27. *The GEOLOGY of the GOLD-BEARING and ASSOCIATED ROCKS of the SOUTHERN TRANSVAAL.* By WALCOT GIBSON, Esq., F.G.S.
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I. INTRODUCTION.

(1) *General Sketch of the Geology of the Southern Transvaal.*

THE rocky floor of the Transvaal is very distinct from that of South Africa in general. Travelling for several hundred miles through the northern parts of Cape Colony and the Orange Free State, such strata as are seen consist of horizontal sandstones and shales of Karoo and Stormberg age. These are injected and overflowed in numberless directions by masses and thin sheets of igneous matter, while worn-down stumps of volcanic necks can be frequently recognized. But in the Transvaal the nature of the strata undergoes a complete change. Instead of flat-lying sandstones and shales of the wide-spreading Karoo formation, we find twisted and highly inclined quartzites and conglomerates of undetermined geological age. The igneous rocks occur more in the form of bosses than sheets, and make rugged hills with precipitous slopes which are almost bare of vegetation.

At first sight the geological structure of the southern part of the Transvaal appears quite simple, the impression being that the rocks merely form an ordinary basin. So far, however, from this simplicity being real, the geological structure of the country is in fact highly complex, and is rendered still more difficult to unravel from its being apparently impossible to find any distinctive petrological band, available as a means of mapping the ground, or any group of fossiliferous strata, which might be used as a stratigraphical index. The difficulties of mapping the district are also increased by the fact that most of the country is covered by a deep red surface-layer, which is often many feet thick, and entirely conceals any outcrops over large areas. So far as is at present known the rocks are wholly unfossiliferous; while they are highly faulted, and in many cases sheared and overthrust.

The dominant rocks of the Southern Transvaal are sandstones, quartzites, and conglomerates, with here and there a few bands of shales and slates. A large portion of the country is also occupied by a later intrusive set of igneous rocks of basic and sub-basic types. Sometimes however—as near Vredefort and to the north of Johannesburg—the crystalline floor of South Africa, with its granites, gneisses, and schists, comes to the surface from below the stratified formations already noticed (see Map, Pl. XI.). These crystalline rocks, together with a dark-coloured limestone, become the chief geological features in the Northern Transvaal, and, unlike the same rocks in the south, rise up into hills of moderate height, particularly round Zoutpansberg.

The area more particularly described in the present paper is that lying immediately to the east and west of the town of Johannesburg. This area will be regarded as constituting the typical district for the development of the stratigraphy of the Transvaal. The rocks are well displayed both in the numerous mines and in natural and artificial cuttings; and the writer has had abundant opportunities,

especially in inspecting many of the mines, of studying somewhat thoroughly the nature and the local sequence of the beds and the amount of movement and alteration they have undergone. With respect to other districts the information of the writer is more general, being founded largely upon occasional observations and sometimes upon facts gained in hasty traverses. The sections across these more distant portions are therefore to be viewed as broad generalizations, to which future observation will certainly add much in the way of detail.

(2) *Summary of previous Geological Work bearing on the District.*

Our knowledge of the geology of most of South Africa, and more particularly of the Southern Transvaal, is still of an imperfect character.

The collective results of the researches of the large number of geological workers in South African areas outside the Transvaal proper have, of course, proved more or less helpful towards a general understanding of the relationship of the beds of the Transvaal area to those of other districts. In this respect Prof. Green's recognition of an unconformity between the Dwyka-Ecca Beds and the overlying Kimberley Shales appears to the author to be especially important, and will probably be found of wide application in South Africa. The fact also that palæontological evidence has shown the Karoo and Uitenhage Beds to be homotaxial with the Lower Mesozoic and Cretaceous formations of other countries is another factor of the highest value in the correlation of the South African strata.

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- GRIESBACH, C. L., 'On the Geology of Natal,' *Quart. Journ. Geol. Soc.* vol. xxvii. (1871) p. 53.
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- JONES, Prof. T. RUPERT, 'Notes on Specimens from Klip Drift and Pniel, South Africa,' *Mining Journal*, Mar. 1871.
- , 'The Mineral Wealth of South Africa,' *Proc. Imp. Colonial Inst.* 1887.
- , 'Coal in South Africa,' *Mining Journal*, Jan. 1871; *ibid.*, Dec. 1886.
- , 'On the Diamond Fields of South Africa,' *Geol. Mag.* for 1871, p. 49.
- , 'Notes on some Fossils from the Devonian Rocks of the Wittenberg Flats, Cape Colony,' *Quart. Journ. Geol. Soc.* vol. xxviii. (1872) p. 28.
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- MOULLE, A., 'Sur la Géologie Générale et sur les Mines de Diamants de l'Afrique du Sud,' *Annales des Mines*, 5ème sér. vol. vii. (1885) p. 193.
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- WYLEY, A., Report on the Copper Districts of Namaqualand. 1856.
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II. GEOLOGY OF THE WITWATERSRANDT.

A. THE GOLD-BEARING CONGLOMERATES AND ASSOCIATED ROCKS OF THE JOHANNESBURG AREA.

1. The District in General.

This district embraces an area of about 2000 square miles. It is variously known as the Witwatersrandt, Randt, or Johannesburg Goldfield.

