valley were the subject of a report by Lightfoot in 1911 but it was not until 1947 that Government conducted a programme to make preliminary assessment of the potential. 4 065 metres of diamond drilling were carried out. The three main areas examined were *Bendezi*, on the east bank of the Lundi River, *Malilongwe*, 35 km to the east-north-east beyond the Chiredzi River and *Mkushwe*, just west of the Sabi River. At Bendezi, very thin lenticular seams of high volatile coal were considered to have some potential southwards beneath basalt cover. At Malilongwe, two coal horizons separated by 10 metres of grit were examined. Each varied in thickness from less than a metre to 3,5 metres of bituminous coal with coking properties but high ash content. Reserves were calculated as 87 million tonnes in the upper group and 173 million tonnes in the lower group. Zones of burning occasioned by dolerite intrusions were expected to be common. The most easterly, or Mkushwe seam is the largest in the area but is composed of non-coking, semi-anthracite with a high ash content and is not amenable to beneficiation. Reserves to the west of the Sabi River, in five blocks at depths less than 175 metres were computed at 308 million tonnes. The thin Dendera coal seam, lying 90 metres stratigraphically above the Mkushwe seam appeared to be of little value.

Recent detailed work has confirmed the potential of the Bendezi area and a considerable tonnage of a very high-grade coking coal mixer has been determined. The coal is of Upper Ecca age and main maceral is vitrinite. Tonnage at Mkushwe had been reduced by the discovery of shale intercalations and further evidence of doleritic intrusions. None-the-less there is a large tonnage of mineable coal acceptable to a thermal power station.

Fireclay. This is a leached modification of the black carbonaceous shales and not a seat earth. It is intermittently developed above the coal measures at Wankie, Entuba, Lukosi and in the Sinamatila Ranch area. Resources are practically unlimited but have not been subjected to detailed examination. Average composition is: silica — 58 per cent, alumina — 29 per cent and water — 10 per cent, with iron, magnesia, lime and alkalis comprising the remainder. In the Sabi Valley, at Chivumburu, near Bendezi Coalfield, fireclay of a similar nature is present in large quantity in a similar stratigraphic position.

KAROO AND RELATED IGNEOUS ACTIVITY

Vast outpourings of lava, chiefly of basaltic composition, brought to an end the very long period of Karoo sedimentation in Jurassic times. These lavas occupy large tracts of country in both Zambezi and Sabi-Limpopo basins. Aeolian sandstone beds frequently occur with the basal flows especially around Matetsi, west of Wankie; and in the Sabi Valley there is clear evidence that the basalt flowed into hollows between sand dunes, causing silicification and polygonal cracking in the sandstones at the inter-surfaces. At Gokwe, lava occupies an erosion channel cut 100 metres deep through Forest Sandstone into Pebbly Arkose. In the central part of the Middle Zambezi Valley there appears to be as much sandstone as lava in the lower parts of the succession. Some of the sandstones are massively current-bedded rocks of sub-aqueous origin and with them pillow lavas have been noted. In a wave-cut cliff in one of the lava-sediment exposures at Lake Kariba reptile remains of a new genus and species of sauropod, named *Volcanodon karibaensis*, have been found.

The basalts are seen in their most spectacular development at the Victoria Falls, where the gorges have been cut through four horizontal flows, the upper and lower margins of which are distinguished by amygdaloidal rocks with gas cavities containing well-crystallized zeolites. The thickness of the lavas is not known, since neither the bottom nor the original top are exposed, but it appears to approach 1 000 metres. The Deka fault west of Wankie bounds this tract on the south-east side, and the Kalahari beds overlie the basalts in the south-west. South-east of Wankie, basalts again underlie most of the Kalahari-covered tracts as is known from boreholes and from inliers in the Lupani Valley, at Sawmills and elsewhere. North of Bulawayo basalts rest on the sandstones, giving rise to flat-topped hills bounded by abrupt scarps. Elsewhere as 50 km south and south-west of Salisbury, Karoo basalt rests directly on the Basement Complex.

Throughout this area north-west of the present watershed the basalts are fairly uniform in type, consisting dominantly of labradorite phenocrysts in a groundmass of augite granules, magnetite, finely divided feldspars and some interstitial glass. Varieties bearing olivine or nepheline have never been reported. The most notable chemical feature is the high titanium content, which in most analyses exceeds 3 per cent, resulting in abundant ilmenite in the basalts.

The most extensive tract of Karoo lavas in Rhodesia occurs in the south-eastern part of the country, stretching from Tuli to the Mozambique border. Again the total thickness is not known, but at Honde, in the extreme east, a drill passed through 580 metres of basalts without reaching the base of the series.

Some of the basalts in this area resemble those around Victoria Falls, but much of the material is limburgitic, consisting of phenocrysts of olivine and augite in a glassy groundmass devitrified to varying extents. Nepheline-basalts and nephelinites occur in lesser amounts, while andesites and andesitic ashes are rare. Individual lava flows are thin. Sills of all these types cut the Karoo sediments and lavas.

All these volcanic rocks are also rich in titania. Related limburgites occur around Featherstone. The exposures here, overlying aeolian sandstone, are non-amygdaloidal, but amygdaloidal basalt is extensive as scree nearby. The dividing line between the lava type of Victoria Falls and the limburgitic types of the Sabi thus appears to coincide with the present watershed.

The consensus is that most of the lavas, both in the Zambezi and Sabi-Limpopo basins were conducted to the surface mainly by fissure eruption. The swarms of dykes resulting can be seen in the Sabi area, cutting all rocks, including the basalts themselves. In spite of this, there is no known instance of dykes cutting the Permian rocks at Wankie and elsewhere nearby; and in an area of some 4 000 km² to the north of the Sabi basalt area not more than ten dykes have been found. They are also rare on the watershed of the country although a limburgitic plug located east of Gwelo and a poorly exposed vent in Charter District are probably of Jurassic age and may have contributed to the flows preserved so far away from the Karoo basins. However, it appears likely that most of the magma was conducted to surface only in the two trough areas where the basalts are now found in great thickness, and that outflow was probably accompanied by block sinking.

