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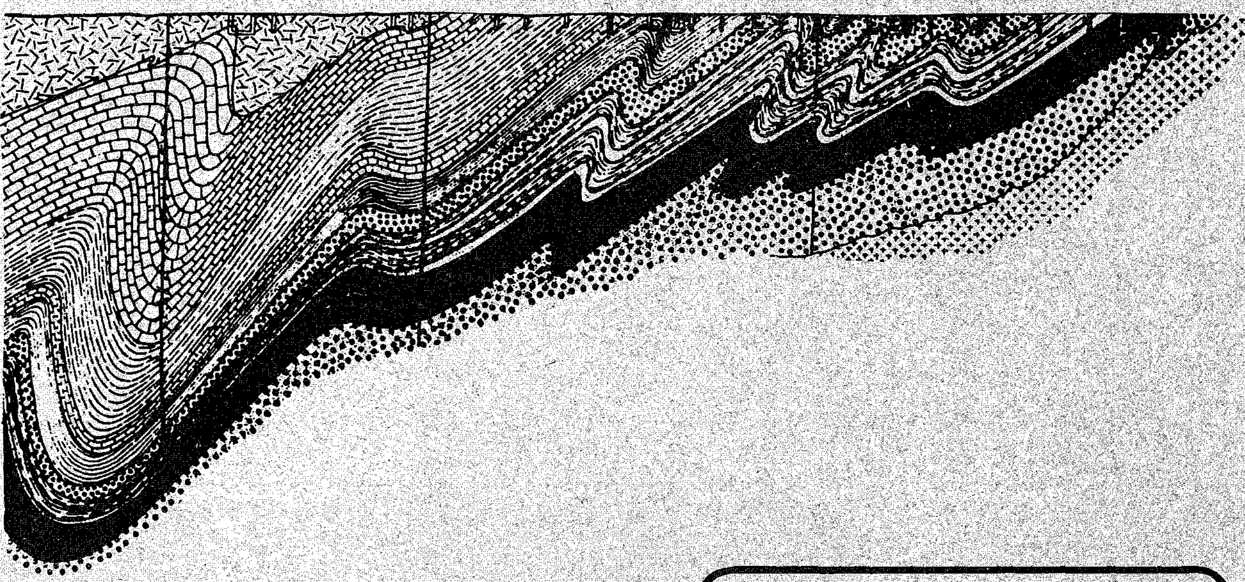

ECONOMIC GEOLOGY

RESEARCH UNIT

UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

THE GEOLOGY OF THE SOUTH RAND GOLDFIELD

by

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THE GEOLOGY OF THE SOUTH RAND GOLDFIELD

ABSTRACT

The South Rand Goldfield is one of the two minor fields which, together with the seven major gold-producing areas, are located within the Witwatersrand Basin. It is contained in the area between the Sugarbush Fault and the Vaal River and acts as host to the southeasternmost exposures of the Witwatersrand System within the confines of the basin. The nearest gold producers are the Witwatersrand Nigel Mine, in the East Rand Basin, 26 miles to the northwest of the centre of the South Rand Goldfield, and the Bracken Mine, in the Kinross Goldfield, 29 miles to the northeast. Five gold mines - Edenkop, Kildare, Heidelberg-Roodepoort, Southeast Witwatersrand and Hex River - have been intermittently active in the 75 years since gold was first discovered at the Heidelberg-Roodepoort Mine in 1887.

All members of the Witwatersrand System are present in the area, but in a much attenuated form, thinning progressively southeastwards from the East Rand Basin, through Heidelberg, so that in the extreme south of the area, at the Hex River Mine, they have the following thicknesses : Hospital Hill Series - 2000 feet; Government Reef Series - 2500 feet; Jeppestown Series - 800 feet; Main-Bird Series - 800 feet; Kimberley-Elsburg Series - 1100 feet. The Lower Division is thus 5300 feet thick in this locality, and the Upper Division 1900 feet, making a total thickness of the Witwatersrand System of 7200 feet. In the northernmost portion of the area the Lower and Upper Divisions are 8900 and 4700 feet thick respectively, and the System as a whole 13,600 feet thick. The Witwatersrand strata are overlain by amygdaloidal, porphyritic and massive andesitic lavas of the Lower Series, and tuffs, thin lavas, and sediments of the Middle Series of the Ventersdorp System. Above these again are the Black Reef and Dolomite Series of the Transvaal System, and the Middle Stage of the Ecca Series of the Karroo System. Underlying the Witwatersrand System are the Old Granite and the Moodies Series of the Swaziland System, the arenaceous members of which have been mistakenly ascribed in the past to the Orange Grove Quartzites at the base of the Witwatersrand System.

Conglomerates in the South Rand area are substantially lesser in number and extent than in the goldfields to the north, and in the whole System there are only two which contain economic quantities of gold. There are no payable reefs in the Main Stage, none in the Bird Stage, only one in the Kimberley Stage, and none in the Elsburg Stage of the Upper Division. The Ventersdorp Contact Reef, if present, at the base of the Ventersdorp System, has not been shown to carry economic values of gold. Many

persistent auriferous conglomerate horizons recognized over extensive areas in other goldfields, such as the Main Reef Leader (Nigel Reef) at the base of the Main Stage in the East Rand Basin, are not developed at all in the South Rand area. An anomalous feature of this area, when compared with the Central Rand, East Rand and Kinross goldfields, is the development of economic banket on the Coronation Reef horizon of the Government Reef Series. This is the only instance outside the Klerksdorp Goldfield where this reef has been successfully exploited. Intensive prospecting operations over an area of about 1900 square miles have failed to reveal any deposits of gold other than those contained in three narrow payshoots in the Kimberley Reef in four mines and one payshoot in the Coronation Reef in one mine south of the Sugarbush Fault.

The area has suffered considerable deformation in the form of folding and faulting that resulted from two stress fields in which compression was in a more-or-less horizontal plane, and a stress field where vertical forces were operative. Two sets of folds are present with axial plane traces trending N 50° W and N 30° W, and these can be correlated with the longitudinal and transverse folds recognized in the East, Central and West Rand areas, and in the Vredefort Dome locality. The interference of the fold systems has given rise to a series of structural culminations and depressions which, in turn, have produced the two regional synforms and two regional antiforms that control the distribution and preservation patterns of all pre-Karroo rocks in the area. The axes of these structures trend north-north-westwards and the regional plunge is in the same direction, resulting in a large mass of granite and Swaziland rocks terminating the South Rand area to the south and southeast. On the north the boundary of the area is formed by the impressive Sugarbush Fault, a displacement which has a general east-north-easterly strike, is of the normal type, and has a downthrow to the south of up to 16,000 feet. A very considerable area of development of Witwatersrand rocks has been preserved from erosion because of this fault which is one of a series of conspicuous normal, and attendant antithetic, faults that follow parallel, sinuous courses, the latter characteristic being the result of bending of these relatively early fault planes about the axes of the transverse folds. These and two other groups of normal faults are considered to be the products of the vertical stress field, while the remaining thrust and wrench faults, which abound in the area, can be satisfactorily assigned to the two horizontal stress fields.

The systematic thinning and wedging-out to the southeast of all members of the Witwatersrand System is taken to indicate an original limit to the basin in this direction. However, the pattern of facies change and the direction of transport of sedimentary fill, as indicated by cross-bedding azimuths, render it doubtful whether any material was contributed to the basin along this original shoreline south of the present Vaal River. It was a shoreline which simply marked the edge of the depository against a static landmass which was not undergoing vertical uplift and consequent erosion. If these latter features were operative, then they were restricted to very early Witwatersrand times when auriferous material to form the locally significant Coronation Reef might have been derived from the southeastern shoreline.

Regional and local evidence suggests a close relationship between sedimentological and structural features. Deformation according to patterns which persisted to at least post-Transvaal times was active during the processes of sedimentation, and folding between cycles of sedimentation led to synclinal downwarps forming topographic troughs in which thicker accumulations of sediments took place. Material was transported down these synclinal troughs and spilled over the flanking, parallel anticlinal ridges. Thicker developments of conglomerates and greater accumulations of gold took place in these long, narrow troughs, and hence payshoots are parallel to cross-bedding azimuths and to fold axes.

Sedimentological data also show that the South Rand Goldfield was formed in the half of the basin opposite to the northwestern rim. What is thought to be the central axis of the original depository runs through the area, indicating the considerable distance over which the small amounts of gold present have been transported. Facies changes point to the transporting currents having had low velocities and load capacities by the time the centre of the basin was reached, and therefore having been incapable of bringing into the southeastern half of the basin any substantial quantities of coarser material and heavy minerals. The area lay at too great a distance from the active edge of the depository for it to have any greater potential than has been indicated in the past by the meagre amounts of gold produced. A total of 45,786 ounces of gold has been recovered from 268,000 tons of ore crushed by five small mines and one prospect to give an average recovery grade of 3.42 dwts. per ton. This amount represents only 0.007 per cent of all gold produced in the Witwatersrand Basin.

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THE GEOLOGY OF THE SOUTH RAND GOLDFIELD

INTRODUCTION

Contained within the Witwatersrand Basin are seven major goldfields - Orange Free State, Klerksdorp, West Wits Line, West Rand, Central Rand, East Rand and Kinross - and two minor fields, Vredefort and South Rand. The basin has a roughly arcuate shape, concave to the southeast, with the northwestern margin being formed by a granite ridge containing the Johannesburg Dome. To the southeast of the ridge lies the Potchefstroom Synclinorium and this, again, is followed by a relatively elevated structure containing the Vredefort Dome. All the important mining areas are located on the northwestern limb of the synclinorium, while both the minor goldfields are on the southeastern limb. The source of the material which filled the basin lay to the northwest, and thus the Vredefort and South Rand fields were formed in the centre or near the southeastern margin of the depository, and well away from the original shoreline, near the northwestern granite ridge, where optimum conditions for gold concentration prevailed.

The contribution which the minor goldfields has made to production from the Witwatersrand Basin is meagre to the point of being almost negligible. Only a few small mines have been sporadically, and generally uneconomically, active at Vredefort and the South Rand during the past 75 years, but both areas have witnessed extensive surface and subsurface prospecting operations. As a result, considerable geological information has been accumulated, and this has aided in the understanding of the geology of the Witwatersrand Basin to an extent out of all proportion to the economic importance of the areas.

A. LOCATION OF SOUTH RAND GOLDFIELD

This field is the eastern one of the two minor goldfields and lies approximately 100 miles east of the main workings on the western flank of the Vredefort Dome. Four dormant mines - the Kildare, Heidelberg-Roodepoort, Southeast Witwatersrand and Hex River - constitute the actual South Rand Goldfield. The Kildare and Heidelberg-Roodepoort mines adjoin each other and represent the northeastern extremity of the field. Ten miles to the south-south-west are the Southeast Witwatersrand and Hex River mines which have a common boundary and which form the southern extremity. No mines or prospects exist between the above two groups of mines, but the reef horizon is, for the most part, either covered by younger formations or faulted out, and there is no evidence of any attempts to test the potentialities of the greater part of the gap. The centre of the mining area lies 57 miles southeast of Johannesburg, 31 miles southeast of Heidelberg, 50 miles east-south-east of Vereeniging and 34 miles south-south-west of Kinross (see Fig. 1). The nearest important gold producers are the Witwatersrand Nigel Gold Mine, 26 miles to the northwest at the southern extremity of the East Rand Basin, and the Bracken Gold Mine, 29 miles to the northeast in the centre of the Kinross Goldfield. The Heidelberg-Roodepoort Mine is located approximately at longitude 28°46'E. and latitude 27°47'S., and has an elevation of about 5300 feet above sea-level.

The South Rand forms part of a large tract of country in which rocks of the Witwatersrand System outcrop at irregular intervals between the southern limit of the East Rand Basin and the northern limit of the extensive, uninterrupted cover of the Karroo System which spreads into the Orange Free State and Natal. One other gold producer - the Edenkop Gold Mine - and three prospects once existed outside the limits of the actual South Rand Goldfield, but within this area, which also acted as host to numerous prospecting ventures at various periods in the past. This paper deals with the geology of the whole of the area which is contained between the Sugarbush Fault in the north and the Vaal River in the south and between the eastern- and westernmost exposures of the Witwatersrand System. The boundaries of the area and the location of the actual South Rand Goldfield within the area are shown in Fig. 1.

The area measures approximately 57 miles east-west and 34 miles north-south, and covers about 1900 square miles. The New Springfield Colliery at Grootvlei is situated to the north of the centre of the area, while the main collieries of the Vereeniging Coalfield - Cornelia, Sigma and Coalbrook - lie within 10 miles of the western boundary. The South Rand Goldfield occupies the central eastern portion of the area, while the New Rand Locality, the scene of intensive prospecting operations prior to the 1920's, is located towards the southwestern corner. Balfour, the largest town in the area, is 18 miles southeast of Heidelberg. The only other settlement in the Transvaal is the village of Greylingstad, a further 12 miles in the same direction. Villiers, in the Orange Free State, is 22 miles southwest of Greylingstad, and between these two villages is the South Rand Goldfield. Twenty-five miles west of Villiers is Oranjeville, situated on the western boundary of the New Rand Locality. Deneysville is 10 miles northwest of Oranjeville, both of these villages also being in the Orange Free State. The main Johannesburg-Durban railway line runs through the northeastern corner, the Balfour-Frankfort line through the central portion, and the Vereeniging-Grootvlei line through the northwestern corner of the area.

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Physiographic features shown on the geological and structural maps (Figs. 2, 3 and 4) which accompany this paper are based on Sheets 2628 East Rand and 2728 Frankfort of the 1 : 250,000 Topo-Cadastral Series of the Republic of South Africa. According to these sheets, the mines and prospects in the area are located on the following farms:

Edenkop G.M.	-	Rietbult Estates	505
Wilgepoort Prospect	-	Rietfontein	561
Heidelberg-Daspoort Prospect	-	Daspoort	564
Phoenix Prospect	-	Witpoort	565
Kildare G.M.	-	Roodepoort	598
Heidelberg-Roodepoort G.M.	-	Roodepoort	598
Southeast Witwatersrand G.M.	-	Hexrivier	634
Hex River G.M.	-	Hexrivier	634
Oceana Transvaal Colliery	-	Modderfontein	410
New Springfield Colliery	-	Grootvlei	453

Various names have been attached to the area since gold was first discovered in 1887. A map accompanying the Annual Report of the Transvaal Chamber of Mines for the year 1893 labelled the portion of the area stretching from the Heidelberg-Roodepoort Mine, through the Edenkop Mine, to the town of Heidelberg as the South Heidelberg Goldfield. The Molyneux, Rose Reef, Molyneux West, and the present Witwatersrand Nigel mines, all north of the Sugarbush Fault, were included in this goldfield, but the Hex River Mine was not considered to fall within the boundaries. Sawyer (1904) called the area embracing De Kuilen, Witkleifontein, Grootvlei, Rietvlei, Rooiwal, the Hex River Mine and the Heidelberg-Roodepoort Mine the South Rand Goldfield (see Fig. 2). The locality subjected to intensive core-drilling from Lepelkop to Oranjeville and southwards up the Wilge River in the Orange Free State was referred to as the New Rand Goldfield by Sawyer (1907), despite the fact that no payable gold was ever found in the locality. Subsequently, the name Balfour-Greylingstad Goldfield was applied to the Heidelberg-Roodepoort and Hex River localities, which were, still later, to be called the Southern Gold Area (Sharpe, 1956). Borchers (1961) discussed the mining activities as having taken place in the Balfour Area.

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B. HISTORY OF PROSPECTING AND MINING

(a) The Period 1886 - 1902

The discovery of the Main Reef Leader at the end of March, 1886, on the farm Langlaagte near Johannesburg on the Central Rand started a search for auriferous conglomerates wherever rocks of the Witwatersrand System outcropped. Prospecting soon extended to Heidelberg and beyond to Greylingstad where the discovery of gold on Roodepoort 598 and Hexrivier 634 by persons whose names are unrecorded led to the official proclamation of these farms as goldfields in March and September, 1887, respectively.

The Nooitgedacht Company prospected the Hex River discovery up to 1889 and then abandoned the property without, apparently, any gold having been produced. In August of the same year the Heidelberg-Roodepoort Gold Mining Company Ltd. was formed with a working capital of £10,000. Without doing any extensive work, this company held the ground until February, 1892, when it was tributed to the South African Trust and Finance Company which produced the first gold in the area, but at a substantial loss. In January, 1893, the New Heidelberg-Roodepoort Gold Mining Company was formed to take over the mine and by February, 1894, had sunk a main shaft to an inclined depth of 510 feet, plus three subsidiary inclined shafts. These operations exhausted the financial resources of the company and in April, 1895, it was taken over by the Johannesburg Consolidated Investment Corporation which, with a working capital of £93,000, sank two further inclined shafts, traced the reef along the outcrop for 1200 feet, and started treating, in the plant shutdown in 1892, the old dumps and ore from the surface to the 200 foot-level. On October 10, 1896, a new battery of 40-stamps was opened and, despite being struck by lightening and temporarily closed down on October 20, crushed 13,000 tons of ore by the end of the year. By October, 1897, the payable ore reserves had been depleted and no further production took place before the mine closed down completely on the outbreak of the Anglo-Boer War in 1899.

The Hex River Mine was repegged in August, 1895, by the Hex River Exploration Company, but no gold was produced up to the end of 1902. In May, 1895, the Heidelberg-Daspoort Syndicate completed an inclined shaft to 95 feet on the prospect of the same name which was abandoned because of the absence of any significant mineralisation. The Kildare G.M. Company also came into being in the same year, but no ore was mined on this property. In 1896 an inclined shaft was put down to a depth of 413 feet on the Phoenix Prospect without encountering any payable reef. The

Greylingstad G.M. Co. was formed in 1897 to work the deep-level extensions of the Heidelberg-Roodepoort Mine below 2000 feet, but nothing concrete came of these intentions.

In 1895, A.R. Sawyer started, in the South Rand area, the first large-scale, systematic exploration program by means of diamond-drilling in the Witwatersrand Basin. Borchers (1961) described this undertaking, plus later work in the New Rand Locality, as "the beginning of the search for the continuations of the edge of the basin, under the Karroo, southwards into the Orange Free State". Sawyer, who had been on the Witwatersrand since 1889 and was a former Government Inspector of Mines, formed a partnership with J. Heath to work the South Rand coal deposit which was later to become the New Springfield (Grootvlei) Colliery. The profits were transferred to the South Rand Gold Corporation Ltd. for the purpose of carrying out a diamond-drilling program to search for the Witwatersrand reefs under a cover of Ventersdorp lavas and Karroo sediments. A total of 21 boreholes between the Sugarbush Fault and the Vaal River - shown on Fig. 2 as the SR. series - was drilled up to July 3, 1899, when prospecting operations were suspended because of the imminence of war between the South African Republic and Great Britain. All the cores were preserved, but during the war the core-trays and the core-sheds were used for firewood by the belligerents and the cores themselves were scattered and lost.

The South Rand Colliery and the Perserverance and Oceana Transvaal properties, which were all producing by 1895, were among the earliest coal mines opened up in the Transvaal.

(b) The Period 1903 - 1918

Some time was to elapse after the end of the Anglo-Boer War before mining operations were restarted, and it was not until 1906 that the Bon Accord Syndicate, tributing from the New Heidelberg-Roodepoort G.M. Co. Ltd., commenced production from this property again. Between this date and 1910 the mine reached the peak of its life. In the following year, the syndicate sold out to the New Heidelberg-Roodepoort Tribute which produced during 1911 and 1912 and then closed down the mine, again because of the inability to establish adequate ore-reserves.

The Hex River Exploration Co. Ltd. produced gold from their property from 1911 to 1913, shutting down before the outbreak of World War I. Very small amounts of gold were produced during 1908 and 1909 by Kildare Gold Mine Ltd. from their property adjoining the Heidelberg-Roodepoort Mine, and

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during 1913 by the M.C. Tribute from the Wilgepoort Prospect. Between 1906 and 1908 the Edenkop Syndicate tributed the Edenkop Mine from Coronation Syndicate and Rietbult Proprietary Mines Ltd., and produced gold from a relatively rich payshoot which terminated at a shallow depth against a branch of the Sugarbush Fault. The considerable vertical displacement on this fault prevented any mining operations from taking place thereafter.