The chief towns in its northern portion are Johannesburg, Heidelberg, and Pretoria; of these Johannesburg occupies the most central position. The Vaal River forms the southern boundary of the district. East and west the area has no defined limits, but it certainly extends eastwards to where the older strata are concealed by later deposits of Karoo age, and westwards until they are buried beneath igneous matter or lost under the expanse of open veldt.

As a whole the district may be said to form the northern part of the great central plateau of South Africa. Gradually rising from the Vaal River, its highest point is reached near Johannesburg in an elevation of 5600 feet. Here three parallel ridges extend in an east-and-west direction for about 45 miles, and the high ground thus formed constitutes the watershed between the Limpopo and Vaal Rivers; the streams to the north are tributaries of the former river, while those to the south flow into the Vaal. Most of the stream-courses are mere dry channels during the winter months, but in the summer they become filled with rushing turbid torrents.

Broadly speaking, the visible rocks in this district consist of a sedimentary series of sandstones, quartzites, and conglomerates, and an igneous and much later series of basic and sub-basic lavas and intrusive sheets. Here and there in the folds of the former set of rocks, shallow deposits of coal-bearing strata have been laid down; but these do not, so far as the writer's knowledge goes, cover any great extent of surface in the Transvaal, although coal-beds of apparently the same age extend over a large area in the Orange Free State.

The quartzites and conglomerates have generally a southerly dip, with an east-and-west strike. Behind Johannesburg, and again to the south, they constitute two main parallel lines of elevation composed of several smaller ridges running east and west.

The discovery of gold in the conglomerate-beds around Johannesburg in 1885 has caused this town to spring up in what five years ago was a desert, and has given these strata a world-wide reputation. Since the goldfields have been started mining operations have been extensively carried on along the outcrop of the conglomerate. There are now (1890) over 70 mines, the workings extending in an east-and-west line from Johannesburg for nearly 40 miles. The greater number of these mines are situated on what has been named the Main Reef, the course of which is marked all along its outcrop by derricks, hauling machinery, and all the usual adjuncts of mining operations.

2. The Main Reef Series.

(a) *The Type-sections of the Main Reef Series in the Salisbury and Henry Nourse Mines.*

As it is impossible for the geologist to locate his position definitely in the Witwatersrandt conglomerate series, and as neither the summit nor the base of this group of strata has been discovered, he is driven to take some arbitrary starting-point. It is most convenient to begin with the line of conglomerate-bands which have been opened up by the various gold-mines. The sections are complete, and the data, if ordinary care be exercised in selecting them, are reliable.

(1) *The Salisbury Gold-mine* is situated almost in the centre of the line of conglomerates, and shows very clearly the relationships of the beds to each other. The strata are very little metamorphosed and only slightly disturbed by faulting; and the mine is well opened up, so that a complete section can be obtained.

The conglomerate-beds and the associated rocks make no appearance at the surface, their outcrop being concealed beneath the superficial red soil. The mine is worked by two levels at a depth of 66 feet and 130 feet respectively. Both levels give a very instructive section from north to south of nearly 150 feet in length. The dip is high—85° S.; the strike due east and west. The dip remains constant throughout the mine and on both levels. On the upper level a ‘cross-cut,’ north and south, near the western boundary of the mine passes through the sequence of strata, beginning at the north, enumerated in the explanation of fig. 1 facing this page.

The four conglomerates (*c, e, g, j*) are collectively termed the Main Reef Series. On Wyld’s map of the Witwatersrandt Gold-fields (1888) and in the map accompanying the present paper (Pl. XI.) this Main Reef Series is represented as one bed, the scale in both cases being too small to admit of the separate beds being shown.

The word ‘reef’ must not be taken in its ordinary meaning; the reefs are not veins in any sense, but are true conglomerate-beds. The term ‘banket’ is often applied in the district to any conglomerate-bed whether it contains gold or not, and a series of sandstones and conglomerates is often spoken of by Afrikanders as a ‘banket formation.’

The four conglomerate-reefs are strikingly similar in appearance, though a miner who has worked for any length of time in any one mine recognizes distinct differences between them.

The *Main Reef* proper, in the Salisbury Mine, and indeed in most of the other mines, is the thickest and least coherent of the series. The pebbles are numerous and of all sizes, varying from half an inch to two inches in diameter. They are chiefly of milk-white quartz, very much broken; but others, formed of a yellow talcose material, looking something like hardened clay, are not uncommon. The cementing-material, or that in which the pebbles are embedded, is

Fig. 1.—Section across the Salisbury Mine.

Fig. 2.—Section across the Henry Nourse Mine.

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composed of silvery-grey micaceous matter, and is schistose in character.

The composition of the *North Reef* is very similar to that of the Main Reef, but the pebbles are on an average smaller, and many composed of quartzite are met with.

The *South Reef* has usually a larger number of black quartz-pebbles, and the rock is much more compact than any of the other reefs. It is most like the Main Reef Leader, and is generally the richest in gold, though there are patches in the other reefs which are sometimes as rich. In one or two places this reef is very considerably narrowed, but it is never quite lost.