Around the lower part of the Nuanetsi River the basalts are overlain by several hundred metres of ignimbritic rhyolites of identical type to those of the Lebombo Range in South Africa.

Closely following the phase of acid vulcanicity, gabbros were emplaced as horizontal sheets of "cedar-tree" lopoliths and a very large granophyre sheet, some 200 metres thick, on the south-eastern border invaded the basalts. Related granitic intrusion in the Mateke

Hills collapsed the lopolithic structures and led to the formation of four aligned ring complexes. These have dyke equivalents of porphyry and syenite which intrude both Karoo rocks and the paragneisses of the Beitbridge Group.

Copper-tungsten *mineralization* is associated with the granophyre along the Sabi River and occurs in quartz veins emanating from it into the surrounding basalts. This mineralization has been exploited at the Hippo, P & O, Mutandawhe, Mapani and several other small mines. High-grade crystal calcite and fluorite occur in vughs and veins in the basalts in both Wankie and Sabi Valley areas but the deposits are extremely small and impersistent; and at one time perlitic zones in the rhyolites attracted attention.

ALKALI RING COMPLEXES

In the upper Sabi Valley in the eastern part of the country there are three alkali ring complexes, known as Shawa, Dorowa and Chishanya which are sub-volcanic intrusions into the granitic rocks of the Basement Complex there. They are cylindrical structures that have been formed by the rupture of the country rocks caused by magmatic emanations from great depth. Age of intrusion has been placed as late-Mesozoic. The invaded granitic rocks were progressively modified into syenite, nepheline syenite and ijolite and other varieties collectively known as fenites. The process of fenitization involves desilication and enrichment in alkalis to form rocks usually devoid of quartz but containing feldspars, feldspathoids and variable proportions of the bright coloured sodic amphiboles and pyroxenes. Some of the fenites were liquidified in the process and were intruded both inside and outside the complex as dykes and sheets. Accompanying or following the emanation stage there are intrusions of carbonatites, which are calcium or magnesium carbonate rocks of igneous origin, and with which are associated pneumatolitic deposits of magnetite, apatite, micas and rare minerals. These last may contain uranium, thorium and rare earth elements, sometimes present in economical concentration. Of the three deposits, only that at Dorowa is currently being exploited on a large scale for its phosphate content. The magnetite and vermiculite in the complexes have not attracted much attention. The Katete deposit, 50 km north-east of Wankie which intrudes Upper Karoo sediments is apparently younger as an age of 87 Ma has been attributed to the structure, the form and complexity of which is not known as outcrops consist solely of carbonatite.

Of a different type is the alkaline, acid-basic association known as Marungudzi. It is a much larger complex, some 80 km² in area, and is located 70 km east-north-east of Beitbridge. Six successive migrating intrusion centres have been distinguished cutting through the meta-sediments and hornblende gneisses of the Diti Formation of the Beitbridge Group which forms the basement of this area. The age is calculated at 190 $\pm$ 12 Ma derived from K-Ar determination. A large gabbroic core has superimposed rings of such rare rocks as pulaskite, foyaite and pseudoleucite juvite but carbonatites are not a feature and no economic mineralization has been discovered.

The two ring structures in the extreme north-east of the country vary considerably from the foregoing and are apparently much older. They contain carbonatites with accumulations of magnetite, and some apatite and rare earth minerals are present. The complexes are, however, composed essentially of rocks of skarn rather than alkaline affinity. The core of Nanuta Hill is composed of labradorite-andradite granulite which grades into pyroxene-amphibole-garnet granulite and both are sporadically veined by diopsode-scapolite rock. Mineralization consisting of chalcopyrite with trace amounts of bornite and pyrite are present. As both structures provided evidence of having been folded together with the host rocks of the Kahire Group, the time of emplacement must ante-date the 400-650 Ma Miami metamorphic event.

KIMBERLITE

Kimberlite is a very rare type of ultramafic igneous rock derived from great depths in the earth's interior, at the junction of the crust and the mantle. In areas that have had heavy crustal loading it may be injected through pipes and fissures up to surface as a very fluid magma containing a high proportion of carbon dioxide. This has corrosive action and on solididification the kimberlite contains numerous fragments of disrupted wall rocks carried up in the magma in addition to a great variety of primary minerals among them diamonds in infinitesimally small quantity. Even in a payable deposit this may be as little as one part in 30 million, so in prospecting and exploration exercises the primary minerals of kimberlite, being of an unusual nature, such as chrome diopside, pyrope garnet, forsterite olivine, phloglopite mica, ilmenite and others are sought as indicators. At surface the kimberlite is invariably serpentinized and oxidized to become a gritty clay known as yellow ground. With depth it hardens to blue ground, a carbonated serpentinous rock which often has an agglomeratic or brecciated appearance.

In Rhodesia three groups of pipes are known. Eight intrusions penetrate the granites of the craton, in a cluster of three in the Formona granite some 60 km north-east of Bulawayo, and as several isolated occurrences over towards Gwelo. Nine of post-Triassic age have been discovered at the south-western end of Lake Kariba and there are two in the Limpopo Mobile Belt. All are poorly exposed and although each has been well investigated, none other than that on River Claims, west-north-west of Beitbridge, has shown promise of developing into a profitable mine.

In the past, and by analogy with most South African occurrences, these kimberlites were assigned in age to the Cretaceous. However there is no good evidence for this belief and those of the craton and mobile belt could be very much older but it may be significant that all occur in close proximity to outcrops of the Karoo System. None has any apparent relationship to the alkaline ring complexes of the country however, although a relationship of this nature has been demonstrated in other parts of the world.