Drilling operations during this period were conducted almost entirely by Sawyer, but, in addition, at least four other holes were put down, DMR.1 in 1904 by the Daspoort Main Reef Company at the Heidelberg-Daspoort Prospect, RB.3 and 7 in 1904 by Rietbult Proprietary Mines Ltd. at the Edenkop Mine, and WP.1 in 1910 by South East Africa Ltd. at the Wilgepoort Prospect. It is possible that boreholes other than the two mentioned above were drilled by Rietbult Proprietary Mines Ltd., but there is no record of their location.

Sawyer and Heath could not raise enough money from their coal mining operations to resume the South Rand drilling program immediately after the Anglo-Boer War. However, in 1912 they were able to form a new company, the South Rand Exploration Company Ltd., and between this date and 1917 five more holes in the SR series were drilled, but no information is available concerning their positions or the formations encountered. The total number of holes drilled by Sawyer in the South Rand area thus amounted to 26.

In 1903 Sawyer embarked on another venture - an intensive drilling program in the Orange Free State at the junction of the Vaal and Wilge Rivers. The reasons for selecting this so-called New Rand Goldfield for detailed investigation were identical to those which started the South Rand project. Two conspicuous outcrops of south-dipping, massive quartzites occur at Vaalrand and Lepelkop (see Fig. 2). Both of these were mistakenly identified as Orange Grove Quartzites, and Sawyer, firmly believing that the conglomerate reefs were always better gold carriers where they dipped south, drilled south of these ridges which have subsequently been classified as Moodies quartzites of the Swaziland System. Boreholes SR.1, 2 and 3 went into granite beneath the Karroo cover and the South Rand program was changed immediately, drilling thereafter being restricted to localities where Upper Witwatersrand rocks were exposed. However, in the case of the New Rand holes, Witwatersrand strata were intersected beneath the Karroo and mistakenly logged as belonging to the Main-Bird Series of the Upper Division. It would now appear that the holes were drilled into members of the Hospital Hill and Government Reef Series of the Lower Division. Under this incentive, drilling operations were intensified and by the end of 1907 boreholes NR.1, 2, 4, 5, 6 and 7 had been completed on Hartebeestfontein and NR.3 on Schaapkraal. In none of these were any payable intersections of reef made,

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but this did not deter Sawyer, and by the end of 1910, NR.8, 9, 10, 11, 12 and B had been drilled on Nooitgedacht and NR.13 on Hartebeestfontein. All these holes are shown in Fig. 2. A further 9 holes NR.14 - 22, were completed on Knoppiesfontein by the end of 1917. No records of these holes are available, but they must have been sited in the vicinity of Boreholes OV.1 and OV.2 drilled much later and shown on Fig. 2. There is no evidence to show that any encouraging values were obtained in any of Sawyer's holes and hence the name New Rand Goldfield for this locality is not justified.

The South Rand Colliery was still being worked by the partners in 1917 and was producing about 400,000 tons of coal per year. As World War I drew to a close, Sawyer seems to have disappeared from the scene, leaving behind 48 boreholes drilled over 23 years in a program that must rank as one of the most historically important efforts in the exploration of the Witwatersrand Basin.

(c) The Period 1919 - 1932

Mining and prospecting activities came to an almost complete halt in the South Rand area in the years between World War I and the Depression. In 1921 - 22 the Alwado Syndicate produced a very small quantity of gold from retreating the old dumps at the Heidelberg-Roodepoort Mine. An even smaller amount came from similar operations by private individuals at the same mine in 1930 - 31.

(d) The Period 1933 - 1945

South Africa's departure from the gold standard at the end of 1932 revitalised the gold mining industry and interest was again shown in the South Rand area. The Heidelberg-Roodepoort Mine was brought back to production in 1938 - 39 by the Greylingstad Gold Recovery Syndicate and mining operations were continued up to 1942 by the Goedehoop Maatskappy. The adjoining Kildare Mine was acquired by the East Nigel G.M. Company which tributed it, for two years of production in 1941 and 1942, to the Day Dale Mining Co. (Pty.) Ltd. To the south, the Hex River Mine was worked by New Rand Reef Ltd. in 1935, by Phoenix Reefs (Pty.) Ltd. in 1936 and 1937, and by the Last Hope Mine in 1939 and 1940. A new mine adjoining the Hex River Mine was exploited by the South East Witwatersrand Gold Mining Co. Ltd. from 1935 to 1938.

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Geophysical exploration was first applied in the area in 1934 when the Elbof Geophysical Prospecting Co. Ltd. carried out a magnetometric survey for Coronation Syndicate in the De Kuilen - Witkleifontein locality. Following on the survey, four boreholes, COR.1 - 4, were drilled by Coronation Syndicate in 1935, but no payable reefs were located. Another drilling program was put into affect in 1934 by East Witwatersrand Gold Mining Areas Ltd., resulting in the completion of EWG.1 at the Hex River Mine, RTV.1 and 1A in the Rietvlei locality, RWL.1, 1A and 2A in the Rooiwal locality, and NS.1 southwest of Nurney Hill (see Fig. 2). The results did not encourage any further prospecting. Klip Nigel Estate and G.M. Co. Ltd. drilled KN.3 adjacent to the Sugarbush Fault in 1935, and in the same year Boreholes L.1 and R.1 were put down at the Heidelberg-Roodepoort Mine by the East Nigel G.M. Company. The drilling marked the end of the surge of prospecting induced by the increase in the price of gold. No new deposits had been discovered in the South Rand area and the importance of this section of the Witwatersrand Basin appeared virtually negligible.

(e) The Period 1946 - 1962

At the end of World War II the earlier discoveries of significant gold mineralisation in the Odendaalsrus area of the Orange Free State prompted a resumption of prospecting in Sawyer's New Rand Locality. The O.F.S. Prospecting Syndicate drilled OV.1, OV.2 and AB.1 in 1946 and 1947, and proved the presence of Upper Witwatersrand rocks below the Karroo System. However, no economic auriferous conglomerates were present in the borehole intersections. The area between Fortuna and the Hex River Mine was acquired in 1946 by Coronation Syndicate and Eastern Holdings, then both subsidiaries of New Union Goldfields Ltd., which group drilled RDP.3 at the Heidelberg-Roodepoort Mine in 1948.

In 1953 the South Rand Goldfield was taken under option by Mineral Search of Africa (Pvt.) Ltd., an exploration subsidiary of the Rio Tinto Group, and 18 boreholes were drilled up to February 14, 1956, when the project was abandoned due to the lack of encouraging results. The area between the South Rand and Kinross goldfields was investigated by General Mining and Finance Corporation in 1956, but the holes WAK.1, HGF.1, KS.1 and KST.1 and 2 failed to reveal the presence of the Upper Division of the Witwatersrand System.

In this post-World War II period only the Hex River Mine was worked, the others all remaining dormant. South Geduld Gold Mines Ltd. produced in 1946 and 1948, and Doravale Investments (Pty.) Ltd. in 1961 and 1962, the latter company being responsible for reworking old dumps only.

C. SOURCES OF INFORMATION

The surface geology of the area south of the Sugarbush Fault, as shown in Fig. 2, has been compiled from three maps prepared by the Republic Geological Survey :

(i) a geological map of the country around Heidelberg, surveyed by A.W. Rogers, A.K. Parrott and L.T. Nel in the period 1918 - 1921 (Rogers, 1922)

(ii) Sheet 62, Vereeniging, surveyed by L.T. Nel in 1922, 1925 and 1934, H. Jansen in 1946 - 1948, and A.W. Rogers in 1918 - 1921 (Nel and Jansen, 1957)

(iii) an unpublished series of field sheets of the area between Fortuna and the Hex River Mine surveyed by A. Leube, K.E. Schalk and A.A. Snyman in the period 1953 - 1956.

Local detail has been filled in from geological maps prepared by the Elbof Geophysical Prospecting Co. Ltd. in 1934 of the De Kuilen-Witkleifontein locality, and by Mineral Search of Africa (Pvt.) Ltd. in 1956 of the Rietvlei - Stryfontein - Kildare - Hex River locality. In other instances modifications in the generalised geology have been made by incorporating information brought to light by diamond-drilling operations.

The positions and histories of mines, prospects and boreholes have been established from :

(i) reports by A.R. Sawyer (1904, 1907 and 1917) on the investigations in the South Rand and New Rand localities

(ii) the geological map of the Heidelberg area prepared by Rogers (1922)

(iii) maps and drilling records prepared by the Elbof Geophysical Prospecting Co. Ltd. in 1934 for the De Kuilen-Witkleifontein locality.

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(iv) maps and generalised borehole logs compiled by B.V. Carmichael (1952)

(v) maps, sections and detailed logs prepared by Sharpe (1956) for the South Rand Goldfield

(vi) the paper written by R. Borchers (1961) on the history of exploration within the Witwatersrand Basin

(vii) records in the Government Mining Engineer's office in Johannesburg.

Data on folding presented in Fig. 3 have been obtained from :

(i) the published and unpublished maps of the Geological Survey

(ii) field work carried out in 1961 and 1962 by M. J. Mountain for the Economic Geology Research Unit, University of the Witwatersrand

(iii) field work carried out by the writer in 1963.

The pattern and history of faulting, as shown in Fig. 4, were determined from :

(i) the published and unpublished maps of the Geological Survey

(ii) a study of borehole logs obtained from Sawyer's publications and from Mineral Search of Africa (Pvt.) Ltd.

(iii) field work carried out by M. J. Mountain in 1961 and 1962

(iv) field work undertaken by the writer in 1963

(v) a photogeological study of linear features and drainage patterns carried out in 1963 by the writer.

Sedimentological data contained in Figs. 3 and 5 were derived from :

(i) reconnaissance studies carried out by R. B. Hargraves (1962)

(ii) detailed field work by M. J. Mountain in 1961 and 1962 between Heidelberg and Balfour

(iii) detailed field work undertaken by the writer in 1963 in the South Rand Goldfield

(iv) an assessment by the writer in 1963 of detailed drilling logs supplied for the South Rand Goldfield by Mineral Search of Africa (Pvt.) Ltd.

(v) an examination of past mining activities in the South Rand Goldfield carried out in 1963 by the writer in the Government Mining Engineer's Office.

All data on gold and silver production from the various mines and prospects in the area were obtained from records in the Government Mining Engineer's Office, Johannesburg, and from various issues of the "South African Mining Journal" published in Johannesburg in the period 1890 - 1898.

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STRATIGRAPHY AND LITHOLOGY

The area described in this paper constitutes a folded and heavily faulted portion of the Witwatersrand Basin, preserved from erosion as a result of an appreciable downthrow along the Sugarbush Fault. Three major structures are clearly discernible - the Deneysville Synform in the west, the Villiers Antiform in the centre, and the Balfour Synform in the east. These fold structures have a north-north-westerly trend and plunge in the same direction. As a result of this regional plunge, progressively older rocks appear southwards along each structure. However, the elevation of the country decreases towards the south so that more and more of the younger Karroo cover is preserved, and along the Vaal River the effects of the reduced elevation are more pronounced than those of the regional plunge, with the result that no further exposures of older rocks appear through the Karroo strata.

A large number of boreholes in the De Kuilen-Witkleifortein locality permitted a reliable determination of the stratigraphic succession along the eastern limb of the Deneysville Synform. Excellent exposures from Vaalrand through the Wilgepoort Prospect to Balfour and the Fortuna locality provided data for a compilation of a column on the northwestern and central portions of the Balfour Synform relatively close to the Heidelberg area. Logs of boreholes coupled with information from mine workings and surface exposures rendered it possible to draw up a third column for the Hex River Mine locality where the southernmost exposures of the Witwatersrand System occur in the hinge zone of the Balfour Synform.

Significant variations occur in the thicknesses of the various formations in each of the localities. Consequently, it was considered advisable to present all three columns rather than to attempt one generalized stratigraphic column for the area as a whole. These are shown in Table 1 where a comparison is made with the columns for the Heidelberg area of the East Rand Basin and the Johannesburg area of Central Rand.

All the formations normally encountered in prospecting operations within the Witwatersrand Basin, with the exception of the Dominion Reef System, are present in the area, and these reach a maximum total thickness of 23,000 feet in the centre of the Balfour Synform. Appreciable thinning of the Witwatersrand, Ventersdorp and Transvaal systems takes place southwards from this locality, and this decrease in thickness is accompanied by facies changes. The combination of the two phenomena indicates that the edges of the depositories of the various sedimentary formations originally lay at not too great a distance south and southeastwards from the present South Rand area.

Formation	Deneysville Synform	Balfour Synform		East Rand Basin	Central Rand
	Witkleifontein	Wilgepoort - Fortuna	Hex River Mine	Heidelberg	Johannesburg
Karroo System	+ 1000	+ 400	+ 200	+ 800	+ 200
Transvaal System	-	+ 400	-	+ 700	3600
Middle Ventersdorp Series	-	1700	-	-	+ 2000
Lower Ventersdorp Series	+ 3000	5000	+ 2100	5000	5000
Kimberley-Elsburg Series	2700	3000	1100	3100	6100
Main-Bird Series	900	1700	800	1800	3300
Jeppestown Series	1200	1800	800	1900	3700
Government Reef Series	2800	3900	2500	4100	6300
Hospital Hill Series	2500	3200	2000	3200	4900
Swaziland System	?	+ 1800	?	+ 1000	+ 700
Old Granite	?	?	?	?	?
Total Thickness of Column	+ 14,100	+ 22,900	+ 9,500	+ 21,600	+ 35,800

Table 1 : Regional Stratigraphic Succession South of the Sugarbush Fault Compared with Those of the Heidelberg and Johannesburg Areas (thicknesses in feet)

Formation	Deneysville Synform	Balfour Synform		East Rand Basin	Central Rand
	Witkleifontein	Wilgepoort - Fortuna	Hex River Mine	Heidelberg	Johannesburg
Upper Witwatersrand	3600	4700	1900	4900	9400
Lower Witwatersrand	6500	8900	5300	9200	14,900
Witwatersrand System	9,100	13,600	7,200	14,100	24,300

Table 2 : Thicknesses of the Witwatersrand System South of the Sugarbush Fault Compared with Those of the Heidelberg and Johannesburg Areas (thicknesses in feet)

A. OLD GRANITE

No exposures of the Old Granite have been recorded in the area south of the Sugarbush Fault. However, its presence beneath the Karroo cover has been amply proved by boreholes on the Villiers Antiform and on the Waterval Antiform which separates the Balfour Synform from the synclinal structure containing the Kinross Goldfield to the northeast. The average depth to the granite beneath the Karroo is 700 - 800 feet below surface near the hinge zones of the antiform structures. No information is available from the logs concerning the nature and composition of the granite intersected in these holes, except that in NR.3 in the New Rand Locality a gneissic structure was present.

North of the Sugarbush Fault, Rogers (1922) reported the granite northwest of the Edenkop Mine to be of the biotite variety and to be slightly gneissose. The gneissosity trends in a WNW. direction, parallel to the schistosity in remnants of Swaziland rocks in the vicinity, and approximately parallel to the axial plane traces of major folds in the area. Fresh granite porphyry occurs near the Edenkop Mine. Aplites and quartz-felspar pegmatites cut the granite in all directions.

Snyman (1956) stated that the granite north of the Sugarbush Fault is usually grey or pink. Orthoclase, microcline, albite, biotite and quartz are present. In some specimens small amounts of muscovite were noted, as well as amphiboles in streaks or schlieren. Rogers (1922) reported that the felspar is frequently converted to a mass of greenish micaceous material. In general, this granite which belongs to the Devon Dome, appears to be identical with that composing the Johannesburg Dome.

B. SWAZILAND SYSTEM

North of the Sugarbush Fault, near the Edenkop Mine, Rogers (1922) found red schistose slates with some quartzose bands unconformably underlying the Orange Grove Quartzites at the base of the Witwatersrand System. These, together with banded magnetic quartzites found further to the north, he classified as belonging to the Swaziland System. The strike of these beds is WNW. and the dip is either vertical or very steep to the south, whereas the Orange Grove Quartzites strike NNW. and dip to the west at 40° - 55°. Cleavage in the slates is parallel to the bedding. In the quartzose bands, greenish mica is developed on the cleavage planes and the quartz grains are elongated parallel to these planes. In addition to the above rock-types, Snyman (1956) found greywackes and serpentinites with amphibole schists developed on their contacts with the metamorphosed sediments. Possible isoclinal folds were also recognized.

Lithologically, these rock-types appear to belong to the Onverwacht and Fig Tree Series of the Swaziland System, with the serpentinites possibly being members of the Jamestown Complex. However, south of the Sugarbush Fault, the Swaziland System appears to be represented mainly by the Moodies Series and intrusives of the Jamestown Complex. Conspicuous outcrops of massive quartzites at Vaalrand, north of the New Springfield Colliery, and at Lepelkop, north of Oranjeville, were originally considered by Nel (1933), Snyman (1956), and Nel and Jansen (1957) to be the equivalents of the Orange Grove Quartzites. Present investigations indicate that they are probably pre-Witwatersrand in age and are most likely members of the Swaziland System.

The quartzites at Vaalrand are thickly-bedded and have sporadic and inconsistent lenses of very coarse conglomerate at or near the base (Nel, 1933). Higher up, stringers of small-pebble conglomerates and grits are infrequently developed. The conglomerates are characterized by pebbles which are almost exclusively chert, both banded and massive, with a black variety being the most prevalent among the latter. Snyman (1956) reported the presence of a number of thin layers of black shale, frequently brecciated, and, at the eastern end of Vaalrand, thin folded bands of metamorphosed, impure limestone. Mountain (1962) found intercalated layers of talc schists in the quartzites, and cross-cutting bodies of serpentinite. The strata have been isoclinally folded with the axial planes dipping to the south at steep angles so that the southern limbs of the synclines are overturned. Pseudotachylite veins in the quartzites have been reported by Snyman (1956) from the eastern end of Vaalrand.

At Lepelkop two bodies of quartzite are present separated by a zone of banded slates which are highly contorted. The quartzites are fine - to medium-grained and contain no conglomerates (Nel and Jansen, 1957). The overlying formations are composed of a thick succession of ferruginous shales and banded ironstones with intercalated, thinly-bedded, fine-grained quartzites in bands up to 5 feet thick. Isoclinal folding is not obvious and the general dip is much less steep than at Vaalrand, being of the order of 30^{o} to the south. In Borehole NR.3 to the southeast, intercalated quartzites, chlorite schists and massive talc rock were found above the gneiss. Sill-like bodies of quartz diabase, enstatite peridotite and serpentinite were also present (Sawyer, 1917).

The influence of these occurrences of quartzites on prospecting operations in the area has been mentioned earlier. The assumption was made that they belonged to the Orange Grove Quartzites, but subsequent drilling results could not effect a satisfactory correlation between the strata actually encountered and the rocks that should have been intersected if the supposition were valid. This discrepancy is considered to cast considerable doubt on the quartzites representing the base of the Witwatersrand System, and the following arguments are offered in further support of the Vaalrand and Lepelkop quartzites being members of the pre-Witwatersrand Swaziland System :

(i) the true stratigraphic thickness of the quartzites at Vaalrand is approximately 1800' and at Lepelkop 1000'; the thickness of the undoubted Orange Grove group of quartzites and shales at Heidelberg is 500 feet and at Johannesburg 770 feet; evidence shows that the Witwatersrand formations all thin to the south and southeast, and it seems unlikely that the Vaalrand and Lepelkop occurrences, if they are Orange Grove equivalents, should be such a notable exception to this trend.

(ii) at no localities in the area where undisputed Lower Witwatersrand strata have been mapped, are substantial developments of quartzites to be found at the base; the evidence would appear to indicate that the Orange Grove Quartzites rather than thickening appreciably, have thinned and changed facies to the extent of being represented by a narrow horizon of alternating thin quartzites and shales hardly distinguishable from higher members of the Hospital Hill Series.