The *Main Reef Leader* calls for little remark, except that, when traced east and west from the central shaft, it is found to 'pinch out' in many places, giving it the local appearance of a series of lenticles.

The predominating colour both of the reefs and of the rock between them (called in the district the 'country rock') is chocolate-red. Many of the harder portions, however, which are unchanged, are blue or bluish-grey in colour; and in the lower (130 feet) level the whole of the rock is found to be blue, except along joints and faults where water can find its way. The whole of the strata at this lower level, but more particularly the conglomerates, are crowded with cubical crystals and ellipsoidal particles of iron pyrites, and it is clearly by the oxidation of these and the consequent iron-staining that the red colour is produced. The reefs also at this lower level are found to retain their relative positions, but a complete change has taken place in the character of the cementing material and of the rock between the reefs. The conglomerates and sandstones, which on the upper level are soft and incoherent, become lower down dense and hard.

The surfaces of the adjacent rocks in contact with the conglomerates—that is, the 'foot and hanging walls,' as they are called—are smooth and polished, as if the beds had been pushed over one another from the south. That this movement has taken place, at least partially, is made clear in the eastern half of the mine, where there is a reversed fault of a few feet upthrow. The pebbles and cementing-material of the conglomerates show signs of having undergone great pressure. The pebbles, which are of a beautiful milk-white colour, are completely shattered; while the cementing-material is decidedly schist-like, and is squeezed in and out and around the pebbles. Much silica appears to have segregated out from the rock and exists now as quartz-veins. These are not numerous in the Salisbury Mine, but in the mine next to be described they form a very prominent feature.

In the eastern half of the Salisbury Mine the strata are broken through by a dyke of altered igneous rock whose original composition the writer has not yet been able to determine. The dyke is about 40 feet wide, and strikes across the beds at a very acute angle along a line of fault which shifts the reefs horizontally for a foot or two.

(2) *The Henry Nourse Mine* is situated about 3 miles east of

the Salisbury Mine, on the outcrop of the Main Reef. There is in this mine, as in others, a great difference between the rocks at the upper and lower levels. No one, probably, examining the beds at the surface alone, would think that the red-stained, crumbling, soft pebble-beds and shales looking like a series of ordinary sedimentary deposits above, become below bluish conglomerates, schistose rock, and hard quartzites. Surface-outcrops in the Transvaal, therefore, are not to be relied upon as showing the true nature of the rocks as they appear below.

The sequence of the beds on the lower level is shown in the section on p. 411 (fig. 2).

The quartzite (*a*) is intensely hard and reveals planes of movement. It carries a large proportion (sometimes as much as 10 per cent.) of crystals of iron pyrites. Much of the silica has segregated out in the form of quartz-veins, many of which reach a thickness of 2 feet.

The conglomerate-bands or reefs (*b-b₄*) are here *five* in number, and appear from the strike to be continuations of those in the Salisbury Mine. As far, however, as can be judged from a section of such limited height (5 feet) as a 'drive,' the bands are always distinctly wedge-shaped, the thin end of the wedge being downwards. The pebbles are shattered, and the cementing-material is in a schistose condition. On the surface of the ground only two reefs are seen. This difference can be accounted for in two ways: either the bands (*b-b₄*) are lenticles of conglomerate, which die out above and below, and are replaced by others at different horizons; or they are duplications of one or more bands by overfaulting. Looking at the metamorphosed nature of the surrounding rock, the latter view seems the more likely.

It should be noticed that it is one of the commonest results of mining operations in this district, as they are continued in depth, to cut through more reefs on the lower than are to be found on the upper levels, or at the surface. This is so in the 'Meyer and Charlton,' the 'Village Main Reef,' and the 'May Deep Levels' mines. Indeed the writer is unaware of a single instance in which this is not the case.

With the exception of band (*b₁*), which is nearly twice the thickness of any of the others, the bands are all of the same size, are identical in composition, and the beds between them are quite similar to each other. It is, however, impossible to say exactly to what extent the same beds have been repeated. Even one band may have been repeated several times. The conglomerate-band (*b₁*) is divided in the centre by a curved 3-inch layer of milk-white quartz. It looks, from the amount of displacement in the cementing-material of the conglomerate, and from the crushed nature of the pebbles, as if the conglomerate-bed had snapped and been thrust forward along a divisional plane marked by the thin quartz-layer.

The igneous rock (*c*) is probably a decomposed diorite. It is not crushed, and thus belongs to a later period than that of the disturbance which has affected the quartzites and conglomerates.

The schistose band (*d*) shows distinctly that very great pressure

has been exerted both on the conglomerates and on the adjacent rocks. This band is about 45 feet thick, the quartzites (*a*) on either side of it being the most highly metamorphosed of any in the mine. It seems clear that this band (*d*) marks the place and the direction in which the rocks have yielded most to pressure. The resulting schist is probably chloritic.

The dip of the reefs in the Henry Nourse Mine is nearly 90°. In the deep level another conglomerate has been struck by a diamond drill at a depth so slight as to lead to one of two suppositions: either the dip of the reefs has decreased very rapidly, or the reef passed through by the diamond drill is one of those in the cross-cut north of the main shaft *repeated by faulting*.