CHISWITI VOLCANICS

Layers of dark coloured tuffaceous lava, agglomerate and pumice form a group of rugged foot-hills north of the Zambezi Escarpment and west of the Senga River in the Chiswiti Tribal Trust Land of north-eastern Rhodesia. This apparently anomalous volcanic occurrence has been down-thrown along a major fault followed by the Senga River and seems to overlie sandstones and conglomerates of Upper Karoo age. Although tectonically undisturbed the Chiswiti volcanics exhibit extensive hydrothermal alteration, in contrast to adjacent Karoo basalts, and may represent the site of a volcano of central type.

The most common exposures consist of a medium to coarse-grained granular rock composed essentially of hornblende and scapolite in the proportion 40:60. The hornblende clearly pseudomorphs pyroxene but as the scapolite is a highly sodic variety of marialite the original composition of the rock is problematical. This granular rock bears both conformable and cross-cutting relationships to fine-grained, well laminated lava flows and welded tuff of similar composition. Some flows are vesicular near the top and ropy lava structures have been preserved by discontinous layers of white potash-rich, siliceous pumice. Hydrothermally altered breccia composed of angular to rounded fragments of fine-grained lava have been noted and may have resulted from local brecciation. No metallic mineralization of economic interest has been recorded from this occurrence.

THE CRETACEOUS

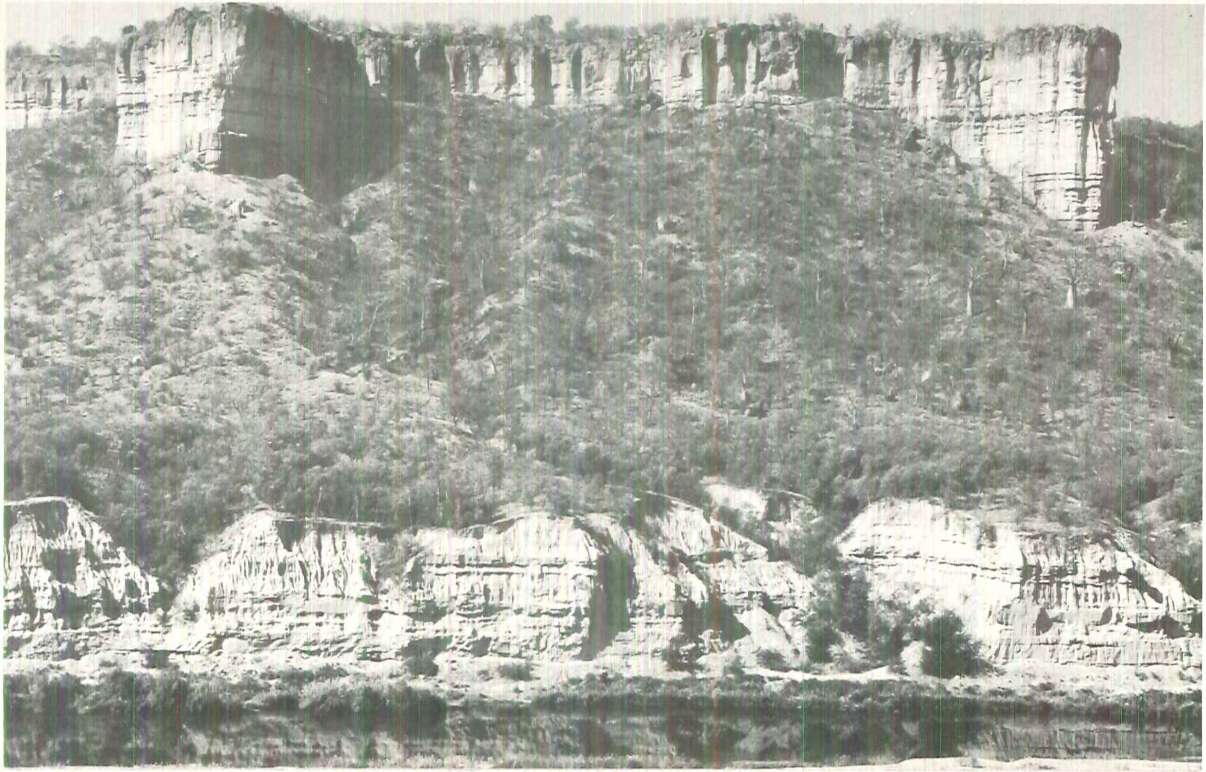
The first record of sedimentary rocks in Rhodesia that are possibly of Cretaceous age was made by P. A. Wagner in 1912 following a traverse in the Darwin District in the north-east of the country. He described flat-lying, red micaceous mudstones, and sandstones, grits, arkoses and coarse conglomerates of pale purple colour, probably overlying the basalts of the area. Comparison of these basalts was made with the Batoka Basalt and it was concluded that they might be of Karoo age.

Subsequently similar deposits were found elsewhere along the Zambezi Valley; and at a much higher elevation in the Gokwe District. But by far the greatest expanse of sediments of similar nature are those in the extreme south-east of the country which occupy an area of approximately 8 000 km² along the Mozambique border, and are known as the Malvernia Beds.

The Zambezi Valley occurrences are not well known but may be of wide extent. Where the Hunyani River enters the valley there are conglomerates, banked up against the Escarpment, containing huge boulders. Similar very coarse conglomerate is present in the Zambezi River 40 km upstream from the Luangwa confluence, and at the confluence itself mauve arkoses and conglomerates occur at an altitude of 320 metres. The highest elevation where the sandstones and coarse conglomerates have been recorded is at about 1 000 metres above sea level on the flank of Chirambakadoma Hill in the gneissic horst, 65 km to the south-west. This would indicate a thickness of some 700 metres of sediments providing fault displacement is minimal.