(iii) the size of the pebbles in the basal conglomerate at Vaalrand is too large to fit into the pattern of progressive degeneration of Witwatersrand banket in the same direction as the thinning of the strata.

(iv) the composition of the pebbles is also foreign to the normal character of both Lower and Upper Witwatersrand conglomerate; the almost total absence of quartz pebbles and the predominance of chert similar to that found in the Fig Tree Series, are features commonly associated with Moodies conglomerates.

(v) the presence of limestone bands in quartzites, as found at the eastern end of Vaalrand, is a phenomenon unknown in the Witwatersrand System elsewhere in the basin.

(vi) serpentinites and talc bodies, both conformable with the bedding and cross-cutting, are also unknown in the Witwatersrand sediments elsewhere, but are common occurrences in the

Swaziland System.

(vii) there is a marked angular unconformity between the Vaalrand quartzites and the Contorted Bed and underlying quartzites east of Borehole SR.1, such a relationship between the Orange Grove Quartzites and the overlying members of the Hospital Hill Series is unknown in the remainder of the basin.

(viii) the tectonic style of the Vaalrand quartzites - isoclinal folds with overturned limbs - is also foreign to the rocks of the Witwatersrand System, but is typical of the Moodies and other rocks of the Swaziland System.

C. WITWATERSRAND SYSTEM

The variations in thickness of the Upper and Lower Divisions and of the Witwatersrand System as a whole in three localities in the South Rand area are shown in Table 2. A comparison is also made with the thicknesses of the equivalent divisions in the Heidelberg and Johannesburg areas. The general thinning of the system to the south can be readily seen.

(a) Lower Division

(i) Hospital Hill Series

In the above arguments it has been shown that previously classified Orange Grove Quartzites probably do not belong to the Witwatersrand System. Nel (1933) concluded that no evidence had been obtained to indicate the presence of the Water Tower Slates, the Ripple Marked Quartzites and the Speckled Bed in the area south of the Sugarbush Fault. It thus seems that the basal members of the Hospital Hill Series were not deposited over a large portion of the area, a deduction which particularly applies to the southernmost exposures where the mapping of Schalk (1956) and Leube (1956) around the hinge zone of the Balfour Synform south and east of the Hex River Mine showed that the lowest members of the Witwatersrand System are represented by thin quartzites and ferruginous shales about 100 feet below the Contorted Bed. In the Johannesburg area approximately 2500 feet of sediments lie between the Contorted Bed and the Old Granite, while in the Heidelberg area the thickness of these strata has been reduced to about 1400 feet.

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At the confluence of the Vaal and Waterval rivers south of the Hex River Mine, the lowest rocks in the Witwatersrand System consist of fine-grained quartzites 20 feet thick (Leube, 1956). These are overlain by highly ferruginous shales in which is the Contorted Bed. The degree of deformation in the Contorted Bed is considerably less than that developed in the Heidelberg and Johannesburg areas, and in most places the bedding is almost totally undisturbed. Folds are replaced by brecciation in some instances where numerous small pieces of ferruginous shale are cemented to quartzite lenses (Leube, 1956). The Contorted Bed is no longer the useful marker horizon it is elsewhere in the basin, and its stratigraphic position can be fixed in the majority of cases only by reference to the more definite Black Grit higher in the succession. The ferruginous shales become more sandy upwards and thin intercalated quartzite bands appear.

The shales are overlain by the Black Grit horizon which attains a maximum thickness of 100 feet, but is lenticular in nature and pinches to 25 feet at intervals along strike. This horizon, which can be traced into the Heidelberg area, is composed of medium-grained, reddish quartzites with sago structure and ripple marks (Leube, 1956). Angular or subangular black chert pebbles up to one inch in size, but generally less than ½-inch, are scattered throughout the quartzite which also contains lenses of black grit. The presence of black chert spots in white-weathering quartzites makes this an easily recognizable marker horizon on outcrop (Nel, 1933). Two quartzite bands succeed the Black Grit and these, in turn, are overlain by 450 feet of shales which become more ferruginous upwards. Two more quartzite bands then occur in which is sporadically developed a conglomerate horizon 12 inches thick with pebbles up to a maximum of ½-inch in a fine-grained matrix. The top of the Hospital Hill Series is marked by a thick succession of hard, yellowish or reddish quartzites which are fine-grained and contain lenses of felspathic quartzite with sago structure. Sheets of quartz dolerite and dolerite are numerous and add appreciably to the thickness of the succession.

In the Witkleifontein locality on the eastern limb of the Deneysville Synform, 400 feet of Hospital Hill Series strata were intersected in one borehole. The Black Grit horizon occurs above at least 110 feet of banded shale and is overlain by 135 feet of quartzite containing narrow shale bands some of which are contorted and schistose. Joints in the quartzites are smeared with green phyllosilicates. In thin section the quartzite consists of a mosaic of quartz and felspar containing shreds and needles of hornblende, granules of pyrite and stringers of mylonitic quartz (Sawyer, 1904). Shales with numerous slickensided surfaces, and at least 155 feet thick, occur above the quartzites. Quartz and calcite veins are abundantly developed in all rock-types and pyrite is usually present. The whole succession has the appearance of being highly sheared and altered.

In the New Rand locality the Black Grit horizon is 75 feet thick and, in addition to the characteristic black chert fragments, contains pebbles of less than ½-inch diameter of white and grey quartz, quartzite, calcareous quartzite, shale and limestone (Sawyer, 1907 and 1917). Pyrite occurs in a finely-disseminated form or as oval granules up to 0.25 in. in diameter. This horizon occurs at the top of at least 950 feet of quartzites, magnetic shales, green, grey, blue and purple shales, and numerous intercalated sheets of quartz dolerite, diabase, mica diorite and enstatite peridotite. Biotite is often present in the shales. Above the Black Grit is a 350 feet-thick zone of quartzites and shales devoid of igneous material. Patchy conglomerate bands and lenses of grit occur in these quartzites. A 1150 feet-thick succession of intercalated quartzites, shales and sheets of intrusive rock apparently forms the top of the Hospital Hill Series in this locality, but the possibility exists that some of the rocks in this succession might belong to the lower portion of the Government Reef Series. Again the rocks give the impression of having suffered appreciable shearing and alteration and the amount of igneous material intrusive into the sediments is exceptionally large.

In the Balfour Synform the Hospital Hill Series thins by about 1200 feet over 20 miles between the Wilgepoort Prospect and the Vaal-Waterval confluence. A decrease in thickness of approximately 500 feet occurs over 10 miles in the Deneysville Synform between the Witkleifontein locality and Oranjeville.

(ii) <u>Government Reef Series</u>

This series is not as well-exposed as the Hospital Hill Series in the South Rand area, nor are there any complete borehole intersections to allow of the detailed succession being determined. South of the Hex River Mine Leube (1956) found that the lowest exposures consist of four narrow bands of fine-grained quartzite with intercalated shales and infrequent pebbles of black chert. These are overlain by a thick group of shales with numerous diabase sheets. White, yellow or red quartzites of the Government Reef group then occur containing beds of ferruginous shale and grit near the top. The top of the series consists of the Blue Grit horizon which attains a maximum thickness of 600 feet in this locality. This easily recognizable rock, which is also well-developed in the Heidelberg area, consists of a bluish, somewhat argillaceous matrix in which are set pebbles less than ½-inch in diameter of chert, limestone, microcline, brown mica schist and chlorite schist, as well as scattered angular fragments of pebbles of up to 5 inches in size of quartzite and devitrified lava. No bedding is apparent in the horizon which is intruded by quartz dolerite. In the Rooiwal locality Schalk (1956) mapped a 200-thick exposure of Blue Grit underlain by quartz dolerite and overlain by medium-grained ripple-marked quartzite.

In the Edenkop Mine the Government Reef Series occurs between two faults which upthrow the Old Granite to the north and downthrow the Ventersdrop System to the south. The strata dip southwards into the faulted contact with the lavas and the succession from the fault northwards, according to Rogers (1922), is shown in Table 3. It is estimated that about 200 feet of the basal portion of the Promise Stage, including the Promise Reef, are not exposed, and that about 900 feet, including the Government Reef, have been cut out by faulting from the top of the Government Stage.

A conspicuous feature of the Government Reef Series south of the Sugarbush Fault is the apparent absence of the tillite and the magnetic West Rand Shales, both of which form useful stratigraphic markers in the East Rand Basin and elsewhere.

(iii) <u>Jeppestown Series</u>

As is the case normally within the Witwatersrand System, the Jeppestown Series does not form good outcrops and, as no borehole penetrated the whole thickness, it is not possible to present the detailed succession of strata. In the Witkleifontein locality about 350 feet of Jeppestown rocks immediately underlying the Main-Bird Series were intersected in one hole. The top of the series is formed by 45 feet of shales and these are followed by 25 feet of quartzites. The next 147 feet are composed of shales, some bands of which are highly contorted or brecciated. Veins of quartz and calcite are present in all the bands. A thickness of 78 feet of quartzites and 45 feet of shales then occurs above an amygdaloidal lava flow into which the borehole penetrated for 10 feet.

In Borehole RT.2 at the Heidelberg-Roodepoort Mine, an amygdaloidal lava 248 feet thick immediately underlies quartzites of the Main-Bird Series. This is succeeded downwards by 14 feet of quartzites, 12 feet of shales and 117 feet of alternating thin quartzite and shale bands. A zone of black shales 189 feet thick was then encountered and below this the hole penetrated 144 feet of quartzites before being stopped.

Nel (1933) reported that, at the Hex River Mine, the Jeppe Amygdaloid consists of two flows in the upper part of the Jeppestown Series. The

Stage	Substage	Rock-type	Thickness (feet)
Government Stage + 60 feet		quartzites	+ 60
		conglomerate	3
Coronation Stage 1830 feet	Coronation A 470 feet	quartzites	460
		Coronation Reef	2
		quartzites	10
	Coronation B 340 feet	shales	10
		quartzites	330
	Coronation C 160 feet	shales	100
		quartzites	60
	Coronation D 860 feet	shales	110
		quartzites	220
		grits	1
		quartzites	260
		micaceous quartzites	30
		quartzites	20
		micaceous quartzites	20
		quartzites	200
Promise Stage + 1040 feet	Promise A 720 feet	shales	440
		quartzites	280
	Promise B 210 feet	shales	10
		quartzites	200
	Promise C + 110 feet	shales	+ 110
	Total thickness of Government Reef Series exposed		2930

Table 3 : Detailed Succession within Portion of the Government Reef Series at the Edenkop Mine on Rietbult Estates 505

one is a dark lava with a few isolated large amygdales. The other is devoid of amygdales, but contains small felspar phenocrysts. To the southeast of the mine Leube (1956) found one flow only, 300 feet thick, with felspar phenocrysts but no amygdales. The lavas are underlain by a thin band of reddish, fine-grained quartzite and overlain by sandy shales in which is present an horizon of lenticular, medium-grained, white quartzites. The rest of the series is composed of shales.

(b) Upper Division

(i) Main-Bird Series

It was once thought (Sharpe, 1956) that the Main-Bird Series thinned progressively southwards from the Sugarbush Fault to the extent of not being developed at all in the South Rand Goldfield. However, this conclusion was based on the assumption that all the amygdaloidal lava flows encountered were members of the Jeppestown Series. Subsequent drilling results permitted a distinction to be made between the Bird Amygdaloid and the Jeppe Amygdaloid and support was thus provided for Nel's (1933) contention that the Main-Bird Series was present, but in a highly attenuated form.

Variations in the thickness of the horizons comprising the Main-Bird Series in four localities in the area are shown in Table 4 and a comparison is also made with the extent to which the equivalent beds are developed in the Heidelberg area. The amounts by which the overall thickness of the series is increased by lava flows are also shown in this table. From the large number of boreholes drilled in the De Kuilen-Witkleifontein locality, it has been possible to compile detailed successions within the Main Stage (Table 5) and the Bird Stage (Table 6). No such comprehensive information is available elsewhere in the area.

The Main Stage has been divided into four substages in this locality and an attempt has been made to correlate these with the two substages present in the Heidelberg area. Four substages have also been proposed for the Bird Stage and these have been compared with the four substages distinguished in the Heidelberg area. The thinning of all substages in both the Main and Bird Stages southwards from the Heidelberg area can be clearly seen, being more pronounced in the case of the former stage. The degeneration in the frequency and robustness of conglomerates, which develops between Johannesburg and Heidelberg, is continued into the South Rand area. Shale beds which, except for the Kimberley Shales, are virtually unknown in the Main-Bird Series in the Central Rand and East Rand become

Stage	Horizon	Witklei-fontein	Hex River Mine	Heidelberg-Roodepoort Mine	Wilgepoort-Fortuna	Heidelberg
Bird	Kimberley Shales	80	110	140	300	380
	Upper Bird Quartzites	510	50	70	210	280
	Bird Marker	-	-	-	-	30
	Middle Bird Quartzites	40	-	-	-	40
	Upper Bird Amygdaloid	-	240	480	260	110
	Lower Bird Grits	10	90	110	80	30
	Lower Bird Amygdaloid	-	110	120	90	60
	Bird Reef Conglomerates	10	-	-	50	60
Main	quartzites, grits, conglomerates	250	200	280	710	810
Total thickness Main-Bird Series		900	800	1200	1700	1800
Thickness of sediments only in Series		900	450	600	1350	1600

Table 4 : Variations in Thickness of Members of the Main-Bird Series South of the Sugarbush Fault Compared with Those of the Heidelberg Area (thicknesses in feet)

Witkleifontein			Heidelberg
Substage	Horizon	Thickness	Substage
Main A 30'	quartzites	1'	Livingstone Reef Substage 510'
	conglomerates	32"	
	quartzites	22'	
	conglomerates	6"	
	quartzites	2'	
	conglomerates	2"	
Main B 16'	shales	2"	
	quartzites	15'	
Main C 14'	shales	1"	
	quartzites	1'	
	conglomerates	3"	
	quartzites	10'	
	conglomerates	2[illegible]"	
Main D 190'	quartzites	190'	Nigel Reef Substage 300'
Total Thickness Main Stage		250'	810'

Table 5 : Detailed Succession within Main Stage on the Witkleifontein Portion of Grootvlei 453 Compared with Thicknesses of Main Substages in Heidelberg Area

Witkleifontein			Heidelberg		
Substage	Horizon	Thickness	Substage	Horizon	Thickness
Bird A Substage 590'	Kimberley Shales Upper Bird Quartzites	80' 510'	Upper Bird Substage 660'	Kimberley Shales Upper Bird Quartzites	380' 280'
Bird B Substage 44'	shales quartzites grits quartzites	4' 29' 2" 10'	Middle Bird Substage 70'	Bird Marker Middle Bird Quartzites	30' 40'
Bird C Substage 13'	shales quartzites	11' 2'	Lower Bird Substage 140'	Upper Bird Amygdaloid Lower Bird Grits	110' 30'
Bird D Substage 3'	shales grits	2' 8"	Bird Reef Substage 120'	Lower Bird Amygdaloid Bird Reef Conglomerates	60' 60'
Total thickness Bird Stage		650'	Total thickness Bird Stage		990'

Table 6 : Detailed Succession within Bird Stage on the Witkleifontein Portion of Grootvlei 453 Compared with That of Heidelberg Area

Stage	Horizon	Witklei-fontein	Hex River Mine	Stry-fontein	Heidelberg-Roodepoort Mine	Wilgepoort-Fortuna	Heidelberg
Elsburg	quartzites, grits, conglomerates	600	350	580	400	600	650
Kimberley	Upper Kimberley Quartzites	1830	740	1190	890	2000	1620
	Kimberley Reef Conglomerates	70	10	30	10	200	530
	Lower Kimberley Quartzites	200	-	100	-	200	300
Total thickness Kimberley-Elsburg Series		2700	1100	1900	1300	3000	3100

Table 7 : Variations in Thickness of Members of the Kimberley-Elsburg Series South of the Sugarbush Fault Compared with Those of the Heidelberg Area (thicknesses in feet)

prominent in the area south of the Sugarbush Fault, particularly in the Bird Stage.

The Main D Substage, in the Rooiwal and Hex River Mine localities, has a medium-grained white or yellow, cross-bedded quartzite lying immediately above the Jeppestown Series (Leube, 1956). Mica and felspar occur in some places. The quartzites are coarse-grained at the base and locally pass into grits, but no equivalent of the Nigel Reef (Main Reef Leader) of the Heidelberg area is developed on this horizon. In the Witkleifontein locality, the Main D quartzites are characterised by the development of conspicuous amounts of phyllosilicates on parting planes between bedded units (Sawyer, 1917). Conglomerates, which might be the equivalent of the Livingstone Reef, are present, but poorly and sporadically developed, in the Main C Substage throughout the area. In the Witkleifontein locality the amounts of phyllosilicates present in this substage are substantially less than in the underlying Main D Substage. Higher up, the quartzites of the Main A and B Substages in this locality have a particularly clean matrix and phyllosilicates are virtually absent (Sawyer, 1917). The conglomerates found in the Main A Substage do not appear to have any equivalents in the Heidelberg area.

The Bird quartzites in all four substages in the Witkleifontein locality contain thin layers of chlorite and have a chloritic matrix (Sawyer, 1917). Thickly-bedded cream or pinkish quartzites in the Bird C Substage contain scattered pebbles, grit bands and lenses of small-pebble conglomerate in most localities in the area. In the Tweefontein locality, Snyman (1956) reported that the Bird B Substage contained quartzites which weather to a dirty-white or brown colour on outcrop, but which are grey to green when fresh. Sericite is common and appears to be more abundant where the rocks have been intensely sheared. The shales at the top of the succession are red on surface, but become green or grey at depth. They also contain conspicuous amounts of sericite. In the Bird A Substage, the quartzite underlying the Kimberley Shales are fine-grained,reddish or brown varieties on outcrop at the Hex River Mine (Leube, 1956). In borehole intersections at the Heidelberg-Roodepoort Mine, they form a useful marker horizon, being fine-grained, white and silicified and containing occasional pyritic planes and green chloritic partings (Sharpe, 1956).

Of the volcanic material in the Main-Bird Series, the Bird Marker, persistently developed in the East Rand Basin, does not appear to be present in any locality south of the Sugarbush Fault. The Lower and Upper Bird Amygdaloid seem to be restricted to the deeper portions of the synforms and do not extend over the upper sections of the limbs and over the Villiers Antiform. This phenomenon has a parallel in the Johannesburg area where the

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Bird Marker and Amygdaloid do not occur over the Palmietfontein Anticline which continues north from the Villiers Antiform.

The maximum recorded thickness of the Upper Bird Amygdaloid is 510 feet in Borehole RT.1 at the Heidelberg-Roodepoort Mine. There is no information as to what happens to the east of this hole towards the Waterval Antiform. However, southwards and westwards a definite thinning takes place. In RT.2 the Upper Amygdaloid is 380 feet, in HR.1 at the Hex River Mine 240 feet, in RWL.1 100 feet and on the outcrop in the Rooiwal locality only 20 feet thick. It apparently wedges out to zero against the anticlinal structures on the western limb of the Balfour Synform, and in the Witkleifontein locality, on the eastern limb of the Deneysville Synform, has not reappeared although it might be developed again further to the west. The Lower Amygdaloid shows an identical trend from its maximum observed thickness of 120 feet at the Heidelberg-Roodepoort Mine.

In the Malanskraal locality Rogers (1922) found the amygdaloid to be composed of andesine and albite-oligoclase in a devitrified matrix of chlorite, actinolite, brown mica, epidote and small amounts of quartz. The rock is highly altered down to a depth of at least 1000 feet suggesting that the alteration is not the result of weathering along the present outcrop. The amygdales reach up to 4 inches in size, but are generally less than 0.25 inch, and are filled with quartz, although chlorite and epidote fillings have also been observed.

The Kimberley Shales at the top of the Main-Bird Series are ubiquitously developed and form the only persistent marker horizon in the Main-Bird Series in the area. As is the case with the Bird Amygdaloid, the shales show a tendency to thin southwards and westwards. They are usually dark grey to black in colour and either massive or well-banded, the latter feature becoming more prominent towards the top of the horizon. The topmost layer sometimes has a khaki colour and is suggestive of the originally dark shales being weathered before the deposition of the overlying Kimberley quartzites. Thin bands of fine-grained, silicified quartzite and sandy shales alternate with the normal shales.