The sections in the Salisbury and Henry Nourse Mines, described above, undoubtedly prove that the strata have been considerably disturbed, crushed, and metamorphosed. The succeeding descriptions of the Main Reef Series, as it is developed in the mines east and west of the typical locality along the line of strike, will show to how small an extent the strata vary in their original lithological character, and how widespread is such metamorphism as has affected them.

(b) *The Main Reef Series west of the Salisbury Mine.*

In the Robinson Mine, which lies about a mile west of the Salisbury, the Main Reef and the Main Reef Leader have approached until they come close together, the surfaces on either side of the divisional plane being smooth, and suggesting that the quartzite has been nipped out. There are thus in this mine only three reefs—a North Reef, a very thick Middle Reef, and a South Reef. The lower levels alone reveal the true nature of the strata. The schist-like character of the cementing-material is very apparent, portions of it exactly similar to true silvery mica-schist being common. The dip of the three reefs varies from 45° to 50° S., the change from that observed in the Salisbury Mine coming in west of the spruit which divides the Robinson property into two parts.

In the Langlaate Estate Mine, situated still farther west, we find a band 10 feet thick, lying to the north, called the Main Reef, another 5 feet thick (to the south) called the South Reef, and a very inconstant middle reef which may be the Leader. The true North Reef, if it exists at all, has not been reached.

In the Cresus and other mines west of the Langlaate only two reefs, thinner than those described, are found, called respectively the Main Reef and the South Reef. The dip is 30° S. The South Reef is very variable, seldom exceeding 2 feet in thickness, while in many places it disappears altogether.

In the Durban Roodeport and Princess Mines this reef is sometimes represented by a single line of pebbles, while in other parts of the mines it thickens out. The rocks in both mines are highly cross-faulted. The composition of these reefs is almost identical with that of the reefs in the Salisbury Mine.

A drill-hole placed on 'Block B, deep level' reached a depth of 800 feet without striking any reef, the cores showing a schistose material with much iron pyrites. Another drill-hole in the Vogelstruis property (see Map, Pl. XI.) after passing through about 60 feet of the altered surface-rock, entered a bluish schist which continued for a depth of over 100 feet, when a diorite dyke was struck. The depth ultimately reached by the drill-hole was 423 feet, several layers of white crystalline quartz being passed through. Both in this quartz, and in the quartzite, crystals of iron pyrites were exceedingly numerous.

From the Robinson Mine to the Bantjes Mine an average dip of 45° prevails; from the latter to the Kimberley Roodeport Mine the average dip is 70°, and thence to the Banket Mine the dip gradually decreases until at last it is only about 15°. At the Banket Mine the reefs suddenly assume a northerly strike (see Map, Pl. XI.); a deep gully then intervenes, on the opposite side of which the reefs cannot be traced.

(c) *The Main Reef Series east of the Salisbury Mine.*

East of the Salisbury Mine we meet with much the same variation in the disposition of the reefs as in going west. In several of the mines we have more reefs below than are found at the surface. In the Jumpers Mine, 3 miles east of the Salisbury, three reefs are found. The dip between the two mines is never much less than 70°, the strike being nearly due E. and W. At the Jumpers Mine a break occurs, and the dip to the east is found to have decreased to 45°. The dip is still further lowered in the Simmer and Jack Mine to about 10°, after which it again increases; but, so far as the writer is aware, it never goes beyond 65°. East of the Jumpers Mine the strike has a slight northerly trend.

East of the Simmer and Jack Mine the distinction into 'north,' 'main,' and 'south' reefs vanishes. Several reefs are found, but in composition they differ somewhat from those of the Main Reef Series, and resemble more closely those presently to be described as lying to the south. In the United Main Reef Company's Mine a reef has been struck at a depth of 100 feet, which is a true conglomerate dipping at about 64° S.S.W. Immediately below is a band, a few inches in thickness, of glossy black shale. The cementing-material, or matrix of the reef, is very much greyer than that of any of the conglomerates of the Main Reef Series, and a few pebbles or fragments of black shale like that lying below are met with.

In the Cinderella Mine (see fig. 3, p. 416), a little north of Boksburg, a conglomerate or reef striking nearly N.E. and S.W. is worked for gold. Immediately beneath it is a blue slaty shale about a foot thick. The surface of the pebbles in the conglomerate is of a rich peacock-blue colour due to a coating of an oxide of iron. East of Boksburg the reefs are soon cut off by a large mass of diorite.

So far as the writer has observed, the thinning out and partial disappearance of some of the reefs is quite as common to the east

as to the west of the Salisbury Mine; and the soft surface-rocks are also replaced below by hard beds having a schistose character.

In the May Deep Levels Mine five hard and compact conglomerates are admirably shown. These dip at 45° , and associated with them are thick beds of crystalline quartz, having the same dip. These are probably segregation-veins.

Fig. 3.—Section across the Cinderella Gold-mine and Boksburg Colliery.