The Malvernia Beds rest upon a basement of Karoo lavas and acid intrusions of the Nuanetsi Igneous Province. They comprise a monotonous succession of gently dipping, non-fossiliferous, red and white sandstones, grits and conglomerates. They are variably cemented by calcite and weather to thick gravelly sands. Much of the area is a featureless plain but where more dissected a "badlands" type of topography results. In the north-east there are very good exposures along

PLATE VIII



CLARENDON CLIFFS. CRETACEOUS SEDIMENTS, near Lundi River.

the imposing Clarendon Cliffs which rise 150 metres above the Lundi River. The sediments represent a shallow water deltaic or littoral facies of a marine incursion from the east. The Rhodesian part of the basin deepens radially to a point about 20 km north-east of Malvernia on the border with Mozambique where a thickness of 1 350 metres was indicated by seismic investigation. A single exploratory borehole drilled here passed through the entire succession into Karoo basalt without encountering suitable trap structures containing natural gas or oil.

Near Gokwe, reptilian bones were discovered in 1970, at an altitude of 1 250 metres. The sediments overlie Karoo basalt and are partly covered by Kalahari beds. Correlation is uncertain but the dinosaur remains rule out an age later than the end of the Mesozoic, and a single lamellibranch, tentatively identified as belonging to the genus *Anisocardia,* has similarities to the species which span Upper Jurassic to Lower Cretaceous age. The sequence in which they are contained has been named the Gokwe Formation.

To the south-east of Gokwe it outcrops only as a scarp around the margins of the Kalahari beds but to the west it occupies large, well exposed areas. Around Gokwe township the formation rests, with marked unconformity, upon the Karoo basalt surface which slopes gently west-south-west, but 40 km to the west it oversteps the basalt and Forest Sandstone to lie directly on the Pebbly Arkose. The succession attains a maximum thickness of 90 metres and has been divided into two members. The basal Calcareous Member comprises a conglomerate with agate and basalt pebbles, a variety of brown and mauve, current bedded sandstones and lenticular pisolitic limestone. The White Sandstone Member is a sandstone with white clay matrix and distinctive clay pellets. Available evidence points to deposition in a restricted, shallow basin of alkaline water that had short-lived existence in an arid climate. Limit of the basin to the north is not known but scattered outcrops show that it extended at least 100 km to the south-west.

Between the Kadzi and Musengezi rivers in the Zambezi Valley, fossil bones comparable in size to those of the gigantic dinosaur *Brachiosaurus* have been discovered at an altitude of 400 metres. They occur in a 60 metre-thick succession of flat-lying sandstones and siltstones overlain by alluvium. The base of the formation has not been exposed but the presence of large sauropod remains suggests equation with the Gokwe Formation. The siltstones are often calcareous and they, as well as the current-bedded sandstones and grits, are predominantly yellow in colour although maroon varieties are well represented. Fragmentary nature of the bones and the presence of mud pellet conglomerates points to a fanglomerate type of deposition in a shallow inland basin.

All of the formations described have great lithological similarity, are uniformly undeformed and are of post-Karoo age, but they are patchily developed and isolated from one another so that overall correlation is not justified.

To the present the Cretaceous has not been found to contain mineralization of economic value, but it is possible that the Malvernia Beds contain fossil sea-water. Several wells at Marhumbiri, just south of the Sabi River where it flows into Mozambique, contain extremely saline water. It is feasible that the brine could be beneficiated by solar evaporation, under the prevailing high temperatures of the area, to produce salt, a mineral in short supply in the country.

EARTH MOVEMENTS

Very important earth movements which gave rise to the Zambezi troughs and probably initiated the Sabi-Limpopo Basin, took place between the deposition of the Karoo basalts and early or middle Cretaceous times.

The Middle Zambezi fault trough, or rift valley, strikes approximately north-east and is bounded on the southern side by faults arranged *en echelon* with down throw on the north. The best known of these is the Deka fault west of the Wankie Coalfield. In Gokwe and Binga districts the main fault is the Tandazi scarp bounding the Chizarira Plateau; thereafter the scarp steps forward to form the Matusadona Mountains and the hilly country around Kariba Gorge. Corresponding faults, throwing down to the south, face the river on the northern side. In Zambia the same fault trough continues for 800 km as the valley of the Luangwa River.

Near the thirtieth meridian the rift is joined by that of the lower Zambezi which strikes a little south of east, and is bounded on the south by the Mavuradonha Escarpment. The valleys are floored with Triassic and Jurassic rocks which have subsided between walls of Precambrian gneisses.

THE TERTIARY AND QUATERNARY FORMATIONS

KALAHARI SYSTEM

A large part of the western area of Rhodesia, amounting to about 44 000 km², is covered by unconsolidated sands, part of a much larger spread of similar deposits which originally filled a basin-shaped depression stretching from about one degree north of the Equator to more than 20 degrees south. These Kalahari sands are not found on the south-east of the Rhodesian watershed. Their geological age has been difficult to determine, but work by Cahen and Lepersonne has gone far to solving this problem. The lack of diagnostic fossils has prevented dating on internal evidence, and the lack of proper consolidation has allowed the sands to be redeposited at later periods without apparent change in lithology. Such redeposited sands overlie Pleistocene erosion surfaces and gravels with Stone Age artifacts. This led to the contradictory situation that sands which on geomorphological grounds rested on different erosion surfaces, and should be of different ages, could not be separated on their lithological or palaeontological evidence.

This difficulty is now largely resolved, and it is possible to equate our Kalahari beds with the Kalahari System of Zaire and to distinguish redistributed Pleistocene sands of Kalahari type from the main areas of older sands.