(ii) Kimberley-Elsburg Series

This series is better exposed than the underlying members of the Upper Division and, because of its containing the only economically exploitable auriferous reef in the area, has received greater attention during prospecting operations than the Main-Bird Series. Variations in the thickness of the main components of the two stages of this series are shown in Table 7 for five localities south of the Sugarbush Fault, and are compared with those of the Heidelberg area. The progressive thinning of this series in a south-easterly direction from Johannesburg to Heidelberg is shown to be continued into the South Rand area. As is the case with the Main-Bird Series, the minimum thickness of the Kimberley-Elsburg Series has been observed in the southernmost exposures at the Hex River Mine.

Boreholes have penetrated the complete Kimberley succession in the Witkleifontein and Stryfontein localities on the eastern limb of the Deneysville Synform and in the south-central section of the Balfour Synform respectively. Table 8 shows the subdivision of the strata intersected into six substages of the Kimberley Stage and an attempted correlation is offered with the three substages recognized in the Heidelberg area. In Table 9 a detailed succession for these two localities is given in respect of the Kimberley F or Lower Kimberley Substage. The succession within the Kimberley C, D and E or Kimberley Reef Substage is shown in Table 10, and within the Kimberley A and B or Upper Kimberley Substage and the Elsburg Stage in Table 11. Changes in facies from the Heidelberg area can be seen in the development of shale bands in the Kimberley Reef and Upper Kimberley Substages which are exclusively arenaceous north of the Sugarbush Fault, and in the decrease in number and thickness of conglomerate bands in all the substages of the Kimberley Stage and in the Elsburg Stage.

The Kimberley F Substage, occurring between the Kimberley Reef (UK.9A beds of the East Rand Basin) and the Kimberley Shales is 300 feet thick at Heidelberg, decreases to 200 feet at the Wilgepoort Prospect, 100 feet in the Stryfontein locality and zero at the Heidelberg-Roodepoort Mine. The footwall quartzites of the Kimberley Reef are thus not developed at all on the upper portions of the limbs in the southern section of the Balfour Synform with the result that this reef rests directly on the Kimberley Shales in the Rooiwal locality, the Hex River Mine and the Heidelberg-Roodepoort Mine. However, this substage is present on the eastern limb of the Deneysville Synform in the Witkleifontein locality where it reaches a thickness of 200 feet.

In the Tweefontein locality Snyman (1956) found that the Kimberley F Substage contains dirty-white quartzites, coarse-grained, sheared and with abundant sericite. Cross-bedding occurs in a number of beds. In the Malanskraal locality, Rogers (1922) observed that these quartzites contained lenses, up to 5 feet thick, of black, cherty-looking grit in a matrix of cherty silica, chlorite and chloritoid. Subangular and angular grains and pebbles of quartz, quartzite and chert also occur in the quartzites, and the rocks bear a resemblance to the MK.3 horizon of the Lower Kimberley Substage in the Heidelberg area. The lithology of this substage to the south of the

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Substage	Thickness		Substage	Thickness
	Witkleifontein	Stryfontein		Heidelberg
Kimberley A Substage	410	270	Upper Kimberley Substage	1620
Kimberley B Substage	1420	920		
Kimberley C Substage	20	10	Kimberley Reef Substage	530
Kimberley D Substage	40	10		
Kimberley E Substage	10	10		
Kimberley F Substage	200	100	Lower Kimberley Substage	300
Total thickness Kimberley Stage	2100	1320	Total thickness Kimberley Stage	2450

Table 8 : Thicknesses of the Kimberley Substages South of the Sugarbush Fault Compared with Those of the Heidelberg Area (thicknesses in feet)

Substage	Witkleifontein	Thickness	Stryfontein	Thickness
Kimberley F Substage	(i) medium-grained quartzites with scattered pebbles and numerous thin intercalated shale bands, but no conglomerate bands	200	(i) coarse, silicified quartzites with scattered angular pebbles possible equivalent of MK.3 beds of Heidelberg area	100

Table 9 : Detailed Succession within Lower Kimberley Substage on the Witkleifontein Portion of Grootvlei 453 and Stryfontein 609 (thicknesses in feet)

Substage	Witkleifontein	Thick-ness	Stryfontein	Thick-ness
Kimberley C Substage	(i) fine quartzites with shale band 5 inches thick at top, but no conglomerate bands	20	(i) coarse quartzites with large-pebble basal conglomerate 24 inches thick and poorly mineralised, separated by parting 18 inches thick of quartzite with scattered pebbles from second large-pebble, poorly mineralised conglomerate band 24 inches thick; then parting 18 inches thick of quartzite with scattered pebbles overlain by small-pebble conglomerate band 9 inches thick, and fine, silicified quartzites 24 inches thick at top	10
Kimberley D Substage	(iii) fine quartzites 2 feet thick with basal conglomerate 3 inches thick and shale band 18 inches thick at top	4		
	(ii) fine quartzites with basal conglomerate 6 inches thick	25	(i) coarse silicified quartzites with large-pebble, poorly mineralised basal conglomerate 28 inches thick possible equivalent of UK.7 beds of Heidelberg area	10
	(i) medium-grained quartzites with basal conglomerate 9 inches thick, and two small-pebble conglomerate bands 12 inches and 2 inches thick at 3 and 8 feet above base respectively, and fine quartzites 3 feet thick at top	11		
Kimberley E Substage	(i) medium-grained quartzites with well-developed medium-pebble basal conglomerate 40 inches thick; then quartzites 15 inches thick, well-developed conglomerate 20 inches thick, quartzites 9 inches thick, small-pebble conglomerate 6 inches thick, fine quartzites 24 inches thick, and shale band 6 inches thick at top	10	(i) coarse quartzites with scattered pebbles, with large-pebble basal conglomerate 12 inches thick overlain by fine quartzites 30 inches thick possible equivalent of UK.9A beds of Heidelberg area	10

Table 10 : Detailed Succession within Kimberley Reef Substages on the Witkleifontein Portion of Grootvlei 453 and Stryfontein 609 (thicknesses in feet)

Stage or Substage	Witkleifontein	Thickness	Stryfontein	Thickness
Elsburg Stage	(iii) coarse quartzites under Ventersdorp lava with basal conglomerate 12 inches thick	150		
	(ii) coarse quartzites with basal conglomerate 18 inches thick and two conglomerate bands less than 12 inches thick at 200 and 210 feet above base	410	(i) coarse quartzites and grits, but no conglomerate bands	560
	(i) coarse quartzites	40		
Kimberley A Substage	(i) coarse quartzites with basal conglomerate 12 inches thick and one conglomerate band 3 inches thick at 280 feet above base, and with shale band 3 feet thick at top	410	(i) coarse quartzites and grits, but no conglomerate or shale bands	270
Kimberley B Substage	(ii) medium-grained quartzites with basal conglomerate 3 inches thick and shale band 12 inches thick at top	575		
	(i) coarse quartzites with basal conglomerate 12 inches thick, one conglomerate band 6 inches thick at 275 feet above base, and five poorly-developed conglomerate bands all less than 3 inches thick at 455, 490, 585, 790 and 825 feet above base	845	(i) coarse silicified quartzites with three small-pebble conglomerate bands each 12 inches thick at 649, 651 and 671 feet above base	920

Table 11 : Detailed Succession within Elsburg Stage and Upper Kimberley Substages on the Witkleifontein Portion of Grootvlei 453 and Stryfontein 609 (thicknesses in feet)

above localities is shown in Table 9.

Other than in the Witkleifontein and Stryfontein localities, it has not been possible to distinguish between the Kimberley C; D and E Substages, as shown in Table 10. In the Rooiwal locality, Schalk (1956) has shown that the Kimberley Reef at the base of the Kimberley E Substage consists of well-rounded, whitish quartz pebbles in a fine-grained matrix. Above the reef are medium-grained quartzites, light red, white or greenish in colour, with cross-bedding and ripple-marking common. Small lenses of conglomerate are developed in certain places. At the Hex River Mine the Kimberley Reef Substage consists of a conglomerate at the base with well-rounded pebbles averaging 1 inch in diameter, overlain by dull-weathering, coarse-grained quartzites, micaceous in some instances and frequently cross-bedded (Leube, 1956).

In the Witkleifontein locality, the Elsburg Stage and Kimberley A Stage, as shown in Table 11, contain numerous thin, lenticular bands of grit with scattered small pebbles. Flaky phyllosilicate minerals are abundant in the quartzites and grits, and pyrite is also a common component (Sawyer, 1904). Only a few thin shaly partings, usually less than one inch thick, are intercalated with the quartzites. The Kimberley B Substage contains a lesser amount of grits and scattered pebbles, and the quartzites are of a finer grain. Phyllosilicates are still conspicuous, but, together with pyrite, become progressively less abundant downwards. Thin shale bands are definitely more abundant than in the overlying rocks.

In the Annie's Rust locality Nel and Jansen (1957) found that the Elsburg quartzites are medium- to coarse-grained and are usually dull-weathering. Grits and pebble bands are rare and, when present, normally take the form of thin washes with the thickness of a single line of coarse, gritty grains or small pebbles less than 0.25 in. in diameter. Leube (1956) observed that the Elsburg Stage in the Drukfontein locality is composed of quartzites, with grits and scattered quartz pebbles appearing only near the top.

D. VENTERSDORP SYSTEM

Members of both the Lower and Middle Division of the Ventersdorp System are present in the area. The lower group of rocks consists essentially of basic lavas with a zone of tuffs, ash, tuffaceous sediments and volcanic breccias developed at the base in certain localities. The lavas occur throughout the area and form by far the majority of the outcrops. In surface areal extent they are second only to the sediments of the Karroo System. The Middle Division is restricted to the extreme northern limit of the area adjacent to the Sugarbush Fault where the northwestwards-plunging structures have their maximum depression. This group consists essentially of conglomerates, grits, shales and thin lava flows.

(a) Lower Division

In Table 12, data are presented to show the nature of the basal portion of the Ventersdorp System as revealed by outcrops and boreholes over the whole area. The transition zone, or passage beds, range from zero to a maximum of 280 feet in thickness and there is no readily apparent pattern to their distribution. They are probably localised in what were depressions in the pre-Ventersdorp and post-Elsburg erosion surface but insufficient information is presently available to ascertain whether the formation of such depressions was structurally controlled or not.

In the Annie's Rust locality the passage beds, 70 feet thick, rest on Elsburg grits and are overlain by amygdaloidal lava. They consist of dark, very fine-grained tuffaceous rocks, with gritty fragments, and volcanic breccias (Nel and Jansen, 1957). In the Tweefontein locality the whole thickness of 30 feet consists of tuffaceous sediments (Snyman, 1956), while in Borehole DMR.1 to the southeast, the transition zone was composed of clay-rich sediments. In the Rooiwal locality, the base of the Ventersdorp lavas is made up of a hard, dark tuffaceous rock (Schalk, 1956). At the Hex River Mine, Borehole HR.6 disclosed the presence of 54 feet of amydaloidal lava above the Elsburg Series. This was succeeded by 16 feet of dark grey, coarse to gritty quartzites with numerous lava fragments, capped by a gabbro intrusive 50 feet thick. In the Drukfontein locality, the passage beds consist of a narrow band of quartzite with scattered quartz pebbles lying above the Elsburg grits. Above this are tuffaceous rocks with two intercalated narrow bands of amygdaloidal lava (Leube, 1956). Borehole RT.8 at the Heidelberg-Roodepoort Mine intersected a dark, fine-grained basic extrusive at the bottom of the Ventersdorp lavas, containing inclusions of bleached quartzite. Fox (1939) found that the transition zone at one locality on the outcrop at the Heidelberg-Roodepoort Mine consisted of the following:-

+ 180 feet	:	amygdaloidal lava
220 feet	:	porphyritic and amygdaloidal lavas
50 feet	:	decomposed lava with relict amygdales

Borehole No.	Locality	Overlying Formation	Ventersdorp Lower Lava	Ventersdorp Basal Transition Zone	Underlying Formation
RF.1	Rietfontein 177 (O.F.S.)	Vent.Mid. Seds.	480	absent	Old Granite
OV.2	Knoppiesfontein 5 (O.F.S.)	Karroo	880	?	?
outcrop	Annies Rust 763 (O.F.S.)	none	+ 100	70	Elsburg
outcrop	Modderfontein 410	none	+ 100	30	Elsburg
outcrop	Tweefontein 560	none	+ 100	30	Kimberley A
DMR.1	Daspoort 564	none	1100	60	Bird A
RWL.1	Rooiwal 607	none	nil	230	Bird A
RTV.1	Rietvlei 600	none	60	280	Bird A
RW.2	Rooiwal 607	none	1010	absent	Kimberley B
SD.1	Stryfontein 609	none	3420	absent	Elsburg
HR.6	Hex River Gold Mine	none	80	70	Elsburg
HR.1	do.	none	490	absent	Elsburg
HR.4	do.	none	1790	absent	Elsburg
HR.5	do.	none	1980	absent	Elsburg
HR.7	do.	none	2140	absent	Elsburg
outcrop	Drukfontein 613	none	+ 100	50	Elsburg
outcrop	Roodepoort 598	none	+ 450	120	Elsburg
RT.8	Heidelberg-Roodepoort Mine	Karroo	390	40	Kimberley B
RT.3	do.	Karroo	790	10	Elsburg
RT.4	do.	Karroo	30	absent	Kimberley B
RDP.3	do.	none	90	absent	Kimberley B
RT.2	do.	none	190	10	Kimberley B
RT.5	do.	none	880	absent	Kimberley B
NS.1	Van Kolderskop 547	none	150	absent	Bird A

Table 12 .: Nature of the Base of the Ventersdorp System Showing Transgressive Relationships with Witwatersrand System (true thicknesses of intersections in feet)

50 feet	:	shale or ash, and deeply weathered brown micaceous shaly material possibly representing decomposed lava
20 feet	:	quartzite, clear and white in the upper few feet, but darker with interstitial chlorite in lower part
40 feet	:	volcanic ash, grading up through fine-grained dark chloritic quartzite to the purer quartzite above
10 feet	:	lava, in the form of a thin, impersistent, badly weathered flow
+ 100 feet	:	Elsburg grits

The lavas of the Lower Division were classified by Rogers (1922) as acid andesites. They are invariably highly altered and composed of secondary minerals which include epidote, chlorite, actinolite, calcite, quartz, augite and felspar set in a matrix of devitrified glass. The felspar is frequently replaced by chlorite and quartz. Massive, amygdaloidal and porphyritic varieties occur, with the last-named being relatively rare and confined to one particular horizon. The phenocrysts, up to 4 inches in length, are composed of felspar. The amygdales are of quartz, chalcedony, epidote and calcite. Near the base of a flow they are rare, but in the middle they are common and generally rounded, while at the top of the flow they are most abundant and flattened. Leube (1956) noted that the flows near the Hex River Mine varied between 20 and 100 feet in thickness, while near Balfour Snyman (1956) observed 20 flows over a distance of one mile.

An analysis of lava from Carsar's Vlei, west of the Lagerspoort locality, showed the following composition (Rogers 1922):

SiO_2	54.85	Fe_2O_3	1.30	CaO	7.80
TiO_2	0.95	FeO	9.60	Na_2O	3.05
Al_2O_3	15.15	MgO	4.30	K_2O	1.50

In the Heidelberg area a zone of porphyritic lava, 30 feet thick, occurs between 300 and 900 feet above the base of the System ([illegible] and Jansen, 1957). Southwards into the South Rand area, this useful m[illegible] cuts down lower and lower towards the base as the intervening massive and amygdaloidal lavas thin, until in the Lepelkop locality only a few feet of lava separate the porphyritic horizon from the top of the transition zone.

(b) Middle Division

The Middle Division of the System is exposed in the Fortuna locality and at Nurney Hill. In the former place a basal conglomerate overlies the uppermost lavas of the Lower Division which are much paler than the normal dark green to dark grey, probably due to alteration by weathering subsequent to the pouring out of the lavas and prior to the deposition of the sediments. The conglomerate has a clayey matrix and pebbles and boulders up to 10 inches in size. These consist of quartz, quartzite, black and white chert, shale and lava of a more acid composition than normally found in the Lower Division (Rogers, 1922). Above this basal conglomerate are tuffs, shales, sandy shales, grits and further conglomerates with thin lava bands towards the bottom (Snyman, 1956). At Nurney Hill a similar assemblage is found. The basal conglomerate is, in fact, a boulder bed with angular and well-rounded boulders up to 36 inches in diameter. The pebbles, which are badly sorted, include numerous specimens of banded ironstone (Snyman, 1956).

(c) Relationship with Witwatersrand System

The Ventersdorp System is conformable with the Witwatersrand System in some places and unconformable in others. The transgression of the lavas can be well seen around the eastern section of the hinge zone of the Villiers Antiform. Near the axis of this structure the Ventersdorp System lies conformably on the Elsburg Stage, as on Modderfontein 410, north of the defunct Oceana Transvaal Colliery. Proceeding eastwards towards the axis of the Balfour Synform the lavas cut down over successively lower strata, resting on the Kimberley A Substage in the Tweefontein locality and the Bird A Substage at the Heidelberg-Daspoort Prospect. This is the lowest horizon in the Witwatersrand System on which the lavas have been proved to rest. However, the possibility exists that the transgression might extend over the Lower Division of this System north of Greylingstad. In Borehole RF.1 southwest of Oranjeville the Ventersdorp rocks rest directly on the Old Granite.

There appears to be a possible relationship between conformable and unconformable contacts and the present structures, suggesting that the latter features were being or had been formed at the time of the outpouring of the lavas and have been subsequently reactivated. Conformable contacts are seen on the relatively shallow-plunging hinge zones of broad fold structures and along the axes of synforms. Unconformable relationships are most pronounced on the more steeply dipping limbs of the same structures.

The lavas are conformable with the Elsburg Stage in the hinge zone of the Deneysville Synform, as seen at Annie's Rust, of the Villiers Antiform around the Oceana Transvaal Colliery, and of the Balfour Synform, as shown by the drilling results at the Hex River Mine. In the Stryfontein locality, the Ventersdorp System is also conformable with the Elsburg Stage along the axis of the Balfour Synform. Unconformable relationships are evident in the Witkleifontein locality on the eastern limb of the Deneysville Synform, between Tweefontein and the Phoenix Prospect on the northern portion of the western limb of the Balfour Synform, in the Rietvlei-Rooiwal locality in the southern portion of the same limb, and around the Heidelberg-Roodepoort Mine on the eastern limb of the Balfour Synform. Drilling results have shown that Ventersdorp rocks transgress across lower and lower members of the Witwatersrand System, the higher the elevation up the limb. Thus the change from conformity to unconformity is a product of the change in attitude of the underlying sediments from near horizontal towards the axis of a synform to relatively steeply dipping midway between this axis and the axis of the adjoining antiform.

E. TRANSVAAL SYSTEM

The only occurrence of the Transvaal System in the area lies at the northernmost point where the Black Reef and Dolomite Series have been preserved in the folded Fortuna basin. The base of the System in this syncline consists of a conglomerate with a dark clayey matrix in which are pebbles of quartz, quartzite and amygdaloidal Ventersdorp lava. Argillaceous quartzites, shales, sandy shales and quartzites with grit lenses complete the 300 feet thickness of the Black Reef Series. A few small exposures of dolomite and chert, belonging to the Dolomite Series, appear through the Karroo cover.

F. KARROO SYSTEM

Members of the Karroo System are the most abundant rocks in the area. Outliers occur in the northern portion, becoming progressively larger and more numerous to the south, east and west until eventually all the older rocks disappear completely under an increasingly thicker cover of younger sandstones, shales and igneous material. Only the Middle Ecca Stage is represented, the underlying Dwyka, which probably once existed, having been eroded and reworked to form the basal members of the Middle Ecca.