The distance over which the Main Reef Series can thus be definitely traced, from the Banket Mine to the Simmer and Jack Mine, is about 25 miles. Both east and west of the Salisbury Mine, as we have seen, only two conglomerates are found at the surface. Very varying dips are met with, but on the whole the dip decreases both east and west, and the beds gradually assume a southerly trend. Finally, it appears to be invariably the case along the whole line of strike of the Main Reef Series that the rocks, when traced downwards, assume more and more a schistose character.

3. The Gold-bearing Conglomerates south of Johannesburg.

On 'deep-level' properties it is always found that the reef is struck at a much shallower depth than would be calculated from surface indications, and that more reefs are met with below than appear at the surface. These facts are generally considered to show that the conglomerate-beds form a basin, and are decreasing in dip towards its centre. But there is scarcely a mine on the Randt that does not reveal abundant evidence of reversed faulting. In the case of the two diamond drill-holes placed on the Vogelstruis property (see Map, Pl. XI.) there can scarcely be a doubt that the apparent decrease in the dip of the reefs is due to this cause. In one of the drill-holes a sheet of diorite, apparently in a line of fault, was passed through immediately after the reef was struck; while the shaft north of the second drill-hole showed a reversed fault, with the upthrow portion of the beds flat, while the reef still farther north had a dip of nearly 70° . Such facts are de-

cidedly opposed to the theory that the conglomerate-beds lie in a simple basin.

(a) *Second Reef Series, south of the Main Reef.*—There are some conglomerate-beds struck by the diamond drills which, so far as position is concerned, lie nearest to the Main Reef on the south, but these do not apparently come to the surface.

Two conglomerates called the Red and Yellow Reefs crop out, however, about a mile to the south of the Main Reef Series. The Red Reef is best seen in the Great Britam and Kimberley Roodeport Mines, situated about 9 miles west of Johannesburg; while east of Johannesburg both the Red and Yellow Reefs can be studied near Elsburg and Boksburg.

The outcrop of these reefs cannot be traced for any great distance, being generally hidden beneath the ubiquitous, superficial red soil. Where seen, their dip is always lower than that of the Main Reef Series, but proportional to it. As these reefs are not mined to any great depth it is impossible, from the limited nature of the observations, to state exactly what their composition is. Judging from surface-outcrops, they are unlike any one of the members of the Main Reef Series. The cementing-material of the reefs is much softer, and quartz-pebbles are rarer; while white and grey quartzites, together with black speckled sandstones, are very common. The associated rocks are grits and sandstones.

(b) *Third Reef Series, still farther south.*—The next well-marked conglomerates crop out about 5 miles south of Johannesburg, and form a line of escarpment facing the north. They are mined in only one or two places, and, except in the case of the Aurum Mine, never to a sufficient depth to reach the undecomposed strata. There are several of these conglomerates, and they are associated with grits and sandstones. In a shaft on the Aurum estate (see Map, Pl. XI.) the sandstones are found to assume more and more the character of quartzites, and to become slightly pyritous as they are traced downwards. The pebbles in the conglomerates are very much larger than in any of the reefs to the north—the pebbles averaging about 3 inches in diameter, while some are as large as a man's head. They are nearly all of a pure white quartzite, a few being of sandstone.

These conglomerates can be traced along the escarpment for about 15 miles, east and west. In the direction of the dip they are soon cut off by an immense outflow of basaltic and quartz-amygdaloid lavas, forming the heights called the Eagle's Nest (see Map, Pl. XI.). Along the whole line of strike the conglomerates have a uniform dip of 15° S. This is an interesting point, for north of a line drawn up the Klip River valley the strata are affected in the same manner, as to dip, as the Main Reef Series; while the conglomerates now under discussion, and the associated rocks which lie to the south of this line, are uniform in dip and strike for the whole distance mentioned above. It is thus probable that a fault runs up the Klip River valley. This hypothesis is further strengthened by the fact that the material thrown out at the surface of the 'Klip

Riversberg' Mine, which is situated on this probable fault-line, consists of highly schistose and cleaved rocks very much slickensided.

(c) *Beds near Germiston.*—Near Germiston, a small village S.E. of Johannesburg (see Map, Pl. XI.), three or four conglomerate-beds are shown in the Spruit near the village. This stream also cuts through a greyish-black band of volcanic ash about 15 feet thick, which breaks with a highly conchoidal fracture, and in appearance resembles a foetid limestone. The only other locality known to the writer where volcanic ash comes in is near Boksburg (see fig. 3, p. 416). As the ash-band near Germiston lies more than a mile south of the Main Reef Series, whereas near Boksburg an ash-band closely resembling it, and also associated with similar conglomerates, lies only a few hundred yards south of what is mapped as Main Reef Series, we have either two separate beds of ash associated with conglomerate-groups and lying at different horizons, or there is but one bed of ash, and the associated conglomerates are the same. If the latter is the case, are we to suppose that the beds are thinning out towards Boksburg, or that a strike-fault brings the ash-bed at Boksburg nearer to the Main Reef?

Another solution may be suggested, viz., that the conglomerate-beds near Boksburg, and in fact those east of the Simmer and Jack Mine (situated a little west of Germiston), are *not* the Main Reef Series which occurs farther north, although they are mapped as such. They do not resemble the Main Reef as it occurs nearer to Johannesburg, but are rather more nearly allied to the Red and Yellow Reefs lying to the south.