The large spreads of sands on the interfluves belong to the main phase of the Kalahari System, of Tertiary age; the Pleistocene redistributed sands are found where the rivers have cut through to older rocks, and were derived from the resulting scarps of older sands. Where the Kalahari System has been penetrated by boreholes along the Bulawayo-Victoria Falls railway line, it reaches a thickness of a little over 100 metres, composed of Pipe Sandstone below, and Kalahari Sand above.

The Pipe Sandstone is generally buff or pink in colour, and feebly cemented by silica and traversed by numerous hollow pipes, which may represent cavities made by stems of vegetation during deposition. It is a good water-bearing horizon. The Pipe Sandstone is sometimes secondarily cemented into a hard quartzite or silcrete, hard enough for use as railway ballast.

The Kalahari Sand is a pink or buff coloured structureless aeolian sand; the well-rounded quartz grains have frosted surfaces. There is a high proportion of fine dust. These sands carry important timber forests.

The surface on which the Kalahari System rests is largely flat in the western part of Rhodesia. It is warped into a syncline at the Victoria Falls, and towards the Kalahari depression, and in these areas the sands form the highest part of the topography, blanketing all older deposits. Kalahari beds are found at an altitude of 1500 metres at Salisbury and south of Enkeldoorn, and at 1450 metres at Bulawayo. On the Mafungabusi Plateau they have a maximum thickness of 75 metres on a 1200 metre surface. The floor is at 980 metres at Gwai Bridge, and dips below 900 metres in the Makarikari Salt Pan in Botswana. It is also warped down to 900 metres at the Victoria Falls where the river runs in a gentle syncline. However, lower down the Zambezi Valley, below the end of the Batoka Gorge, there are large areas of similar sands on an erosion surface at 600 metres above which stand scarps of older rocks leading to higher and older erosion surfaces.

The aeolian sands of the Kalahari System bear witness to a long period of aridity over a large part of Southern Africa during the Tertiary.

The only fossils so far found are freshwater snails of the genera *Vivaparus, Paludestrina* and *Limnea* and the seed-like bodies of *Chara*, none of which can be used to give the age of the deposits with precision.

PLEISTOCENE SYSTEM

The Pleistocene period covers roughly the last million years of geological time, and it was during this time that man made his appearance on the scene, possibly in Southern Africa.

In the higher latitudes there were great changes in climate, for this was the period of the Great Ice Age. Such changes can hardly have failed to influence the climates in lower latitudes. As the great ice-sheets waxed and waned the changes in Rhodesia seem to have been periods of wetter climates, interspersed with phases of drier conditions. During this period the finishing touches were put to the landscape as we now see it. There are, however, no great deposits of sediments dating from this period. All we have on which to build a picture of the events of this stretch of time are beds of alluvium and terrace gravels in the river valleys interspersed with periods during which the rivers cut their beds several metres lower in the older rocks. There are also redeposited sands of Kalahari type, some of them windblown in drier phases, and chemical alterations such as ferricretes and calcretes. Fossils are rare, though a mammalian fauna including extinct species has been found at one locality. No human fossils have been found except in the latest cave deposits, but stone implements are abundant in many areas and can to some extent be used in place of conventional fossil remains for local correlation and for comparisons with Pleistocene successions in other parts of Africa. Tentative correlations have also been made using the succession of climatic phases deduced from the geological sequence, but this kind of evidence can only be used with extreme caution as it depends so much on interpretation of geological events in terms of climate. There is not as yet full agreement on the significance of some of the evidence, here or elsewhere.

The best-known Pleistocene successions are on the watershed in Matabeleland, and in the Zambezi Valley near the Victoria Falls. Both successions are given, with the Stone Age culture as the main connecting link.

Plateau	*Cultures*	*Victoria Falls*
Erosion	. . . .	. . . *Erosion*
Abandoned courses Alluvium IIb	Wilton	Sand and Calcareous Tufa
Erosion	. . . .	. . . *Erosion*
Kunkar Alluvium IIa	Magosian	Sandy Calcareous Alluvium
Erosion	. . . .	. . . *Erosion*
Eluvial Gravel		Redeposited Sands Calcification and Ferruginization
	M.S.A.	Younger Falls Gravels
Ferricrete Kunkar		Redeposited Sands Ferricrete
Alluvium I	Chelles-Acheul	Older Falls Gravels I Older Falls Gravels II
Basal Gravel	Pebble Tools	
Erosion	. . . .	. . . *Erosion*

Alluvium I is a stiff yellowish sandy clay, probably formed under conditions wetter than the present. It contains numerous large calcareous concretions (kunkar), formed after its deposition, under a climate probably slightly drier than now.

The ferricrete, a secondary concretionary ironstone, probably needs wetter conditions for its best development. It is common around the edges of valleys cut through the older Kalahari Sand, and appears to pass under the sand. It has not been found, however, in boreholes through the sand, and appears to form by lateral percolation along the edges of valleys, as first suggested by A. M. Macgregor. By forming this way it cements up any loose gravel, including stone implements, which may be present and gives the appearance of a continous bed passing under the sand. It actually does, but dies out away from the valley sides. It yields stone implements mainly of the Sangoan culture.

Alluvium II is a soft sandy deposit of yellow or reddish-brown colour with a gravel bed at its base. It is often deeply dissected by the rivers, and may be as much as 25 metres thick. There is a minor erosion surface within it which divides it into Alluvium IIa and IIb.

There is only one known section where Pleistocene deposits have yielded both stone implements and mammalian fossils, and this is in the Chelmer spruit a few kilometres north of Bulawayo. The section is difficult to correlate with the others on the plateau. The fossil mammals are older than a Middle Stone Age series of implements. Fourteen species of mammals have been determined, of which six are extinct, and two were new species. The extinct forms include *Homoiocereas bainii*, *Equus capensis*, a giant extinct wildebeest *Connochaetes grandis* and an extinct gazelle, *Gazella bondi*, as well as such living forms as *Equus burchelli* and *Hippopotamus cf. amphibius*, which probably indicates a wetter climate than nowadays.