Variations in the preserved thicknesses of the Karroo System from west to east across the area are shown in Table 13. The gradual thickening from north to south is illustrated by the data from the Deneysville Synform where the northernmost borehole COR.1 intersected 525 feet of Karroo and the southernmost AB.1 1477 feet. From west to east there is no marked change in thickness across the Villiers Antiform from the Witkleifontein locality to the New Springfield Colliery. It would seem that the Karroo rocks were deposited in a trough in this latter locality and that a ridge occurred in the pre-Karroo floor between this trough and the Rietvlei-Rooiwal locality where the preserved cover is unusually thin. The differences between the thickness of Karroo on the eastern limb of the Balfour Synform and over the Waterval Antiform are not marked. The higher figure for Borehole NS.1 indicates an increased accumulation of sediments over the most depressed portion of the Synform.

The lower portion of the Middle Ecca Stage is composed of conglomerates, grits, brown shales and mudstones, and, in some places a coal seam. The conglomerate is not the Dwyka Tillite, but it might have been produced as a result of disintegration and reworking of the glacial material almost in situ. The maximum recorded thickness of this basal group is about 300 feet in the Fortuna locality. Details of the succession within it are shown in Table 14, compiled from boreholes around the Heidelberg-Roodepoort Mine where the thickness has decreased to a maximum of a little over 200 feet. Both striated and unmarked boulders have been found, some reaching up to 48 inches in diameter. They are composed almost exclusively of Witwatersrand quartzite and Ventersdorp lava. To the south and east of the Hex River Mine numerous well-rounded pebbles of quartzite and quartz up to 8 inches in size occur in a soft, medium-grained matrix.

The upper members of the Karroo System present in the area consist of medium- and coarse-grained arkoses, lenticular conglomerates with large pieces of unweathered felspar in places, fine-grained white and yellow sandstones with mica and decomposed felspar, and grey, purple and black shales. The sandstones are calcareous in places and contain concretions of calcite and also silicified wood. Cross-bedding and ripple-marking are common. Lenses of sandy and pure limestone up to 18 inches thick have been noted along one stratigraphic horizon in the vicinity of the Hex River Mine (Leube, 1956). There is a suggestion of a general coarsening in grain size of the sandstones from north to south across the whole area.

Coal has been intersected in a number of boreholes in many localities, but at present is being exploited only in the New Springfield Colliery at Grootvlei. Here the mined seam is 12 feet thick and occurs about 400 feet below the surface and 300 feet above the base of the Karroo System. Annual production is of the order of 2,250,000 tons almost all of which is consumed by the Klip Power Station of Escom.

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Schaaplaats Antiform		Deneysville Synform		Villiers Antiform		Balfour Synform		Waterval Antiform	
Borehole	Thickness	Borehole	Thickness	Borehole	Thickness	Borehole	Thickness	Borehole	Thickness
RF.1	124	AB.1	1477	NR.3	750	SR.4	337	HGF.1	688
		OV.1	1071	Springfield	725	SR.6	172	WAK.1	611
		OV.2	883			SR.12	212	KT.1	793
		NR.2	670			SR.13	212		
		NR.5	660			SR.14	206		
		NR.6	680			RIV.1A	24		
		NR.10	720			RT.3	581		
		NR.11	740			RT.4	514		
		NR.12	760			RT.8	637		
		NR.13	820			NS.1	970		
		SR.15	200						
		SR.18	951						
		SR.19	626						
		SR.20	695						
		SR.21	491						
		COR.1	525						

Table 13 : Variations in Intersected Thicknesses of Karroo System in Boreholes from West to East, South of the Sugarbush Fault (Thicknesses in feet)

	Borehole RT.3		Borehole RT.8		Borehole RT.4	
	Thickness	Elevation	Thickness	Elevation	Thickness	Elevation
alternating sandstones and dark shales	+ 121'	+ 581	cut out by dolerite intrusion		+ 82'	+ 514
alternating bright and dull coal with narrow shale partings	42"	460			absent	
alternating sandstones and dark shales	145'	456	+ 143'	+ 480	121'	432
alternating bright and dull coal with narrow shale partings	15"	311	12"	337	21"	311
alternating sandstones and dark shales	145'	310	182'	336	95'	309
brown mudstones	25'	165	22'	154	67'	214
alternating bright and dull coal with narrow shale partings	56"	140	absent		absent	
conglomerates, grits, brown shales, mudstones	135'	135	132'	132	147'	147
Ventersdorp System	800'	0	430'	0	30'	0

Table 14 : Detailed Succession within the Basal Portion of the Karroo System in the Vicinity of the Heidelberg-Roodepoort Gold Mine (elevation of top of horizon in feet above top of Ventersdorp System

G. EXTRUSIVE AND INTRUSIVE ROCKS

There is ample evidence of considerable igneous activity in the area and the volume of material resulting from such phenomena definitely exceeds that of the sedimentary fill of the various basins which existed throughout geological time. Extrusive rocks are best represented by the amygdaloidal lava flows in the Jeppestown Series and the Bird Stage of the Witwatersrand System and by the massive, porphyritic and amygdaloidal andesites of the Lower Division of the Ventersdorp System. However, it is possible that other lavas might exist among the mass of igneous material, particularly in the Hospital Hill Series and the Karroo System. Intrusive rocks occur in all formations from the Swaziland to the Karroo System and have been injected at a number of different periods.

The oldest intrusives are the serpentinites found in the Moodies Series at Vaalrand and Lepelkop. Some of the chloritic and talc schists associated with these rocks might also represent altered intrusives of different composition. The next oldest group of intrusives are the highly altered diabases which occur in the Witwatersrand System, particularly the Lower Division, and which are probably of Ventersdorp age. Unlike those of similar age on the Central Rand, these diabases are predominantly sills, and dykes appear to be of minor importance. In the New Rand Locality they are exceptionally common and in one borehole drilled by Sawyer (1917) 14 diabase sheets ranging in thickness from 7 inches to 352 feet were encountered over a vertical distance of 3000 feet. Sheets of ultrabasic composition, including enstatite peridotites and pyroxenites, are also present in this area, but it is not known whether they are associated in time with the diabases.

Quartz dolerite intrusions which are plentiful throughout the area might be of Bushveld age. They intrude the Witwatersrand and Ventersdorp Systems, forming sills in the former and dykes in the latter. They are more abundant in the shales of the Lower Division of the Witwatersrand System than in the quartzites of the Upper Division. Flat-dipping bodies of norite and gabbro which reach up to 800 feet in thickness in the same two systems might also belong to the Bushveld period of igneous activity, but the possibility of their being of Pilanesberg age cannot be discounted.

Intrusives of definite Pilanesberg age have been recognized by Nel and Jansen (1957) as comprising diorite, quartz gabbro, diabase of the calc-alkali suite, and slightly lamprophyric types. The most conspicuous dykes in the area belong to this group. They strike consistently NNW. and NNE.

Karroo dolerite of the Kokstad-type (Nel and Jansen, 1957) is intruded as numerous sill-like sheets up to 350 feet thick and dipping slightly towards the south. Dykes of this age and composition are much less common. The intrusions occur in members of the Witwatersrand, Ventersdorp and Karroo Systems. Southwest of a line running approximately from the Hex River Mine to the New Springfield Colliery, the dolerites are essentially coarse-grained, while to the northeast they are fine-grained (Leube, 1956).

The general impression is gathered that igneous intrusions, particularly in the form of sills, are more common in the South Rand area than on the Central Rand and East Rand. In the area itself there are also indications that intrusions become more frequent southwards, reaching an unusually high figure in the New Rand Locality. The influence of these intrusives and extrusives on the thickness of the Upper Division of the Witwatersrand System is shown in Table 15. Their overall affect is to increase the thickness of the succession in the southern portion of the Balfour Synform by one-third.

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Series	Locality	A	B	C	D	E
Kimberley-Elsburg Series	Stryfontein 609	1	3	100	1755	6
	Rooiwal 607	2	2	123	2585	5
	Hex River Mine	7	1	2461	7604	32
	Heidelberg-Roodepoort Mine	8	2	827	4316	19
	Totals and Average	18	3	3511	16,260	22
Main-Bird Series	Hex River Mine	2	2	788	1012	78
	Heidelberg-Roodepoort Mine	3	2	2001	1984	101
	Totals and Average	5	2	2789	2996	93
Average for Upper Division of Witwatersrand System						33

Table 15 : Affect of Dykes and Sills on the Thickness of the Kimberley-Elsburg Series and of the Bird Amygdaloids on the Main-Bird Series in the Southern Portion of the Balfour Synform

A : number of boreholes in which Series intersected

B : maximum number of igneous bodies intersected in any one borehole

C : total thickness vertically down boreholes of igneous material intersected (feet)

D : total thickness vertically down boreholes of sediments intersected (feet)

E : percentage increase in thickness of Series caused by introduction of igneous material

CONGLOMERATES AND GOLD MINERALISATION

The only known gold occurrences south of the Sugarbush Fault are found in conglomerates of the Witwatersrand System. There are no recorded instances of the metal having been found in banded pyritic quartzites, or as thin films on parting planes in quartzites between unconformities or disconformities, or in quartz veins, or in dykes, as elsewhere in the Witwatersrand Basin. Wherever conglomerate bands outcrop in the area prospecting operations have been conducted, and no inconsiderable amounts of time and money have been spent in testing the potentialities of all formations within the Witwatersrand System. Countless trenches, pits, winzes and shafts are to be found all the way from Nurney Hill to Annies Rust. In Fig. 2 no attempt has been made to show all these and only those prospects and mines where the more intensive investigations were carried out have been plotted. At least 95 boreholes have been drilled in the search for new reefs or to test known ore-bodies at depth.

As Nel (1933) stated, from the Central Rand southeastwards there is a distinct falling off in thickness and number of conglomerates, and in the area between Balfour and the Vaal River the pebble beds become even more reduced in importance. The economic potentialities suffer a sympathetic deterioration. Kessler (1904), reporting on the Heidelberg-Roodepoort Mine, stated that the "reef attains a good width, but is of such a low grade that the mine cannot be worked at a profit". Despite all the work that was undertaken in the intervening years, Borchers (1961) could not draw a more favourable conclusion than that "consistent gold values seem to be lacking in the reefs in this area". The South Rand Goldfield would thus appear to be a pauper among the princes of the Witwatersrand gold mining industry.

A. CONGLOMERATES IN THE LOWER DIVISION OF THE WITWATERSRAND SYSTEM

(a) Hospital Hill Series

In the mistaken belief that the Vaalrand quartzites of Moodies age were members of the Hospital Hill Series, the basal conglomerates and stringers of pebbles were prospected without any significant gold values being obtained. No exploitable auriferous horizons have yet been found in this series anywhere in the Witwatersrand Basin and nowhere outside the

Basin have the Moodies conglomerates been proved important. Consequently, it cannot be anticipated that any minable banket is present either at Vaal-rand or Lepelkop.

In his prospecting of the New Rand Locality, Sawyer correlated reddish coloured quartzites in the Black Grit horizon with the Red Bar which underlies the Main Reef group of reefs on the Central Rand. As a result he drilled hole after hole into the Black Grit itself searching for a conglomerate development comparable with the Main Reef. Scattered pebbles of white and grey quartz, quartzite, calcareous quartzite, shale and limestone, all less than ½-inch in diameter, occur in a dark grey matrix over a thickness of 75 feet. Only one 3 inch-wide conglomerate band was intersected and, although it was mineralised with pyrite, no gold values were proved.

(b) Government Reef Series

Only in the extreme north of the area, at the Edenkop Mine adjacent to the Sugarbush Fault, has gold been found in and won from conglomerates in the Government Reef Series. Elsewhere in the South Rand area, the pebble beds, if present, have proved to be devoid of significant mineralisation.

The Coronation Reef at Edenkop Mine attains an average thickness of 30 inches on the outcrop and, where mined, had an average gold content of 11.0 dwts. per ton on the surface. The reef was well-developed, persistent for a short distance along strike, and contained pebbles up to 2 inches in diameter. Further conglomerates are present 460 feet higher in the succession, at the base of the Government Stage, but these do not contain payable quantities of gold. Neither the Government Reef nor the Promise Reef is present due to the top and bottom of the Government Reef Series being faulted out.

This occurrence is of considerable interest because it represents the only locality in the Witwatersrand Basin, outside the Klerksdorp Goldfield, where conglomerates in the Government Reef Series have been mined. Too little is known of this series in the Central Rand, East Rand and Heidelberg areas to draw any definite conclusions, but it would seem unlikely that the presence of significant amounts of gold can be fitted in with the normal sedimentological trends which indicate a source of material north of Johannesburg and a dissipation of pebbles and heavy minerals in a southeasterly direction from this source. Rogers (1922) was unable to find similar conglomerates in the Government Reef Series around Heidelberg, but did find a possible equivalent on Steynskraal, 8 miles to the west on the north side of the Sugarbush Fault. The indications are, therefore, that a local source, possibly to the north over the present Devon Dome of Old Granite and Swaziland rocks, or along the original southeastern edge of the basin, was responsible for the development of the conglomerate and the provision of the gold.

(c) Jeppestown Series

In no surface exposures or borehole intersections have conglomerates been found in this series. However, outcrops are invariably poor and the holes have penetrated for only a short distance into the succession, with the result that the possibility cannot be entirely excluded of pebble beds being present

B. CONGLOMERATES IN THE UPPER DIVISION OF THE WITWATERSRAND SYSTEM

On the Central Rand, the conglomerate bands in the Main-Bird and Kimberley-Elsburg Series total about 2000 feet in thickness. The Upper Division is there 9400 feet thick and the conglomerates thus represent some 21 per cent of the total column. The extent to which this Division has changed facies by the time it reaches south of the Sugarbush Fault can be seen in Table 16. The two series total only 3600 feet and the conglomerate content has dropped to 0.6%. Probably there are of the order of 300 well-developed pebble beds between the North Reef and the topmost Elsburg Reef on the Central Rand. In the Witkleifontein locality only 29 have been recorded. The Main-Bird Series which acts as host to most of the significant auriferous horizons elsewhere, here contains only 7 thin, impersistent conglomerate horizons none of which contains gold in exploitable quantities. The Kimberley-Elsburg Series, in which are developed at least 250 pebble horizons on the Central Rand, contains only 22 in the South Rand area, and all of these, except for localised patches of one only, are totally devoid of any economic concentrations of gold.

(a) Main-Bird Series

The Nigel Reef or Main Reef Leader which is the most important gold carrier in the East Rand Basin and persists as far as the Witwatersrand

Substage	Witkleifontein				Stryfontein			
	No. of Bands	Range in Thickness	Average Thickness	% of Substage Thickness	No. of Bands	Range in Thickness	Average Thickness	% of Substage Thickness
Elsburg	4	9 - 18	12	0.7	nil	-	-	nil
Kimberley A	2	3 - 12	8	0.2	nil	-	-	nil
Kimberley B	8	3 - 12	5	0.2	3	9 - 12	12	0.3
Kimberley C	nil	-	-	nil	3	9 - 24	19	47.5
Kimberley D	5	3 - 12	6	7.4	1	28	28	23.3
Kimberley E	3	6 - 40	22	54.9	1	12	12	10.0
Kimberley F	nil	-	-	nil	nil	-	-	nil
Kimberley Stage	18	3 - 40	8	0.6	8	9 - 28	17	0.8
Kimberley-Elsburg Series	22	3 - 40	9	0.6	8	9 - 28	17	0.6
Bird A	nil	-	-	nil	not intersected			
Bird B	1	2	2	0.4	do.			
Bird C	nil	-	-	nil	do.			
Bird D	1	8	8	22.2	do.			
Bird Stage	2	2 - 8	5	0.1	do.			
Main A	3	2 - 32	13	11.1	do.			
Main B	nil	-	-	nil	do.			
Main C	2	3 - 23	13	15.5	do.			
Main D	nil	-	-	nil	do.			
Main Stage	5	2 - 32	13	2.2	do.			
Main-Bird Series	7	2 - 32	11	0.7	do.			
Upper Witwatersrand Division	29	2 - 40	9	0.6				

Table 16 : Percentage of Conglomerates in Upper Witwatersrand Division on the Witkleifontein Portion of Grootvlei 453 and Stryfontein 609 (thicknesses in inches)

Nigel Mine at Heidelberg, is not present in the South Rand area. The Main D Substage which lies above the Jeppestown Series is composed essentially of quartzites with only a few lenticular bands of grit in places. There is no recorded instance of the development of a conglomerate immediately above the Jeppestown shales, which is the stratigraphic horizon occupied by the Main Reef Leader. In a number of localities the presence of this reef has been alleged by prospectors, but as more detailed information was provided by further investigations, it was invariably shown that the conglomerate found lay above the Kimberley Shales and not a member of the Jeppestown Series, and was, therefore, the Kimberley Reef and not the Main Reef Leader. At its best, in the Malanskraal and Tweefontein localities, Rogers (1922) found that the Main Reef Leader horizon was composed of nothing better than thin, coarse grits devoid of any sign of sulphide or other mineralisation. In his summing up of drilling operations in the South Rand Goldfield, Sharpe (1956) concluded that, in all instances, the horizon was very poorly represented and contained no economic reefs.

In the Main A, B and C Substages which occupy a relatively thin zone at the top of the Main Stage are lenticular, small-pebble conglomerates which have been observed on outcrop or intersected in boreholes in a few localities. They were possibly deposited during the Livingstone Substage. The maximum recorded thickness of any one of these bands is 32 inches in the Witkleifontein locality. At Tweefontein the most conspicuous band is 6 inches wide and consists of white and blue vein quartz pebbles set in a matrix of clear quartz and sericite. No gold values of interest have been obtained from these conglomerates in any locality.

The Bird Reef conglomerates which occupy the Bird D Substage do not occur in the area, except for one thin barren band at Witkleifontein. They are poorly developed in the southern portion of the East Rand Basin and seem to have virtually disappeared before the Sugarbush Fault is reached. In the Wilgepoort-Fortuna and Witkleifontein localities quartzites without conglomerates are present in the bottom portion of this substage, but at the Heidelberg-Roodepoort and Hex River mines they have been cut out and the overlying Lower Bird Amygdaloid rests directly on the arenaceous members of the Main Stage.

Between the Upper and Lower Amygdaloid, at the base of the Bird C Substage, there is frequently developed a series of grits which locally pass into small-pebble conglomerates. They have been found only in the Balfour Synform but insufficient evidence exists at present to conclude that they are totally absent from the Deneysville Synform. The maximum observed thickness of one of these bands is 10 inches. No payable values have been encountered, although both the grits and the conglomerates are

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usually mineralised with pyrite. One very narrow pebble band of no economic significance was noted in the overlying Bird B Substage in the Witkleifontein locality, while no conglomerates appear to be present in the thick Bird A Substage which is topped by the Kimberley Shales.

(b) Kimberley-Elsburg Series

(i) Kimberley Reef

In the East Rand Basin 80 or more conglomerates are present in the Kimberley group, but in the South Rand goldfield only one appears to have any persistent development (Sharpe, 1956). In the Heidelberg area 300 feet of quartzites, grits, puddingstones and shales form the Kimberley F or Lower Kimberley Substage which occurs between the exploited UK.9A Kimberley Reef and the top of the Kimberley Shales. In the Wilgepoort-Fortuna locality the thickness has decreased to 200 feet which is the same as at Witkleifontein. At Stryfontein the substage has been further reduced to 100 feet. Quartzites with scattered pebbles and intercalated narrow shale bands are the constituents and there are no conglomerates south of the Sugarbush Fault in this substage.

By the Heidelberg-Roodepoort Mine, the Kimberley F Substage has been cut out completely and the Kimberley E Substage, containing the exploited Kimberley Reef at its base, occurs in direct contact with the Kimberley Shales at the top of the Main Stage. This condition still prevails at the Hex River Mine. Only in the vicinity of these two mines has the Kimberley Reef been proved to contain economic quantities of gold. Elsewhere in the area, intensive prospecting work has failed to disclose any localities where conditions have favoured the concentration of the metal.