Unfortunately the ground north of Boksburg is covered with grass, and exposures are rare. Taking into consideration, however, the change of strike in the Cinderella Mine, and the appearance of conglomerate-beds identical with the Main Reef Series to the N.N.E. (as shown in the Chimes and Van Ryn properties), together with the fact that the ash-band is similar to that near Germiston, it seems at least probable that the real Main Reef Series lies farther north of the Cinderella Mine.

4. The Conglomerates north of the Main Reef Series.

North of the Main Reef Series conglomerates seem to have been met with in only two places. One or more bands are said to exist north of Durban Roodeport, but these the writer has not examined. An interesting and excellent exposure, however, occurs in an isolated hill behind Jeppe's Township, situated about a mile east of Johannesburg.

The hill is about a mile and a half long by half a mile wide, and rises to a height of nearly 200 feet above the level of Johannesburg. It is partially cleft in the centre by a gully in which a section (see fig. 4, p. 419) was obtained. Two very marked groups of beds are exposed. The lower one is composed of quartzites of varying hardness, and quartz-schists resting on hardened red shales; the

upper one is composed of conglomerates and compact sandstones. The lower set suggest the beds of the Main Reef Series highly compressed; the upper set bear a strong petrological resemblance to the conglomerates and sandstones described as occurring about 5 miles south of Johannesburg, and therefore about 6 miles south-west of this hill.

The shales (*a*) dip at an angle of 60° S. Traced westwards from the gully they thin out like a wedge; eastwards they broaden, ascend the hill, become intensely hard, black, and much twisted, and finally end off against hard white quartzites. There is no sign of break or fault where the junction occurs, nor do the two sets of beds interdigitate. This curious phenomenon is possibly due to a thrust-plane. The schist and quartzites (*b*) and the conglomerates (*c*) climb the hill with the black shales and end off similarly against the white quartzites. The reef-like beds (*e*) consist of very hard white quartzite with a few scattered and broken pebbles. The quartzites and micaceous schist (*g*) show signs of great pressure. The bands of schist are distinctly wedge-shaped, and are caught up and twisted in and out among the associated quartzite in a remarkable manner. There is also at this point a change of dip from 60° S. below to not more than 30° S. above. This seems to

Fig. 4.—Hill behind Jeppe's Township.

mark the place where the beds have given way most, though any distinct plane of movement is not apparent. The conglomerates and sandstones (*j* to *n*) do not call for special mention. Assays give no trace of gold. They dip to the S. at an angle of 30° , and are soon faulted against red shales apparently identical with band (*a*). These red shales (*p*) have a slight northerly dip close to the fault; they then become vertical, assume a southerly dip, and finally pass beneath nearly perpendicular quartzites (*q*). The whole of the red shales mentioned appear to be identical in composition, and probably in thickness, with those presently to be described as lying north of Johannesburg. The fault (*f*²) is marked by a two-foot band of white quartz.

The remarkable conglomerates, &c., of this hill must either be above or below the Main Reef Series. If, as their composition and poorness in gold tend to show, they belong to the series lying south of the Main Reef Series, they can have come into their present position only in one of two ways—either they have been faulted down, or they have been brought up from below. If the latter be the case, and if their close resemblance to the more southerly reefs may be relied upon as proving the identity of the two, then the apparent sequence of the conglomerate-beds of the Randt is a false one, and the reefs which are now the highest are the oldest. If, however, they have been faulted down they are of course newer.

5. The Lower Quartzite-and-Shale Group north of Johannesburg, and its relation to the Main Reef Series.

Immediately north of Johannesburg the ground rises in an abrupt ridge to the height of about 130 feet above the town. This ridge is one of four, all of which present steep escarpments to the north, and are separated from each other by deep valleys running east and west. The ridges consist for the most part of white quartzite, while the valleys between are excavated in red and highly ferruginous shales. The quartzites have an average dip of about 45° S., but the shales show varying dips—sometimes nearly 90° , and never much below 45° . The first ridge consists of white quartzite underlain by grey and yellow flaggy sandstones, the second and third ridges are entirely of white quartzite, while the fourth is in places a white, crystalline quartz-rock. The first valley is widest and reveals more of the strata than the other two. In it the shales underlying the flaggy sandstones are beautifully ribbed with layers of crystalline quartz; they are black above, but pass down into red shales of the same character. Both are considerably hardened. The two succeeding valleys to the north are occupied by red shales alone. Quartz veins, often crossing each other at right angles, are frequent both in the shales and quartzites, but are far more numerous in the fourth ridge than in the others. The bands of quartzite and shale can be traced westwards for nearly 20 miles to a little beyond Krugersdorp. Eastwards the third and fourth bands of quartzite soon unite and finally end off against a strongly-marked fault (see Map, Pl. XI.). (See figs. 5 & 6, facing this page.)

Fig. 6.—Section from Orange Grove to Metropolitan.