The succession at the Victoria Falls includes true terrace gravels resting on benches cut in Karoo basalts. The gravels are thin, being all that remains of beds of alluvium from which all the fines have been removed. There are also redeposited Kalahari-type sands, derived from the scarps of older Kalahari Sands bounding the Zambezi Valley. Some of these sands were redeposited by wind action in dry phases, others were derived by lateral hill wash and by transport in the Zambezi itself.

Qualitative assessments of climatic changes tend to exaggerate them and the only study which has so far been made of quantitative change indicates that at the height of the wet phase in the Middle Stone Age the increase was from 650 mm per annum as at present to about 900 to 1 000 mm, while in the succeeding minor dry phase the rainfall only dropped to about 500 mm per annum.

The extensive tract of alluvium in the middle portion of the Sabi Valley perhaps also belongs to the Pleistocene. Formerly regarded as a lake deposit, research has now shown that it was laid down by the Sabi River, which meandered widely before stabilizing its present water-course. The alluvium is proving to be a very important aquifer.

Another large area of similar alluvium, in the Umniati Valley below Robb's Drift in Mafungabusi area, is also proving to be of great importance agriculturally; and in the Zambezi Valley several expanses of alluvium have newly been distinguished but not yet closely investigated. The fanlike occurrence, east of Chirundu, is an attractive exploration target as its provenance is a gneissic area containing uranium-bearing pegmatites.

The Pleistocene deposits have not yet been found to contain minerals of economic value. As stated earlier there seems to be little alluvial gold in old river terrances and indeed the present beds of rivers draining gold belts have not been very productive.

The major rivers of Matabeleland have been thoroughly prospected for alluvial diamonds, but the results were disappointing. The main interest of the Pleistocene period is the development of human cultures, and Rhodesia is rich in these remains.

DEVELOPMENT OF THE TOPOGRAPHY

The later history of Rhodesia is concerned mainly with denudation and uplift.

Most Rhodesian hills have flat tops. These were formed at some time in the past when a long period of stability, during which the continent has been eroded to a nearly flat surface only a little above sea-level, was brought to an end by an uplift which initiated a new cycle of erosion to a lower base level. Even when the hill tops are not flat a view from one of them generally shows that surrounding peaks rise to approximately the same level. This is often the case in granite country in which erosion takes place most rapidly where the rock has been weathered and softened by stagnant water beneath the soil, and very much more slowly in massive rock off the bare surface of which the rain flows as it falls. In a limited area it is safe to say that hills of the same height were bevelled at the same time. But the policy of some authorities of correlating erosion surface over wide areas by their height above sea-level, without careful investigation to ascertain that the surfaces are horizontal, is subject to serious objection.

Recent detailed study of the geomorphology of the country by Dr. L. Lister of the University of Rhodesia has led to a very good understanding of the several erosional cycles and their resulting land surfaces which may be recognised. They are listed below and briefly described in the sequel.

Pre-Karoo	Late Palaeozoic
Intra-Karoo	Triassic
Gondwana	Middle to end Jurassic
Post-Gondwana	Early Cretaceous
African	Middle Cretaceous to end Oligocene
Post-African	Miocene
Pliocene	Pliocene
Quaternary	End Pliocene to present day

The pre- and intra-Karoo erosion surfaces appear to have had little effect on present day topography. The Gondwana cycle commenced with the erosion of the basalts of Jurassic age. Although ultimately a largely well-planed surface there was a high ridge at the present Mount Inyangani in the Inyanga District on the eastern border.

The break up of Gondwanaland towards the end of the Jurassic created a new base level and initiated the post-Gondwana erosion cycle. During this cycle late Jurassic to early Cretaceous sediments were laid down in a basin in the Gokwe District, in the north-east, and in early to middle Cretaceous in the south-eastern part of the country. Faults in both the north-west and south-east parts of the country emphasized the already developing Zambezi and Limpopo river systems.

Crustal warping created a new base level and initiated the African erosion cycle. By early Tertiary times the land surface had been eroded to an altitude of approximately 600 metres. The ridges on the eastern border, the northern part of the Great Dyke and isolated hills such as Mount Hampden, north-west of Salisbury remained as remnants of the post-Gondwana surface. In the south, resistant pre-Karoo masses were stripped of their Karoo cover and stood up as inselberge in the flat plain. These were the prelude to the modern Mount Buhwa and Belingwe mountains. As the surface reached senility, disturbance due to erosion of the vast pediplain was minimal and bauxites formed in the eastern areas and calcretes in the west.

At the end of the Oligocene, gentle uplift of the African continent caused the post-African erosion cycle. At the same time warping gave rise to a basin in the mid-Zambezi region thereby imparting a westerly tilt to the existing African surface.

During the Miocene period and probably extending into the Pliocene, the Kalahari aeolian sands were deposited over the western half of the country covering the African and post-African erosional surfaces. At the end of the Miocene, major movements initiated the Pliocene erosion cycle across most of Africa. Uplift affecting Rhodesia was along the line of the Eastern Highlands which were once again raised in elevation. Erosion commenced to cut back into the pre-existing surfaces up the now established Zambezi and Limpopo valleys where the erosion of the loose aeolian sands further modified the river courses.

About four million years ago in the Pliocene-Pleistocene period, major uplift along the north-easterly axis of the present day watershed brought the earlier land surfaces to their present elevation and launched the Quaternary erosion cycle. This has modified much of the coastal regions of Africa but insufficient time has elapsed for there to have been a marked effect on the continental interior. Erosion is limited to deep gorges of rejuvenated rivers. Upstream from the penetration of the erosional cycle a number of rivers underwent a marked reduction in their carrying capacity and thick deposits of alluvium such as that in the Sabi Valley, were laid down.