1. Heidelberg-Roodepoort Mine

The Kimberley Reef in the Heidelberg-Roodepoort Mine, originally known as the East Reef and thought to be the equivalent of the Nigel Reef of the Main-Bird Series, consists of a well-developed conglomerate with a dark matrix, almost black in the upper levels of the mine, in which are pebbles of white, milky white, grey and black quartz, greenish lava or shale, and massive and banded chert. The white quartz pebbles predominate by far. Maximum pebble size is 2 inches, with the average being less than

0.75 inch. In some places the matrix becomes decidedly chloritic towards its bottom contact with the Kimberley Shales. Quartzite partings are frequent. Pyrite mineralisation is heavy in places, generally surrounding the pebbles, but in some instances almost completely replacing chert pebbles up to 1 inch in diameter. In other places the pyrite content is low to the point of being almost non-existent. The conglomerate is generally intensely fractured and becomes friable when weathered.

On the surface the reef was payable over a strike length of 1300 feet, averaging 14 dwts. per ton over a width of 26 inches. In places it swelled to a maximum of 60 inches, and in others pinched to a minimum of 12 inches. The strike of the conglomerate on surface along the payable zone was south-south-east and the dip 55° to the west. By the 4th level, the dip had flattened to 30°. The average value decreased down dip, but the mine was worked to at least 1000 feet down the incline, although the actual depth might exceed this figure. No plans of the workings are available. Mining operations eventually ceased when an oblique fault was encountered upthrowing the reef an appreciable distance vertically on the downdip side. To the north of the mine workings, a normal fault caused the reef to be upthrown on the northwestern side and the outcrop to be advanced westwards. The much smaller Kildare Gold Mine was developed in this locality (see Fig. 5).

In this figure an attempt has been made to prepare an inch-dwt. plan of the Kimberley Reef in the vicinity of the two mines. All available information from surface sampling, underground workings and diamond drilling has been considered, but due to excessive spacing between points at places, the plan has suffered a certain amount of subjective extrapolation. What does appear to emerge is that a well-defined NW-SE trend influences the distribution of the contour lines and that this trend is oblique to the strike of the bedding, the angle between the two directions being about 20°. A single payshoot trending northwestwards includes both the Heidelberg-Roodepoort and Kildare Mines. There is no indication of a further payshoot of similar importance occurring to the southwest although a zone of relatively higher values, parallel to the payshoot, is present between boreholes RT.4 and RT.2. No prospecting has been carried out to the northeast to determine whether further payshoots might be anticipated between the Kildare Mine and Greylingstad. It is also apparent that no exploration has taken place at depth on the northwestwards extension of this shoot, all previous drilling operations being concentrated to the southwest.

2. Hex River Mine

This was a much smaller undertaking than the Heidelberg-Roodepoort Mine, but still represented the second most important producer in the area. Payable values were found on surface over a strike length of 500 feet approximately, and averaged 8.6 dwts.per ton over 15 inches, the variations in reef width being between 9 and 18 inches. The conglomerates had a strike of almost due east-west. Dips on the outcrop reached up to 45^{O}, but flattened to 25^{O} a short distance down the mine. The reef, where worked, was generally thinner, less well-developed, and of a lower grade than that exploited in the Heidelberg-Roodepoort Mine. Kessler (1904) reported that where the reef was thick, poor values were encountered, but that where it narrowed, much better values were obtained. Workings were continued to 750 feet down the incline where a shallow-dipping, 800 feet-thick gabbro still was encountered. The reef was displaced vertically downwards by an amount equivalent to the thickness of the sill and this deterred further mining operations. On the adjoining Southeast Witwatersrand Gold Mine, the sill was encountered at a depth of 250 feet down dip, and also terminated mining activity.

An inch-dwt. plan of the Kimberley Reef in the locality surrounding the two mines is shown in Fig. 5. The trends shown by the contours are identical with those disclosed in the Heidelberg-Roodepoort Mine. Again, the payshoots are oblique to the strike of the bedding. Two separate pay-shoots occur, the one through the Hex River Mine containing appreciably higher values than the one to the east, but neither compares in gold content with the payshoot through the Heidelberg-Roodepoort and Kildare mines. The shoots have not been tested in depth, and it is also apparent that the tract of country between the Hex River and Heidelberg-Roodepoort mines might possibly contain further payshoots running parallel to those already proved, but concealed beneath a cover of Ventersdorp lava and Karroo sediments.

(ii) Other Reefs in the Kimberley Stage

Where a thicker development of the Kimberley Stage is present, as in the Witkleifontein, Malanskraal, Tweefontein, Heidelberg-Daspoort and Stryfontein localities, further conglomerates are developed in the Kimberley Reef Substage. These occur in the Kimberley C and D Substages above the exploited Kimberley Reef. The maximum recorded width of any one such band was 28 inches in Borehole SD.1. Gold values are generally low and erratic and no economic importance can be attached to their presence. Where the Kimberley Stage is relatively thin, as at Rooiwal, the Hex River Mine and the Heidelberg-Roodepoort Mine, conglomerates are absent from the Kimberley C and D Substages.

The Kimberley A and B formations in the thick, Upper Kimberley Substage act as host to 10 conglomerate bands in the Witkleifontein locality and 3 at Stryfontein. These have a maximum width of 12 inches, but are almost totally devoid of gold mineralisation.

(iii) Elsburg Stage

Unlike the Central Rand, where conglomerate bands form at least half the succession within the Elsburg Stage, the South Rand area contains at the most four pebble beds ranging up to 18 inches in width. In all localities the conglomerates deteriorate over short distances into thin washes of grit and scattered pebbles less than 0.25 inch in diameter. Gold values are poor without exception. Rogers (1922) reported an appreciable development of conglomerate bands in the Elsburg Stage north of Heidelberg, but added that they became considerably less conspicuous southwestwards and disappeared altogether north of the Sugarbush Fault. There is no evidence to show that they reappear in any strength south of this structure.

(iv) Ventersdorp Contact Reef

Conglomerates at the contact between the Ventersdorp and Witwatersrand Systems have been reported only from the Annies Rust and the Heidelberg-Roodepoort Mine localities. Small pebbles are contained in a dark matrix, and the maximum width recorded is 12 inches in the former locality. In one borehole intersection at the mine the reef was only one inch wide. Gold values are negligible. Although sediments are present in the Ventersdorp transition zone in a number of localities, conglomerates do not appear to be a normal component.

The average thicknesses and gold contents of all conglomerates which have been sampled in the area are summarised in Tables 17 and 18. Pebble bands other than those shown are not known to be auriferous. It can be clearly seen that in no instance does any conglomerate horizon other than the Kimberley Reef and the Coronation Reef constitute a potentially economic source of gold in the South Rand area.

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Locality	VC T - V	KE T - V	BC T - V	MABC T - V
Hex River Mine Outcrop	n	15 - 8.6	12 - 2.2	15 - 0.8
HR.1	a	25 - 8.4	3 - tr.	n
HR.3	n	12 - tr.	n	n
HR.4	a	9 - 1.0	n	n
HR.5	a	19 - 2.6	n	n
HR.6	a	25 - 0.8	n	n
HR.7	a	8 - tr.	n	n
Heidelberg-Roodepoort Mine Outcrop	n	26 - 14.0	n	n
RT.1	n	8 - 0.2	6 - tr.	n
RT.2	1 - tr.	25 - 5.5	8 - tr.	a
RT.3	a	10 - 0.2	n	n
RT.4	a	12 - 3.5	4 - tr.	n
RT.5	a	16 - 4.2	n	n
RT.7	n	8 - 1.0	n	n
RT.8	a	14 - 3.2	n	n
L.1	n	9 - 19.5	n	n
R.1	n	n	n	12 - 0.8

Table 17 : Average Thicknesses and Values of Auriferous Conglomerates in the South Rand Goldfield

VC : Ventersdorp Contact Reef
KE : reefs in Kimberley E Substage
BC : reefs in Bird C Substage
MABC : reefs in A, B and C Substages of Main Stage

T : thickness of reef in inches
V : value of reef in dwts. per ton
a : no reef developed on horizon
n : reef horizon not intersected or observed

Locality	VC	KC	KD	KE	BC	MABC	GC
	T - V	T - V	T - V	T - V	T - V	T - V	T - V
OV.1	a	n	n	n	a	12 - 0.2	n
Annies Rust 763	9 - 0.8	a	a	a	n	n	n
Vaalbank 101	12 - tr.	a	a	a	n	n	n
Witkleifontein	a	a	9 - 0.8	40 - 1.0	a	23 - 0.6	n
COR.1	a	10 - 4.3	15 - 0.7	5 - 3.5	n	n	n
Malanskraal 407	a	a	12 - 1.0	15 - 1.2	6 - tr.	4 - tr.	n
Tweefontein 560	a	a	10 - tr.	20 - 2.2	10 - tr.	6 - 0.8	n
DMR.1	a	n	n	n	9 - 1.0	3 - tr.	n
SR.6	n	n	n	n	n	10 - 1.0	n
RTV.1A	n	n	n	n	a	9 - tr.	n
RTV.1	n	n	n	n	n	11 - 1.0	n
RWL.2A	n	n	n	n	8 - 1.8	a	n
RW.1	[illegible]	a	[illegible]	21 - tr.	n	n	n
RW.2	a	a	a	14 - 2.8	n	n	n
SD.1	a	9 - 1.2	28 - 2.1	12 - 1.2	n	[illegible]	n
NS.1	a	n	n	n	6 - 0.4	9 - 1.2	n
Edenkop Mine	a	n	n	n	n	[illegible]	30 - 1.0

Table 18 : Average Thicknesses and Values of Auriferous Conglomerates South of the Sugarbush Fault and Outside South Rand Goldfield

VC : Ventersdorp Contact Reef

KC } reefs in C, D and E
KD } Substages of
KE } Kimberley Stage

BC : reefs in Bird C Substage

MABC : Reefs in A, B and C Substages of Main Stage

GC : Coronation Reef in Government Reef Series

T : thickness of reef in inches

V : value of reef in dwts. per ton

a : no reef developed on horizon

n : reef horizon not intersected or observed

STRUCTURE AND SEDIMENTATION

The pattern of deformation in the area is dominated by four structures - the Sugarbush Fault and three large folds. The fault is of the normal type, follows a sinuous course in a general east-north-easterly direction, and has a considerable, but variable, downthrow to the south. It is the most striking representative of a number of faults of the same class, and these, in turn, are only one group amidst an array of normal, thrust and wrench displacements which affect the whole area. The fold structures are the Deneysville Synform, the Villiers Antiform and the Balfour Synform, large-scale regional features which have been brought about by the superimposition of two fold systems of differing trends. These systems are exactly the same as those disclosed in fine detail by mining operations in the East Rand Basin.

A regional plunge in a general north-north-westerly direction causes the Witwatersrand System to outcrop around the hinge zones of folds against the Old Granite constituting the Devon Dome, east of Heidelberg. These outcrops would have represented the southern limit of preservation of the System had the entire succession, plus the overlying Ventersdorp and Transvaal rocks, not been downthrown by amounts of up to 16,000 feet vertically by the Sugarbush Fault. The result has been that the strata lying up the plunge axes in the Heidelberg area, instead of being eroded, have been dropped into the South Rand area, and thus a considerable development of Witwatersrand rocks has been preserved. The structural pattern clearly delineated by detailed mapping of excellent exposures in the Heidelberg area is thus repeated south of the Sugarbush Fault.

A. THE PATTERN OF FOLDING

(a) Trends of Folds

The traces of the fold axial planes which have been distinguished in the area are shown in Fig. 3. The longitudinal fold axes are those which are parallel to the long axis of the original elongated basin of Witwatersrand sedimentation, while the transverse fold axes are those which are more or less right angles to this long axis, i.e. the former are parallel to the length of the basin, while the latter lie in the same direction as the width. Flexure of the longitudinal axes has taken place, either about the transverse axes, or as a result of a third deformation, the imprint of which has not yet been

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distinguished from that associated with the two clearly recognized fold trends. While the transverse fold axes maintain a relatively constant trend, the flexuring has caused the longitudinal axes to assume a very open Z-shape.

From east to west across the area the strike of the transverse fold axes shows a swing westwards by about 20°. The Winterhoek Anticline on the eastern boundary of the area trends N 15° W, while the Krügersdorp Syncline, towards the western extremity, runs in a direction N 35° W. Along their length, the axes show a slight sinuosity, exemplified by the Springs Syncline, which in the north of the area strikes N 20° W, in the centre N 10° W, and in the south N 35° W. The general trend of the axes of these folds is N 25° - 30° W.

In the South Rand area, the longitudinal fold axes correspond with the diagonal arm of the Z. The two parallel arms, lying outside the area, are represented by the east-north-easterly fold trends in the Potchefstroom Synclinorium which sweeps round the Vredefort Dome, and by the folds which extend from the southern limit of the Kinross Goldfield northeastwards towards the Eastern Transvaal Lowveld. The arm is parallel to that which extends from the Johannesburg Dome through the East Rand Basin towards the Kinross Goldfield. The flexuring can be well seen in the Daleside Anticline, among others. In the extreme northwest of the area this axis trends N 50° W and shows the commencement of the swing around the Vredefort Dome to join the folds in the Potchefstroom Synclinorium. In the centre of the area the axis strikes N 45° W, while at the eastern boundary it has altered to S 70° E as it starts to bend round again in the country south of the Kinross Goldfield. The general strike of the longitudinal fold axes in the area south of the Sugarbush Fault is about N 50° W. The angular difference between the trends of the longitudinal and transverse folds in this area is thus about 25° which, being relatively small, makes it difficult in some instances to classify the folds recognised in the field. Elsewhere in the Witwatersrand Basin, where the transverse folds intersect the parallel arms of the Z, the angular difference is substantially greater, and the two fold trends are clearly distinguishable.

There are no definite indications of the dips of the axial planes for either class of folds. However, the dispositions of successively higher strata in certain synclines suggests that the dip for both categories is towards the southwest at high angles.

In almost all cases, the longitudinal fold axes can be followed through into the East Rand Basin and Potchefstroom Synclinorium, and the names attached to them are those given where the structures have been previously identified. The northwestwards extensions of the transverse folds

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have also been recognised in the past along the West Rand, Central Rand and East Rand areas, and established names have been retained.

(b) Effects of Superimposed Folds

The overall effect of the superimposition of the two fold trends has been the production of a number of structural depressions where syncline has intersected syncline, and structural culminations where anticline has cut across anticline. This phenomenon can be well seen in the development of the Sprucewell Depression where the longitudinal Glenroy Syncline and the transverse Springs Syncline intersect, and in the Beerlaagte Culmination where the transverse Palmietfontein Anticline trends across the longitudinal M[illegible]erton Anticline. Where the cumulative affect of a number of structural depressions is greater, a synform will develop, but where structural culminations combine to produce general elevation of the formation, an antiform will develop. The Deneysville Synform contains the Bethbron and Badfontein Depressions, the Villiers Antiform the Lepelkop, Beerlaagte and Rietkuil Culminations, and the Balfour Synform the Fortuna and Sprucewell Depressions. The Waterval Antiform, plunging towards the Sugarbush Fault, embraces the Boskop Culmination as well as others outside the area. The relative upthrow on the northern side of this fault brings this structure back to surface or to a shallow depth beneath the Karroo formations, and here three further culminations - Kuilfontein, Junction and Vlakplaats - are seen to be developed on the antiform.

The maximum amount of Witwatersrand strata is found in the synforms, and, depending upon the degree of plunge and the extent of erosion, the members might also be preserved on the hinge zones of antiforms as a connecting link between the synforms. Lower and Upper Witwatersrand beds sweep round over the Villiers Antiform between the New Springfield Colliery and the Sugarbush Fault, so that there is an unbroken line, except for portions faulted out, of the Kimberley Reef and Nigel Reef horizons between the western edge of the Deneysville Synform and the eastern limb of the Balfour Synform (see Fig. 3). However, on the Waterval Antiform, there is sufficient room between the granite on the Boskop Culmination and the granite upthrown north of the Sugarbush Fault, for a portion of the Lower Witwatersrand Division only to be found on the hinge zone.

In that the synforms and antiforms are interference structures, their shapes will show a certain amount of irregularity due to the local dominance of one fold trend over the other. The outcrop and suboutcrop pattern of the contact between the Upper and Lower Witwatersrand Divisions in the northeastern and northwestern section of the Balfour Synform is parallel to the longitudinal trend of the Glenroy Syncline, while in the southeastern and southern sections it conforms with the disposition of the transverse trends of the Springs and Zesfontein Synclines. The eastern portion of the Villiers Antiform has a transverse trend parallel to the Palmietfontein Anticline, while the western portion runs in the same longitudinal direction as the Vanderbijl Anticline. In the Deneysville Synform the northern half is aligned along the transverse direction parallel to the Roodepoort Syncline, but the southern half reveals a pattern symmetrical about the longitudinal Verdun Syncline.

(c) Parameters of Folds

The fold pattern along each separate trend in the area is the product of several orders of folds of progressively increasing wavelength and amplitude complementing each other and building up through synclines and anticlines of varying magnitude to the end-product represented by the synforms and antiforms. Sedimentological evidence from the Heidelberg-Roodepoort and Hex River mines suggests that the samllest, or fourth-order, folds belonging in the longitudinal category have an average wavelength of 2500 feet and an amplitude of about 80 feet. Rogers' (1922) mapping adjacent to the Sugarbush Fault, where 14 alternating anticlines and synclines are present in Witwatersrand rocks over a horizontal distance of 13 miles, indicates that the third-order folds have a wavelength of about 5500 feet. Second-order folds, the axial-plane traces of which are shown in Fig. 3, are developed with a wavelength of the order of 14,000 feet ($2\frac{1}{2}$ miles) whereas first-order folds which are represented by the troughs and crests of the synforms and antiforms shown in the same figure have wavelengths of approximately 85,000 feet (16 miles). Insufficient data are available concerning the elevations of marker horizons throughout the area to make assessments of the amplitude of any but the fourth-order folds. Wavelength parameters for the transverse folds are approximately : fourth-order 2000 feet, third-order 9000 feet, second-order 18,000 feet ($3\frac{1}{2}$ miles), and first-order 90,000 feet (17 miles). Again only the second- and first-order structures are shown in Fig. 3.

Because of the local development of culminations and depressions, there are local changes in the directions of plunge, as have been plotted on Fig. 3. On a regional scale, all folds, both of the longitudinal and transverse classes have a general plunge to the north-north-west towards the deepest portion of the Witwatersrand Basin along the Potchefstroom Synclinorium. For the transverse folds, the amount of plunge is about 25° in the hinge zone of the Balfour Synform at the Hex River Mine. The plunge of these folds in the hinge zone of the Deneysville Synform at Annies Rust is of the order of 20°. An indication of the northwestwards plunge of the longitudinal folds can be obtained along the Glenroy Synform. In the South Rand area the hinge zone forms a nose around Greylingstad. Due to the upthrow of the Witwatersrand strata north of the Sugarbush Fault the hinge zone forms a nose again around the old Molyneux Mine. The distance between the duplication of the noses is 23 miles and where the axis crosses the fault the vertical displacement is approximately 16 000 feet, indicating that the plunge of this axis must be of the order of 10°.

The regional plunge indicates an area of considerable structural elevation southeast of the Vaal River and the intersections of Old Granite beneath the Karroo System in a number of boreholes towards Frankfort and Vrede in the Orange Free State (Borchers, 1961) supports this contention. This granite mass, probably consisting of several antiforms building up into one or more domes, has protuberances stabbing deep into the Witwatersrand Basin along the antiforms, as can be clearly seen in the case of the Villiers and Waterval structures.

(d) Ages of Folds

One or more periods of intense deformation preceded the laying down of the Witwatersrand System, as can be seen in the development of isoclinal folds in the Moodies quartzites. Gneissosity in the granite and schistosity in the metamorphics are probably consequences of these same periods. The unconformities between the Swaziland rocks and the Lower Witwatersrand Division testify to the floor of the basin having been folded before deposition of the latter sediments commenced.