The quartzites are identical in thickness, but the shales occupying the first valley are as thick again as those filling the other ravines, owing to the presence of the ribbed black shales. A section across the latter may be seen behind the Landdrost's house. Their disposition is such as to afford most unquestionable evidence that the rocks have been much folded and overthrust. The beds have been thrust forward to such an extent that the axes of the folds have passed the vertical; and even hand-specimens are marked by minor ripplings, which *in situ* have the same general southerly dip and east-and-west strike as the beds themselves. The red shales following the black ones to the north are as a rule inclined at a much steeper angle.

A tunnel on the Houghton Estate (see Map, Pl. XI.), driven into the escarpment formed by the northernmost band of quartzite, passes first of all through an exceedingly crushed and altered shale. Pressure has almost entirely disguised its true nature; it is crossed and recrossed by numerous veins of crystalline quartz, while the original felspathic constituents have become highly talcose, and the banding caused by the different tints of red and green resembles that of serpentine. Traced westward the shale becomes less altered, and can finally be recognized as a hardened red shale identical with that occupying the valleys. In the road-cutting, a little west of the tunnel, the shales are seen to be twisted in and out among the quartzite. They are not, however, so metamorphosed as in the tunnel, and are still recognizable as shales, although intensely hardened and partially changed into schist. Farther in the hill the tunnel shows the strata curving upwards. This is very markedly the case with a two-foot band of conglomerate. The pebbles in it are small and much shattered. The cementing-material (matrix) is a green chloritic substance of schistose character, and this flows between and around the pebbles, forming a rock resembling in appearance an *augen-gneiss*. Gold is present, but is not equally disseminated through the rock.

The crushed state of the shale, the upward curving of the strata, and the visible features of the conglomerate are all strong evidences that a thrust-plane of great importance is being approached; and before long we find the quartzites of the series resting at once on gneisses and schists, the plane of contact being probably the plane where the maximum differential movement of a powerful thrust was brought about.

The third valley is largely filled up by a sheet of diorite. This is very fresh-looking and apparently unaltered. It is clearly later in age than the powerful crust-movements to which the quartzites and shales have been subjected.

The first band of quartzite which has just been mentioned lies about a mile to the north of the Main Reef conglomerate series. Throughout the whole length of its outcrop it retains an average dip of 45° S., never being much higher or lower. The Main Reef Series, on the contrary, is nearly vertical in the centre, while east and west the dip decreases to an average of 15° S. Now the strata

occupying the ground between the Main Reef Series and the Quartzite-and-Shale Group are everywhere found to have the same dip as the Main Reef Series. It has also been already stated that the quartzite bands die out eastwards against a fault. There cannot therefore be any doubt that a fault separates the Main Reef Series and its associated beds from the Quartzite-and-Shale Group below. The strata occupying the ground between the outcrops of the two groups are composed of lenticular bands of sandy quartzite, compact quartzite, and red shales. It will be seen, on referring to the Map (Pl. XI.), that the beds composing the Quartzite-and-Shale Group keep the same relative distance from the Main Reef Series from Johannesburg to the Banket Mine on the west, and to the Jumpers Mine on the east. Evidently the two groups form portions of one larger series, but the exact sequence and relationship of the beds cannot be fully made out, owing to the break occasioned by the fault.

B. PHYSICAL RELATIONSHIPS OF THE WITWATERSRANDT ROCKS.

1. *Relation of the Lower Quartzite-and-Shale Group to the underlying Rocks.*

The rocks underlying the entire series of quartzites and shales already described are found to consist of highly crystalline and metamorphosed beds, which have been intensely crumpled and plicated. The nearest approach to an absolute junction between the two sets is found on the Houghton Estate (see Map, Pl. XI.). It has been previously mentioned that a tunnel driven into the fourth ridge of quartzite passes first of all through some highly metamorphosed shales. In a vertical shaft, a little to the north, gneissic rocks were struck at a depth of about 30 feet; the ground between the mouth of the tunnel and the shaft is quite flat. Small isolated patches of an intensely hard and highly schistose quartzite are found in several localities north of the Houghton Estate. In one or two places these patches can be seen to overlie gneissic rocks, but any absolute junction of the two could not be discovered. In one spot, about 3 miles north of the manager's house, a small boss of pegmatite crops out. The crystals of quartz in this are sometimes 3 inches long and about $\frac{1}{8}$ in. across. The felspar is of a faint pinkish-white colour, the crystals being sometimes very large. The exposure is not sufficiently extensive to show whether this coarse granite is intrusive. To the east, and not more than 200 yards off, a dyke of fresh-looking diorite is found with a north-and-south trend.

In the main shaft of the Houghton Gold-mine a vein of quartz enclosed in quartzite suddenly dies out, at a depth of about 60 feet, against a pinkish-red granite. It was stated by the manager that the quartz-vein and the associated rock commence with a southerly dip, which considerably decreases in amount to the south, till finally the rock becomes horizontal, and then assumes a northerly dip till it ends off against the granite. It is to be noted that the nearer the

quartzites and shales approach the gneissic rocks the more schistose they become, and in no case can it be said with certainty that the granite is intruded into the sedimentary beds.

About six miles west of the Houghton Mine a conspicuous hill rises up from the veldt. It is composed of white schists and quartzites having a high dip to the south. Farther north the surface of the country is composed mainly of igneous rocks.