All of the various erosional cycles have been recognised in the Eastern Highlands. Mount Inyangani and World's View in the Inyanga District display the Gondwana and post-Gondwana surfaces above the rolling African erosion level. The flat plain with inselberge to the north of Inyanga is the post-African surface which gives way northward to the rugged dissected country of the Pliocene erosional level. The Pungwe Falls and gorge are reflections of the rejuvenation caused during the Pliocene period. The Honde Valley, at only 600 metres above sea level represents the Quaternary erosion level which cuts back to the base of the surrounding scarps below the Pliocene surface.

From Inyanga through Marandellas and south-west to Umvuma and Bulawayo with a small off-shoot from Marandellas to Salisbury, the present day main watershed is all that remains of the African planation. The country is rolling, often flat, with inselberge or ranges of pre-Karoo residual masses such as the Mwanesi Range at Featherstone.

Off the watershed to the north-west and south-east the dissected post-

African surface occupies large tracts of ground and the flat low-veld areas in the Zambezi and Limpopo valleys are on the extensive Pliocene erosional surface.

SOILS

In all parts of Rhodesia the majority of the soils bear a very close relation to the underlying rocks, and are classed as "immature soils" by soil scientists. Mature soils owe their particular characters to climatic and ecological conditions and are largely independent of the rocks beneath. It is only in flat ground where erosion is least active that Rhodesian soils tend towards maturity.

In the process of weathering, feldspar, augite and other mafic minerals alter to clays, whitish from feldspar and deep red from the other minerals. Quartz on the other hand does not react chemically, but goes slowly into solution.

Two biological influences play parts in the formation of soil.

The material of which the soil is made is selected by visible organisms, comprising, besides vegetation which supplies the humus, ants, termites and other burrowing insects, and in moister ground earthworms. These animals perpetually spread new layers of mineral substances on the surface. They work throughout the year, but mainly in the wet season.

In burrowing, different kinds of insects make their own selection of the material they move to the surface. Some prefer clay and others prefer sand or small stones, and so they exercise an ecological influence upon the character of the soil produced.

Between the weathered rock and subsoil there is nearly always a thin bed of angular rubble, to which stones gravitate downwards as the result of the removal of mud from beneath them.

Micro-organisms, particularly bacteria, exert a biochemical influence breaking down the mineral substances to colloids and salts, which are essential plant foods. The presence of these distinguishes soil from rock waste.

It is the first of these influences which leads to the very close local connection between the surface soils and the bedrock.

The chemical processes vary with the average temperature and rainfall. Over the greater part of the country the climate is too dry for much silica to be dissolved before erosion sets in, and sand accumulates in the soil of granite areas. These soils vary a good deal from pale yellowish-grey to light reddish-brown, the colour depending partly on the composition of the original granite and partly on the degree of maturity which has been reached. The redder granite soils form most of the good tobacco lands.

In the greenstone country the soil formed under the same climatic conditions is the thick dark-red clay of the maize lands. In the eastern mountains, where the rainfall is heavy, silica and soluble salts are removed in solution and the oxides of iron and alumina accumulate to form lateritic soils. Bauxite (aluminium ore) may be formed by this process where the circumstances are favourable. This mineral was worked north of Penhalonga in Mozambique within a few hundred metres of the Rhodesian border, but it has not yet been found in economic quantity in Rhodesia. Iron oxide tends to accumulate by the same process in other parts of the country and was smelted for iron in early times.

The Kalahari Beds give rise to very loose sandy soils which carry important forests of indigenous timber. Where the bush has been cleared these soils have excellent moisture-holding properties, being well drained. They grow good crops for a year or two, but fertility rapidly falls off, giving rise to a great problem in areas of African resettlement. Erosion is also a serious menace in cleared areas.

As the soil becomes more mature in drier conditions clays accumulate giving rise to the familiar black vlei soils of many areas. Beneath this soil limestone separates as nodules or consolidates into a bed which is dug and burned for lime.

An important mineral deposit which must be mentioned under this head is eluvial gold which may be concentrated in the subsoil rubble overlying mineral deposits, and is mined and crushed as an easy source of ore. In some places no deposits of workable grade have been found in the rock below, but the outputs are declared from mining claims and are not separately recorded.

Table III

RHODESIAN MINERAL PRODUCTION AND VALUE
(to 31st December, 1965)

Mineral or metal	*Production tonnes**	*Declared value Rh. $*	*Current market value $×1 000*
Antimony . . .	21 257	406 366	6 377
Arsenic	15 962	377 208	2 394
Asbestos . . .	3 235 375	297 608 928	808 844
Barytes	14 208	87 262	355
Beryl	11 011	2 374 912	1 652
Chrome	14 726 987	118 894 660	456 537
Coal	92 953 097	126 696 798	836 577
Copper (metal) . .	171 863	57 269 998	103 118
Corundum . . .	44 725	642 606	895
Diamonds . . .	15 957	152 362	—
Fire-clay . . .	360 411	190 058	396
Fluorspar . . .	4 500	31 878	72
Gold	38 980 924	562 108 088	3 508 283
Iron-ore	4 998 780	5 233 192	21 495
Kyanite	1 514	8 674	22
Limestone . . .	12 295 906	6 047 478	12 296
Lithium ores . .	724 273	7 448 584	21 728
Magnesite . . .	254 212	868 990	3 051
Mica	7 593	3 435 256	7 593
Nickel (conc.) . .	10 381	755 826	5 398
Phosphates . . .	29 519	386 336	590
Pollucite . . .	197	31 978	39
Quartz	191 439	249 134	479
Silver	8 749 441	3 013 976	25 373
Tantalite . . .	692	1 666 148	10 380
Tin-metal . . .	5 375	8 727 832	32 250
Tin (conc.) . . .	5 987	2 859 576	—
Tungsten . . .	7 033	5 566 806	42 192
		1 213 140 910	5 908 386