Sedimentological evidence from other goldfields shows that both fold trends, presently observed, were in the process of formation during the actual accumulation of the Witwatersrand sediments. They exerted an important control on the distribution and disposition of the material filling the depository and some evidence of this can be seen in the South Rand Goldfield. The longitudinal folds were possibly the first to form, but it would seem that, for the most part, deformation along the two directions was contemporaneous. Vertical movement was also active during Witwatersrand times, as is evidenced not only by the necessary uplift of terrain around the rim of the basin in order to effect the continued supply of erosion products into the depository, but also by the large-scale development of normal faults which came into being in time to influence Upper Witwatersrand sedimentation at least. Vertical movement might have been the prime producer of stress in the horizontal plane responsible for the development of the two fold systems.

The fold pattern possibly influenced the topography of the surface upon which the Ventersdorp lavas were poured out, as has been previously described. The same can be said for the floor of the basin in which Transvaal sediments accumulated, and there is even a suggestion that Karroo sedimentation might be related to the pattern. Certainly, the Witwatersrand, Ventersdorp and Transvaal Systems have been deformed subsequent to deposition along the same fold axes. It is apparent, then, that the folding cannot be dated as being post-one system or another. It started in Witwatersrand times and continued, probably in pulses, through Ventersdorp and Transvaal times, and might have lasted, in a very much enfeebled form, right up to Karroo times.

It can be said that the relative strengths of the two compressive forces responsible for the folding changed with time. The longitudinal folds were brought about by pressure from the northwest and, during the early stages of the history of the Witwatersrand System, this pressure was greater than that from the northeast which caused the transverse folds. During later stages, and during Ventersdorp and early Transvaal times, the pressures were of equal intensity. As the Transvaal period advanced so the northwest compression began to decrease while that from the northeast assumed much greater importance. In post-Transvaal times this was the dominant direction and the flexuring of the longitudinal axes about the transverse axes is probably a product of this period.

Vertical movement was active at all times and the present regional plunge to the northwest is probably the result of the continued elevation of the granite mass southeast of the Vaal River where elevated ground, marking the southeastern rim of the basin, possibly existed since pre-Witwatersrand times.

B. THE PATTERN OF FRACTURING

(a) Faults

Faulting is intense in the area and has played a considerable part in determining the present distribution pattern of the Witwatersrand strata. In Fig. 4 all major faults which can be recognized on the ground or an aerial photographs have been shown. In addition there are appreciable numbers of faults of smaller extent which cause local displacement of strata, as can be seen on outcrop and in mine workings. In Table 19 these major faults have been classified and their relative frequency shown. This information is also plotted on the above figure.

(i) Thrust and Wrench Faults

The most abundant are the Silverbank-type thrust faults which are probably associated with the development of the transverse folds, the axes of the latter trending about N 25° W compared with the average strike of N 10° W for the faults. The Kalkspruit-type dextral wrench faults (N 40° E) and the Drukfontein-type sinistral wrench faults (N 80° E) would then represent the products of shearing in the same stress field in which P max would have been directed from N 60° E. As is normally the case, one direction of shearing is much more pronounced than the other, the Kalkspruit-type being twice as plentiful as the Drukfontein-type.

The remaining wrench faults which have been recognized in the South Rand area - dextral Lagerspoort-type (N 10° E) and sinistral Vaalkop-type (N 30° W) - are therefore possible products of another stress field in which P max was directed from N 20° W. The Mispa-type thrust faults (N 60° E) conform to such a direction. It can be concluded that this was the stress field which brought about the longitudinal folds indicating that the original long axis of the Witwatersrand Basin was orientated east-north-east before being bent about the transverse fold axes. The Vaalkop-type shears are four times as frequent as the other member of the pair.

(ii) Normal Faults

Six of the fault types which are present can thus be related to the two stress fields responsible for the development of the folds. The P max directions - north-north-west for the longitudinal folds and east-north-east for the transverse folds - were approximately at right angles to each other and were contained in horizontal, or nearly horizontal, planes. The remaining three fault-types - Brandkraal, Malanskraal and Sugarbush - are all of the normal variety and probably represent the effects of a vertical P max with was operative throughout the history of the area. Neither the Brandkraal - nor the Malanskraal-type are as frequent or of such consequence as the Sugarbush-type.

Type	Trend	Nature	No. Observed
Brandkraal	N 75 W	normal	8
Malanskraal	N 60 W	normal	6
Vaalkop	N 30 W	sinistral wrench	17
Silverbank	N 10 W	thrust	18
Lagerspoort	N 10 E	dextral wrench	4
Kalkspruit	N 40 E	dextral wrench	11
Mispa	N 60 E	thrust	12
Drukfontein	N 80 E	sinistral wrench	6
Sugarbush	N 80 E	normal	13

Table 19 : Classification of Observed Major Faults South of the Sugarbush Fault

Formation	Locality	Point	Most ← Frequency → Least			
			1	2	3	4
Karroo sandstones	Riviersdraai 416	4	N 85 E	N 40 W	N 30 E	N 30 W
Ventersdorp lavas	Lagerspoort 406	1	N 45 W	N 15 W	N 65 E	N 5 E
	Vlakfontein 556	3	N 30 W	N 20 W	N 25 E	N 80 W
	Modderfontein 410	7	N 45 W	N 20 W	N 75 W	N 60 E
Kimberley quartzites	Modderfontein 410	8	N 45 W	N 70 E	N 5 E	N 85 W
	Malanskraal 407	9	N 55 W	N 55 E	N 65 W	N 5 W
Main quartzites	Tweefontein 560	10	N 40 W	N 35 E	N 10 W	N 80 W
Government quartzites	Rietbuilt Estates 505	2	N 35 E	N 5 E	N 15 E	N 80 W
Moodies quartzites	Modderfontein 562	5	N 10 W	N 20 E	N 30 E	N 10 E
	Panfontein 452	6	N 5 E	N 15 E	N 15 W	N 85 W

Table 20 : Main Trends of Most Frequent Joints South of Sugarbush Fault

At least 13 faults of the last-named type occur in the area and they are characterised by their sinuous courses and by substantial vertical displacements in some cases. On Fig. 4 the displacements along the Sugarbush Fault, calculated by Rogers (1922), have been shown to reach a maximum of 16,000 feet in the Fortuna locality. Insufficient data are available to the east of this point, but to the west there is a gradual decrease to 4500 feet south of the old Heidelberg-Platkop Prospect, beyond which there is an increase again followed by a further diminution. The maximum displacement occurs over the centre of the Balfour Synform and the first minimum over the centre of the Villiers Antiform. This would suggest that the strata moved downwards in a number of separate fault blocks of restricted size, rather than in the form of solid, extensive masses of rock. It is possible that the other bounding faults of these blocks belonged to the Brandkraal- and Malanskraal-type, in which case the blocks must have had a narrow diamond shape. There was a preferential dropping of these fault blocks into depressed areas and relative retention above elevated areas formed by folding.

The most conspicuous of this type of displacement are the paired Sugarbush and Meyerskop Faults and the Dasville and Bergsig Faults. They can be traced across the whole of the area and are reflected through the Karroo cover in the form of drainage patterns and linear features on aerial photographs. Vertical movement on those faults south of the Sugarbush Fault is as impressive in places as on the latter feature. In the Arndes Rust locality movement of up to 8000 feet appears to have developed on the Dasville Fault.

In most cases the downthrown side of such faults lies to the south, but in the case of the Strybult, Witpoort, Doornhoek and Groenvlei Faults the reverse is the case. This latter group probably represent antithetic faults which are usually developed where large-scale normal faulting has taken place. They occupy curved fault planes down dip which hade towards the Sugarbush and Meyerskop Faults and towards the Dasville and Bergsig Faults.

A conspicuous characteristic of these faults is their tendency to change course along certain directions. At first appearance this sinuosity would seem to be caused by the plane of movement moving from one type of fault to another so that the fault actually represents a compound of a large number of intersecting linear planes. However, the parallel nature of the curving courses across the whole area and the tendency for the points of flexure to be aligned along constant directions from one fault to the next, renders this assumption open to doubt. Closer examination of the points of flexure show that they coincide with the points of intersection of the fault planes and the axial plane traces of transverse folds. The direction of concavity of the flexure points also assumes a constant pattern with the concave side of the curved fault plane being to the south where a synclinal axis crosses and to the north where an anticlinal axis intersects the fault. This is precisely what would happen if a southward-dipping planar feature were folded. The Sugarbush-type faults are normal faults with downthrows to the south and therefore dip to the south. The sinuosity is thus a result of the originally east-north-easterly oriented fault planes being bent around the axes of transverse folds. This is the same effect, only less marked, which these transverse folds have on the longitudinal fold axial plane traces.

(iii) Relative Ages of Faults

Because the thrust and wrench faults are associated with folding processes which were contemporaneous, it follows that these displacements probably have the same age of origin. However, since compression from the east-north-east continued to prevail after that from the north-north-west subsided, faults of the Silverbank-, Kalkspruit- and Drukfontein-types appear to displace those of the Mispa-, Vaalkop- and Lagerspoort-type. Tectonic adjustments consequent upon the continued vertical movement reactivated all previous lines of weakness, with the result that, in many instances, the reverse of the above holds true, as a vertical P max probably continued to act after the horizontal east-north-east P max weakened.

Only the Sugarbush-type fault planes have been folded to any extent, indicating that they were probably in existence before the other fault-types which still maintain a relatively linear disposition. As compression from the east-north-east has been sporadically continuous since early Witwatersrand times, it follows that the longer any structures have existed, the more they will show the affects of this stress field. The relatively older age of these faults is supported by detailed work undertaken by Mountain (1962) in the Lagerspoort locality where it has been shown that the Sugarbush Fault is displaced by faults which can be assigned to the Lagerspoort-, Kalkspruit-, Mispa-, Drukfontein- and Brandkraal-types.

All faults have been reactivated at various periods up to and including Karroo times. There is evidence of strata of this System suffering relatively small displacements along faults of the Sugarbush- and Silverbank-types. Hence, it is not feasible to date the movements in any of the faults as being exclusively of any particular period in geological time.

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(b) Joints

The pattern of jointing in Witwatersrand and other rocks in the area between the Sugarbush Fault and Vaalrand has been studied by Mountain (1962). The results have been summarised in Table 20 and plotted in Fig. 4. There is a marked difference between the patterns in post-Jeppestown formations and those in rocks formed earlier than this series. In the Main and Kimberley quartzites, the Ventersdorp lavas and the Karroo sandstones, joints oriented at about N 45^{o} W predominate, but in the Government Reef and Moodies quartzites no such joints have been observed. Each formation has it's characteristic joint pattern with certain directions of fracturing peculiar to it and not represented at all in other groups of rocks.

With the complex structural imprint left upon the area by a tectonic history of faulting and folding caused by a vertical and two horizontal stress fields of varying relative intensities at various times, attempts to decipher the significance and origins of the different patterns are fraught with considerable difficulty. However, it is possible to relate, in part, the pattern of fracturing in the Moodies and Government Reef Series to the horizontal stress field which produced the longitudinal folds. The predominant joints in these formations seem to be of the shear-type. The most prevalent fractures in the Upper Witwatersrand and Ventersdorp rocks are of the tension-type and can be fitted in reasonably well with the horizontal stress field which existed during the time of development of the transverse folds. The Karroo joints appear to have been brought into existence by a vertical stress field.

A possible conclusion which might be drawn from the variations in the joint patterns supports the deductions made from the fold patterns that although both horizontal stress fields were more or less contemporaneous, the P max directed from the north-north-west was stronger in pre- and Lower Witwatersrand times, whereas the P max acting from the east-north-east gradually assumed progressively greater importance in Upper Witwatersrand, Ventersdorp and Transvaal times. Vertical uplift was more important than either of these horizontal compressive forces during Karroo times.

C. THE PATTERN OF SEDIMENTATION

(a) Variations in Thickness of Strata

(i) Regional Variations

In Table 21 the various series and stages which comprise the Witwatersrand System have been listed for different localities in decreasing orders of thickness. What is significant in this arrangement is that the trends of diminishing thickness remain the same for all groups of rocks from locality to locality. The sediments contained in any one stage or series are thickest in the Heidelberg area, and have the same, or slightly lower, thickness in the Wilgepoort-Fortuna locality. In the Witkleifontein locality they have a lesser development than in either of these two localities, but represent a greater accumulation than in the Stryfontein, Heidelberg-Roodepoort Mine and Hex River Mine localities, where the thinnest development is always round the Hex River Mine. This applies only in the case of actual sedimentary material in the particular stage or series. The figures shown for the Bird Stage do not represent the whole thickness of this group, the lava flows comprising the two Bird Amygdaloids and the Bird Marker having been excluded. The regional pattern of changing thicknesses of the flows is very much different to that associated with the sediments, and it is apparent that, although local controls for the accumulation of volcanic and sedimentary material might have been the same, the regional distribution of the lavas was influenced by conditions which did not prevail during the periods of sedimentary infilling of the basin.

Isopach contours prepared from the data in Table 21 would show that the form-lines strike in a direction more or less normal to the axes of the longitudinal folds, indicating that the formations, as presently disposed, thin towards the southeast. Maximum thicknesses occur along the axis of the Glenroy Syncline which structure, when continued westwards into the basin, probably coincides with the trough of the Potchefstroom Synclinorium. Information from other areas suggests that maximum thicknesses always occur along this axis, increasing in magnitude westwards to the original central, and deepest, portion of the depository somewhere between Vredefort and Potchefstroom. From the northwest where one shoreline of the original basin clearly lay, strata thicken towards this axis and then thin again southeastwards away from it. This latter wedging affect can be taken as strong evidence for the closing of the basin against a second shoreline beyond the southern limit of the South Rand area. Near-shore conditions, as shown in the major goldfields along the northwestern rim of the basin, are most favourable for the concentration of economic quantities of gold. Thus,

Formation	Heid.	W - F.	Witkf.	Stryf.	Heid-R.	Hex R.
Elsburg Stage	650	600	600	580	400	350
Kimberley Stage	2450	2400	2100	1320	900	750
Kimberley-Elsburg Series	3100	3000	2700	1900	1300	1100
Bird Stage Sediments Only	790	640	650	-	320	250
Main Stage	810	710	250	-	280	200
Main-Bird Series Sediments Only	1600	1350	900	-	600	450
Jeppestown Series	1800	1800	1200	-	-	800
Government Reef Series	4100	3900	2800	-	-	2500
Hospital Hill Series	3200	3200	2500	-	-	2000
Upper Witwatersrand Division	4900	4700	3600	-	2500	1900
Lower Witwatersrand Division	9200	8900	6500	-	-	5300
Witwatersrand System	14,100	13,600	9,100	-	-	7,200

Table 21 : Systematic Geographic Variation in Thickness of Members of the Witwatersrand System South of the Sugarbush Fault (thickness in feet)

Heid : Heidelberg area
W - F : Wilgepoort-Fortuna locality
Witkf : Witkleifontein locality
Stryf : Stryfontein locality
Heid-R : Heidelberg-Roodepoort Mine
Hex-R : Hex River Mine

on the evidence of the variations of thickness alone, the South Rand area should have acted as host to significant auriferous deposits. However, it has been shown by the data referring to conglomerates and gold mineralisation, that this is clearly not the case. The discrepancy must therefore be the result of sedimentation factors other than depth of deposition and distance from a shoreline.

The fact that the isopach contours would also show a similar pattern for each series or stage must mean that the morphology of the basin floor in this area was the same at the commencement of each major cycle of sedimentation. Depressions, after having been filled up during one cycle, must have been depressed again approximately along the same trough axes before the onset of the following cycle. Both tectonic stress fields existed contemporaneously through geological time, and the longitudinal and transverse folds, and their accompanying faults, were repeatedly being activitated along the same axes. The constant pattern of sedimentation with respect to formational thicknesses, might thus be a result of this constantly reactivated fold pattern. Troughs of maximum accumulation coincided with the hinge zones of major synclines, while thinner developments of strata took place over anticlinal axes. The interference pattern produced by the two fold directions was responsible for local superimposed variations of thickness on the regional trends where structural depressions and culminations occurred.

(ii) Local Variations

Isopach maps have been prepared for various members of the Bird Stage of the Main-Bird Series in the South Rand Goldfield. One of these - for the Kimberley Shales - is shown in Fig. 5. The contours for all members are consistently aligned in a general northwesterly direction, approximately parallel to the axial plane trace of the Glenroy Syncline. Detailed structural investigations in this locality have shown that numerous third- and fourth-order folds of the longitudinal class lie to the southwest of the Glenroy axis. The maximum thicknesses, whether of Kimberley Shale or Upper Bird Quartzites coincide with such synclines, while thin developments are located over anticlinal axes.

The Kimberley Shales thin to less than 40 feet over an anticline between Boreholes RT.5 and RT.8, thicken to over 120 feet between RT.2 and RT.4, and then thin again to less than 80 feet between RT.6 and T.1. Thickening again is suggested along a synclinal axis to the northeast of the Kildare and Heidelberg-Roodepoort mines. Over the first anticline the Upper Bird Quartzites are less than 20 feet thick, over the syncline 70 feet, and over the second anticline less than 50 feet. Insufficient complete intersections of the Upper Bird Amygdaloid were made to carry comparison further than saying that the maximum thickness of over 500 feet of this lava flow occurs along the syncline between RT.2 and RT.4. Similar relations between isopach maxima and minima and longitudinal synclines and anticlines respectively apply to the locality around the Hex River and Southeast Witwatersrand mines. There are also some indications that the thinnest strata are present where culminations have been formed by the second-order transverse Sundra and Tweefontein Anticlines cutting across the fourth-order longitudinal fold axis.

In both mining localities the axes of the isopach maxima tend to remain fairly constant in plan position from one formation to the next, but the axes of the minima show an inclination to wander to a certain extent between the axes of the maxima. The centre-lines of the local troughs thus remained more or less constant, but the widths altered from formation to formation. Variations in the intensity of downward movement in the synclines underlying the local troughs at each pulse of tectonic activity possibly caused differential tilting of the strata in between, and this led to the migration of the axes of the intervening ridges towards the syncline with the lesser downwarp.

The local variations in thickness point to the same conclusion suggested by the regional variations, viz. that the accumulation of Witwatersrand sediments in this portion of the basin was influenced by the longitudinal folds to a marked extent and also, possibly, by the transverse folds to a lesser degree. Sedimentation and folding therefore must have gone hand-in-hand. Previously deposited strata were folded along constant axes prior to each cycle of sedimentation. In this way local troughs containing relatively greater accumulated thicknesses of any of one formation were continuously being stacked vertically one above the other. A zone of relatively thicker Elsburg quartzite, say, on surface could thus be employed to demarcate zones of thicker development of any underlying unit in the Witwatersrand System.

(b) Facies Changes

Zones of equal thicknesses of accumulated Witwatersrand strata occur on both sides of the Glenroy Syncline, but the facies developed in such zones show very marked differences. In the Main-Bird Series, say, where 4000 feet of sediments occur north of the fold axis, quartzites exclusively are developed below the Kimberley Shales and conglomerate bands are numerous, robust and continuous along strike. Where the equivalent thickness is present south of the syncline, shale beds are conspicuous components the quartzites themselves are more argillaceous, and conglomerate bands are poorly-developed, lenticular gradational into grits, and in many places totally absent. This applies to all stages and substages within the Witwatersrand System with a few minor local exceptions, such as the development of the Coronation Reef at the Edenkop Mine.

In Table 16, the frequency and nature of conglomerate development in the Upper Witwatersrand Division have been shown, and in the section dealing with conglomerates and gold mineralisation, evidence was presented to demonstrate the marked deterioration in the importance of conglomerates between the Central Rand and the South Rand area. The relative proportions of conglomerates, quartzites and shales in some localities south of the Sugarbush Fault have been shown for the Coronation Stage in Table 3, for the Main Stage in Table 5, for the Bird Stage in Table 6, for the Kimberley Stage in Tables 9, 10 and 11, and for the Elsburg Stage in Table 11.