* Gold and silver: ounces, troy
Diamonds: metric carats

Table IIIA

ZIMBABWEAN MINERAL PRODUCTION AND VALUE
(1st January, 1966, to 31st December, 1979)

Mineral or metal	*Production tonnes**	*Declared value Z.$*
Antimony	4 495	1 751 418
Arsenic	1 887	148 947
Asbestos	3 110 914	485 545 767
Barytes	22 227	360 022
Bauxite	19 599	224 228
Beryl	1 871	352 407
Chromite	8 806 476	155 262 792
Coal	41 229 269	192 003 417
Copper (metal)	485 368	360 484 752
Corundum	86 968	1 702 867
Diamonds	3 604	25 368
Fireclay	214 374	301 549
Fluorspar	7 899	107 327
Gold	178 418	368 389 988
Graphite	72 050	3 257 239
Iron-ore	13 777 222	42 569 123
Kyanite	61 676	874 547
Limestone	14 922 200	25 625 042
Lithium (minerals)	329 717	7 826 376
Magnesite	1 263 022	14 933 250
Mica	55 705	1 061 496
Nickel (metal)	125 210	281 729 144
Nickel (conc.)	6 885	668 056
Phosphate	1 541 471	30 267 263
Pollucite	702	128 662
Pyrites	912 586	4 915 199
Quartz	1 835 206	5 171 931
Silver	142 175	14 984 778
Tantalite	360	2 487 307
Tin (metal)	13 635	54 731 264
Tin (conc.)	344	820 683
Tungsten (conc.)	4 256	13 871 761
Other minerals	—	27 835 955
		2 100 419 925

* Gold and silver: kilograms
Diamonds: metric carats

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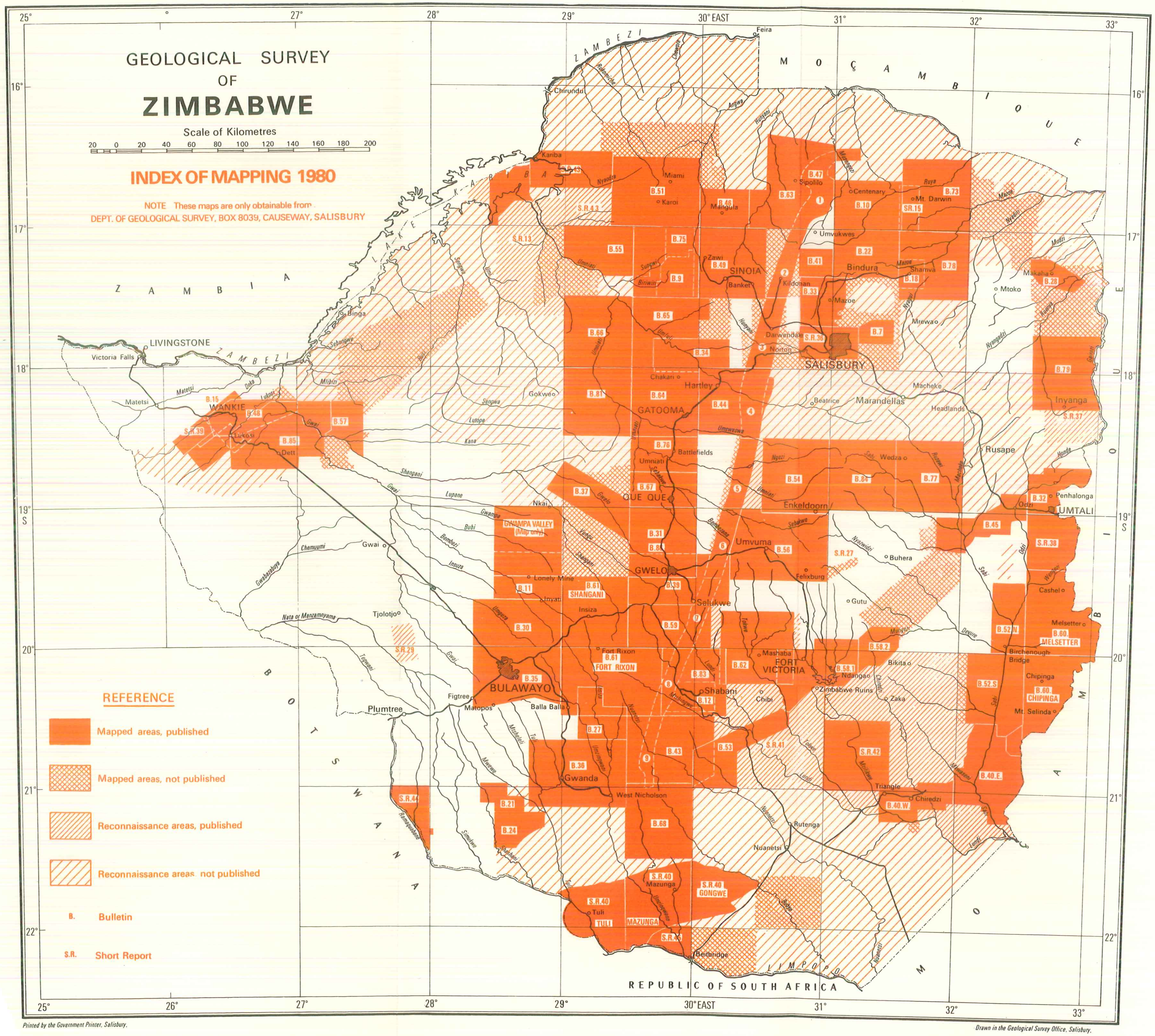
GEOLOGICAL SURVEY
OF
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Scale of Kilometres
20 0 20 40 60 80 100 120 140 160 180 200
INDEX OF MAPPING 1980
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Reconnaissance areas not published
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S.R. Short Report
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