In the South Rand area, therefore, near-shore conditions, as indicated by the southeastwards wedging-out pattern of the thickness of accumulated material, did not act as host to the same assemblage of sediments as did similar conditions north of the Glenroy Syncline. The prevalence of fine-grained components in the form of quartzites and shales over coarser-grained varieties such as conglomerates and grits suggests that no material was contributed into the basin from the original edge of the depository lying south of the Vaal River. The uninterrupted pattern of facies changes from the northwestern half of the basin across the Glenroy Syncline into the south-eastern half indicates that the source of material was on the northwestern edge of the basin only, and that the distribution pattern of sediments from this provenance was not influenced by the influx of any substantial amounts of infill from the opposite edge. Large amounts of heavy minerals, including gold, were not transported great distances into the basin from the shore-line. Thus, such components, coming in along the northwestern edge, did not reach the Glenroy Syncline in any substantial quantities, let alone sweep beyond this axis of the basin. With very little gold washing from the north-west and no material being contributed from the southeastern rim, it is apparent why the near-shore conditions in the South Rand area are not associated with any significant accumulations of the metal.

(c) Direction of Transport of Sediments

Corroboratory evidence for the mode of distribution of sediments postulated above is provided by the directions of transportation of material within the basin, as determined from cross-bedding observations. Hargraves

(1962) concluded that the pattern of such measurements in the Main-Bird Series from the East Rand southwards indicates a consistent southeasterly direction of transport continuing as far south and southeast of Heidelberg as the Main-Bird Series can be identified. More detailed and extensive work by Mountain (1962) has produced the results which have been summarised in Table 22 for cross-bedding in Moodies quartzites, in Table 23 for quartzites in the Jeppestown, Government Reef and Hospital Hill Series, in Table 24 for quartzites in the Main Stage, and in Table 25 for quartzites in the Kimberley Stage. A condensation of all this information is presented in Table 26. The azimuths of the main directions of cross-bedding at each point have also been plotted in Fig. 3.

The pattern of azimuths remains more or less the same north and south of the Sugarbush Fault. For the Government Reef and Jeppestown Series and for the Main and Kimberley Stages, the directions of transportation of the sediments are essentially S 55° E and S 30° W, the two azimuths being almost at right angles to each other. A different pattern prevails for the Hospital Hill Series and yet another for the Moodies Series. Certain aspects of the former are also discernible in the Government Reef Series. The parallelism between the S 55° E azimuths and the trends of the longitudinal fold axes is considered to be more than coincidental, particularly in view of the fact, mentioned previously, that the strike of the isopach form-lines is also parallel to the fold axes.

Considering certain azimuths in the Government Reef and Hospital Hill Series, there appears to have been a local clockwise direction of transport round the granite mass forming the southwestern portion of the Devon Dome. Material seems to have moved from the east-south-east westwards ther northwards, and finally north-north-eastwards. This pattern is totally different from that which prevails in the Government Reef, Jeppestown Main-Bird and Kimberley-Elsburg Series away from the granite mass where sediments were transported by currents flowing consistently to the southeast across the central and southeastern portions of the basin. The contrary pattern in the lower members of the Lower Witwatersrand Division might offer an explanation for the anomalous development in the Ederkop-Steyrskraal locality of significant auriferous conglomerates in the Coronation Stage of the Government Reef Series. If the material forming these reefs came from southeast, as the cross-bedding seems to show, then it would have travelled a relatively short distance from the southeastern rim of the basin, consequently retaining its heavy mineral components. It has been discussed previously how difficult it is to fit these conglomerates into the pattern of facies change brought about by material entering the basin along the northwestern rim only and then flowing southeastwards.

Locality	Direction of Flow	Thickness of Unit	Inclination of Foresets
Vlakfontein 448	N 55 E N 85 E	12	25
Panfontein 452	N 85 E S 65 W	9	21
Modderfontein 562	N 70 E S 85 W	13	18
Averages	N 80 E S 75 W	11	21

Table 22 : Parameters of Cross-Bedding in Quartzites of the Swaziland System South of the Sugarbush Fault
(thickness in inches, inclination in degrees)

South of Sugarbush Fault				North of Sugarbush Fault			
Point	Direction of Flow	Thickness of Unit	Inclination of Foresets	Point	Direction of Flow	Thickness of Unit	Inclination of Foresets
				7 JTS	N 80 E S 55 E S 15 W	10	18
				Av. JTS	S 55 E S 15 W	10	18
5 GRS	N 65 W S 85 E S 60 W	5	18	3 GRS	N 45 E S 45 E S 25 W	6	15
				4	N 60 E S 60 E S 5 W	9	22
				6	N 85 E S 25 W	8	21
Av. GRS	S 85 E S 60 W	5	18	Av. GRS	S 50 E S 20 W	8	21
				1 HHS	N 25 W S 80 E	6	26
				2	N 40 E S 85 E	9	19
				Av. HHS	N 40 E S 85 E	8	22

Table 23 : Parameters of Cross-Bedding in Quartzites of the Lower Witwatersrand Division South of the Sugarbush Fault Compared with Those of the Heidelberg Area (thickness in inches, inclination in degrees)

1. Blinkpoort 396
2. Rietpoort 193
3. Steynskraal 399
4. Lagerspoort 406
5. Rietbult Estates 505
6. Rietpoort 193
7. Steynskraal 399

JTS. Jeppestown Series
GRS. Government Reef Series
HHS. Hospital Hill Series

South of Sugarbush Fault				North of Sugarbush Fault			
Point	Direction of Flow	Thickness of Unit	Inclination of Foresets	Point	Direction of Flow	Thickness of Unit	Inclination of Foresets
15	S 50 E S 25 W	13	24	8	N 80 E S 25 W	16	22
				9	S 75 E S 10 W S 70 W	15	16
				10	N 65 E S 50 W	12	14
				11	S 15 E S 45 W	13	20
				12	S 15 E S 35 W	13	15
				13	S 55 E S 20 W S 75 W	15	15
				14	S 70 E S 10 E S 50 W	10	16
Av.	S 50 E S 25 W	13	24	Av.	S 65 E S 40 W	13	17

Table 24 : Parameters of Cross-Bedding in Quartzites of the Main Stage South of the Sugarbush Fault Compared with Those of the Heidelberg Area (thickness in inches, inclination in degrees)

8. Poortje 389
9. Poortje 389
10. Houtpoort 392
11. Nooitgedacht 390
12. Elandsfontein 412
13. Elandsfontein 412
14. Platkoppie 420
15. Tweefontein 560

South of Sugarbush Fault				North of Sugarbush Fault			
Point	Direction of Flow	Thickness of Unit	Inclination of Foresets	Point	Direction of Flow	Thickness of Unit	Inclination of Foresets
16	S 45 E S 50 W	19	17	17	N 80 E S 20 E S 45 W	16	19
21	S 45 E S 25 W	17	22				
22	S 45 E S 45 W	12	40				
Av.	S 45 E S 40 W	16	26	Av.	S 20 E S 45 W	16	19

Table 25 : Parameters of Cross-Bedding in Quartzites of the Kimberley Stage South of the Sugarbush Fault Compared with Those of the Heidelberg Area (thickness in inches, inclination in degrees)

16. Modderfontein 410
17. Langlaagte 186
21. Malanskraal 407
22. Roodepoort 598

Formation	Direction of Flow	Thickness of Unit	Inclination of Foreset
Kimberley Stage	S 40 E S 40 W	16	25
Main Stage	S 60 E S 35 W	13	18
Jeppestown Series	S 55 E S 15 W	10	18
Government Reef Series	S 60 E S 30 W	7	20
Hospital Hill Series	N 40 E S 85 E	8	22
Moodies Series	N 80 E S 75 W	11	21

Table 26 : Summary of Generalised Parameters of Cross-Bedding in Quartzites of the Witwatersrand and Swaziland Systems between the Heidelberg Area and the South Rand Goldfield

If there were local additions in the South Rand area of sedimentary fill from the southeastern shoreline, then they were restricted to the very earliest periods in the history of the Witwatersrand Basin. From the latter stages of the Government Reef Series onwards cross-bedding azimuths give no indication of transport into the basin from the south, southeast or east. This confirms the conclusions drawn from a consideration of the facies represented in the various series that no appreciable amounts of material were contributed to the depository from the original margin lying south of the Vaal River.

Detailed measurements in the Kimberley Stage rocks surrounding the four mines in the South Rand Goldfield confirm the prevalence of two azimuths of cross-bedding, one parallel and the other normal to the axial plane trends of the longitudinal folds. This is illustrated in Fig. 5 where the long axes of the zones of maximum and minimum isopachs of the Kimberley Shales are parallel to the axis of the Glenroy Syncline, and the main azimuth of cross-bedding is parallel to the isopach form-lines. It would seem that sedimentary fill entering the basin from the northwestern rim was transported into the South Rand area along troughs in the floor which were developed over longitudinal synclines. Spillage of material, possibly during periods of surging, consistently took place over the anticlinal ridge lying to the southwest of the particular synclinal trough. Movement of the overflow in this direction is indicated by the S 30° W azimuth of cross-bedding.

(d) Sedimentation and Gold Mineralisation

All aspects of sedimentation show that the material from which the Upper Witwatersrand gold-bearing conglomerates were formed entered the depository from the northwestern rim, moved southeastwards, and dissipated itself before reaching the trough of the basin which was possibly located along the Glenroy Syncline. The total amount of gold available for deposition in the South Rand area was thus very considerably less than that in the areas to the north and northwest where the East Rand and Central Rand goldfields were formed. What gold did reach the South Rand area was concentrated in and confined to long, narrow payshoots in the Kimberley Reef only. None of the gold and conglomeratic material deposited extensively in the East Rand Basin during the Main Reef Leader (Nigel Reef) period was transported much further south than Heidelberg. The sedimentological characteristics of the Main Stage, as developed in the South Rand area, clearly show that an environment favourable to the accumulation of gold simply did not exist at the time of considerable reef formation to the north. The anomalous development of payable conglomerates in the

Coronation Stage of the Government Reef Series is possibly the result of an anomalous direction of transport of material from the southeastern rim of the basin during early Witwatersrand times. However, insufficient sedimentological data are available for the South Rand area to prove conclusively the validity of this deduction. If a potential source of gold did exist in the originally elevated land south of the Vaal River, then the mode of development of the basin in post-Government Reef times did not permit the erosion products from disintegration of the positive area to enter the Witwatersrand depository lying to the north and northwest.

The payshoots developed in the Kimberley Reef in the South Rand Goldfield (Fig. 5) are parallel to the main azimuth of cross-bedding and to axes of longitudinal folds. They were obviously formed in the deepest portions of long, narrow troughs in the Kimberley Shales, where the maximum amounts of pebbles and gold accumulated. The troughs formed as a result of down-warping along pre-existing synclinal axes during a pulse of horizontal compression subsequent to the deposition of the shales and prior to the washing in of the coarser clastics. The pulse was probably associated with, or the product of, vertical uplift of the northwestern rim of the basin, as a result of which elevation additional material in the source provenance was made available for erosion and distribution southeastwards into the Witwatersrand Basin. After the formation of the payshoots further deformation of a similar nature folded the conglomerates into their present synclinal form.

The orientation of payshoots in the South Rand Goldfield with respect to sedimentological and structural features appears to be the same as that found in the East Rand Basin. Zones of optimum Kimberley Reef development in the latter locality have their long axes in the direction of cross-bedding azimuths. Most of the shoots lie parallel to the axes of the longitudinal folds, but some are also aligned along the trends of the transverse folds, a feature which has not been observed in the South Rand Goldfield. In the Witwatersrand Nigel Mine at Heidelberg the payshoots in the Main Reef Leader are also parallel to the direction of transport indicated by cross-bedding and to the longitudinal fold axes. In Fig. 5 one such shoot has been plotted for comparison purposes. It can be seen that reef development at the southern end of the East Rand Basin and in the South Rand Goldfield was the product of sedimentological conditions which were identical, to all intents and purposes, in the Main and Kimberley Stages. Shoots are elongated along the southeasterly direction of transport of conglomeratic material, and the relative importance of individual payshoots decreases, in a very general way, in the direction of the second cross-bedding azimuth, i.e. greater concentrations of gold occur towards the northeast in the direction of the axis of the Glenroy Syncline and structures beyond this in the East Rand and Kinross Goldfields. The optimum pattern of exploration activities in the South Rand area would therefore involve proceeding as far upstream as possible along the second, southwesterly, cross-bedding azimuth, and then searching for long, narrow payshoots, possibly less than 1000 feet wide, oriented parallel to the first, southeasterly, cross-bedding azimuth.

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GOLD PRODUCTION

The total amounts of gold produced from individual mines in the 75-year history of the South Rand Goldfield are shown in Table 27 for the Edenkop Mine, in Table 28 for the Wilgepoort Prospect, in Table 29 for the Kildare Mine, in Table 30 for the Heidelberg-Roodepoort Mine, in Table 31 for the Southeast Witwatersrand Mine, and in Table 32 for the Hex River Mine. Production from the field as a whole is summed up in Table 33.

The most important producer has been the Heidelberg-Roodepoort Mine which, in 18 years of actual production during the 75-year period, crushed 78 per cent of the ore treated in the area, and recovered 83% of the gold. The average recovery grade of 3.61 dwts. per ton was not the highest for the area, being exceeded by the figure of 5.53 dwts. per ton recorded by the Edenkop Mine. The purest gold was obtained from the Kildare and Southeast Witwatersrand mines where workings were at a shallower depth below surface than at the Edenkop, Heidelberg-Roodepoort and Hex River mines. Although records are insufficient to offer conclusive proof, there is a suggestion that the silver content of the Kimberley Reef increased with depth below surface on both the Heidelberg-Roodepoort and Hex River mines. On the former the average increase was about 80 parts of silver per 1000 of bullion per 500 feet inclined depth on the plane of the reef, and on the latter about 60 parts of silver per 1000 of bullion per 500 feet inclined depth.

The relative insignificance of the South Rand Goldfield can be clearly seen when the following comparisons are made with the Central Rand :

	Tons Crushed	Ozs. Gold Recovered	Average Recovery Grade
Central Rand	1,023,063,519	260,934,953	5.1 dwts. per ton
South Rand	267,969	45,786	3.4 dwts. per ton
SR percentage of CR	0.026%	0.018%	67%

When production from the whole of the Witwatersrand Basin is considered, the very minor nature of the South Rand Goldfield is even further emphasized, its gold output being no more than 0.007 per cent of the total amount won from the seven major and two minor fields.

* *

Year	Name of Producing Company	Tons Treated	Ozs. Gold	Ozs. Silver	Recovery Grade dwts Au./T.	Fineness Au parts /1000
1906/7	Edenkop Syndicate	7,086	1928.42	395.02	5.44	830
1907/8	Edenkop Syndicate	3,557	1015.30	197.42	5.71	837
Total for 2 years' actual production		10,643	2943.72	592.44	5.53	832

Table 27 : Gold Production from the Edenkop Gold Mine on Rietbult Estates 505

Year	Name of Producing Company	Tons Treated	Ozs. Gold	Ozs. Silver	Recovery Grade dwts Au./T.	Fineness Au parts /1000
1913	M.C. Tribute	266	1.77	0.42	0.13	808
Total for 1 years' actual production		266	1.77	0.42	0.13	808

Table 28 : Gold Production from the Wilgepoort Prospect on Rietfontein 561

Year	Name of Producing Company	Tons Treated	Ozs. Gold	Ozs. Silver	Recovery Grade dwts Au./T.	Fineness Au parts /1000
1908/09	Kildare Gold Mine	123	32.52	3.63	5.29	900
1941	Day Dale Mining Co. (Pty.) Ltd.	2566	326.67	34.97	2.55	903
1942	do.	2612	310.58	32.19	2.38	906
Total for 3 years' actual production		5301	669.77	70.79	2.53	904

Table 29 : Gold Production from the Kildare Gold Mine on Roodepoort 598

Year	Name of Producing Company	Tons Treated	Ozs. Gold	Ozs. Silver	Recovery Grade dwts. Au./T.	Fineness Au. parts /1000
1892	South African Trust and Finance Co.	200	103.60	10.80	10.36	906
1896	New Heidelberg Roodepoort Gold Mining Co. Ltd.	12,837	2031.10	435.31	3.26	824
1897	do.	61,340	9725.45	3311.34	3.17	746
1906/7	Bon Accord Syndicate	3,910	735.01	11.10	3.76	985
1907/8	do.	23,072	5512.23	589.45	4.78	903
1908/9	do.	29,253	6110.29	755.00	4.18	890
1909/10	do.	23,840	5645.00	699.00	4.74	808
1910	do.	9,447	2229.00	259.00	4.72	896
1911	New Heidelberg Roodepoort Tribute	6,375	1228.00	140.00	3.85	898
1912	do.	10,818	2977.00	335.00	5.60	899
1921	Alwado Syndicate	445	47.92	7.11	2.15	871
1922	do.	35	3.26	0.82	1.86	799
1930	Bawick and Charles Syndicate	182	5.25	1.31	0.58	800
1931	Miss D. Charles	23	2.49	0.19	2.16	929
1938	Greylingstad Gold Recovery Syndicate	2,100	151.72	16.84	1.44	900
1939	do.	7,150	519.89	50.20	1.45	912
1939	Goedehoop Maatskappy	3,503	148.62	21.71	0.85	873
1940	do.	11,544	421.92	61.90	0.73	872
1941	do.	852	214.63	34.43	5.04	862
1942	do.	2,549	39.01	5.18	0.31	883
Total for 18 years' actual production		209,475	37,851.39	6745.69	3.61	849

Table 30 : Gold Production from the Heidelberg-Roodepoort Gold Mine on Roodepoort 598

Year	Name of Producing Company	Tons Treated	Ozs. Gold	Ozs. Silver	Recovery Grade dwts. Au./T.	Fineness Au. parts /1000
1935	South East Witwatersrand Gold Mining Co. Ltd.	2,176	157.08	18.65	1.44	894
1936	do.	355	29.07	4.18	1.64	874
1937	do.	5,4[illegible]2	646.[illegible]	60.39	2.38	9[illegible]4
1938	do.	3,342	415.43	44.05	2.49	904
Total for 4 years' actual production		11,305	1247.89	127.29	2.21	907

Table 31 : Gold Production from the Southeast Witwatersrand Gold Mine on Hexrivier 634

Year	Name of Producing Company	Tons Treated	Ozs. Gold	Ozs. Silver	Recovery Grade dwts. Au./T.	Fineness Au. parts /1000
1911	Hex River Exploration Co. Ltd.	3,779	434.42	58.78	2.55	892
1912	do.	1,550	88.70	21.00	1.14	809
1913	do.	2,284	258.99	68.00	2.27	722
1935	New Rand Reefs Ltd.	1,487	21.57	4.19	0.29	637
1936	Phoenix Reefs (Pty.) Ltd.	2,407	156.56	37.76	0.92	806
1937	do.	8,007	943.97	199.98	2.36	825
1939	Last Hope Mine	10	3.47	0.50	6.94	874
1940	do.	102	23.17	3.09	4.54	882
1946	South Geduld Gold Mines Ltd.	7,744	703.44	171.59	1.82	804
1948	do.	2,228	321.20	67.73	2.88	825
1961	Doravale Investments (Pty.) Ltd.	310	54.78	0.99	3.53	982
1962	do.	61	11.56	1.83	3.79	[illegible]
Total for 12 years' actual production		[illegible]	3071.93	635.44	1.98	[illegible]

Table 32 : Gold Production from the Hex River Gold Mine on Hexrivier 634

Name of Producer	Tons Treated	Ozs. Gold	Ozs. Silver	Recovery Grade dwts. Au./T.	Fineness Au. parts /1000
Heidelberg-Roodepoort Gold Mine	209,475	37,851.39	6,745.69	3.61	849
Hex River Gold Mine	30,979	3,071.83	635.44	1.98	829
Edenkop Gold Mine	10,643	2,943.72	592.44	5.53	832
Southeast Witwatersrand Gold Mine	11,305	1,247.89	127.29	2.21	907
Kildare Gold Mine	5,301	669.77	70.79	2.53	904
Wilgepoort Prospect	266	1.77	0.42	0.13	808
Total Production	267,969	45,786.37	8,172.07	3.42	848

Table 33 : Total Gold Production from Individual Mines in the South Rand Goldfield

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KEY TO FIGURES

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