These igneous rocks are of two dates. The older set have been intensely altered by pressure, and strike roughly east and west. They appear to have been highly basic in character, and many secondary minerals have been formed—chlorite, talc, and asbestos being the commonest. The chlorite occurs in large plates; the asbestos fibre is short, and not of first-rate quality.

The newer set also consists of basic rocks, but the strike is here north and south, and the material is unaltered. The principal rock is a diorite, which occurs in dyke-like masses and cuts across the older metamorphosed series.

2. Relation of the Quartzite and Conglomerate Series to the overlying Strata.

We have seen that the age of the quartzites and conglomerates can be determined neither from the strata themselves, for they are unfossiliferous, nor from the underlying rocks, as these consist of gneisses and schists. All that can safely be said is that there is a marked unconformity between them and the rocks below; and it is disappointing to find that in the only locality where any of the overlying rocks have yet been discovered a very great unconformity also intervenes. The age of the conglomerates or reef-beds is therefore left wholly undetermined.

The unconformable beds overlying the conglomerate series are the coal-bearing strata of the Boksburg and Heidelberg districts. Good sections can be obtained in any of the coal-pits; but the relation of the coal-beds to the conglomerates can be best studied in the inclined shaft of the Cinderella Mine, and in the adjoining property of the 'Blue Skip.'

The section (see fig. 3, p. 416) displays about 30 feet of white and yellowish-white sandstones, resting nearly horizontally on the edges of the conglomerate-beds which dip 45° S.S.W. That these sandstones belong to the same series of rocks as those shown in the shaft of Wishaw Colliery is sufficiently clear from the contour of the ground and the identity of the beds in the gold-mine and the colliery. The strata in the colliery, lying above and below a seam of coal about 11 feet thick, consist of white and yellowish-white sandstones.

In many places around Boksburg and Heidelberg patches of coal-bearing beds exist, and in some cases are worked for coal. The coal-seams are without underclays; while olive-white and yellowish-white sandstones form the interstratified layers. Compared with English types the coals are of a very inferior quality, containing a very large percentage of incombustible matter. On the Nigel

Mynpacht Mine property (see fig. 8, p. 431), lying about 9 miles S.S.E. of Boksburg, coal has been discovered, and is worked for the use of the 'battery' and mine-engines. In a short visit which the writer paid to the coal-shaft there were found lying on the surface several pieces of dark limestone breaking with a conchoidal fracture and resembling in appearance the 'peldon' bands and *Spirorbis* limestone of the Upper Carboniferous measures of England. No fossils were discovered in it.

Wherever the writer has seen the coal-bearing beds of the Orange Free State—near Klerksdorp, Kroonstad, and Wynburg—they are identical with those of Boksburg and Heidelberg. In the river at Kroonstad a very good section of the horizontal olive-white and yellow sandstones is exposed. In the Heidelberg and Boksburg districts the coal lies in detached basins; these basins are very shallow in the Transvaal, but in the Orange Free State the coal-strata will probably be found to constitute much thicker deposits, while it is certain that they cover much wider areas than in the neighbouring Republic.

From the fact that the coals contain a large quantity of fine black shaly material, and that underlays are invariably absent—coarse sandstones forming both 'roof' and 'floor,'—it is highly probable that the coals are of drift and lacustrine origin. This conclusion is also supported by the fact that all the evidence tends to point to their Karoo or post-Karoo age. For, as it seems generally agreed among all those who are personally acquainted with South African geology that the present central plateau is of pre-Karoo age, the Karoo and Stormberg beds must be of terrestrial and freshwater origin. Now, in the Orange Free State the coal-beds are of acknowledged Upper Karoo and Lower Stormberg age, and it seems certain that the coals of the Transvaal and of the Orange Free State belong to one and the same geological formation.

A detailed account, however, of the coal-beds of the Transvaal is beyond the scope of this paper. What is learnt from them in reference to the Reef Series is, that the interval between the tilting and the denudation of the latter and the deposition of the coal-bearing strata was a long one. Ultimately the Southern Transvaal seems to have been converted into a lake-basin, or more probably into a series of lake-basins, into which logs of timber and other drift-materials were floated, their relics constituting the present coal-seams.

3. *The Faults, Dykes, and Igneous Rock-masses of the Witwatersrandt.*

In a series of rocks which from constitution and alteration are so similar that no distinctive band can be certainly settled to have a definite horizon, and where the outcrops are largely concealed beneath superficial deposits, it is of course impossible to lay down the position and direction of the faults with complete accuracy. The directions of those inserted upon the accompanying Map (Pl. XI.) are thus more or less inferential, but it is believed that in no case

has any fault been laid down without strong evidence of its existence.

The majority of the smaller faults in the mines cut at a very acute angle across the beds, till in very many instances they become strike-faults having an east-and-west trend. Such faults are extremely common, scarcely a mine being without one or more examples. North-and-south faults are somewhat rarer, the outcrop of the Main Reef Series being very little shifted along its whole length.

It has been previously mentioned that west of the Banket Mine there is evidence for a large fault cutting off the Main Reef Series (see Map, Pl. XI.). Now, around Krugersdorp, about six miles north-west of the Banket Mine, several reefs are found having no definite relationship to the Main Reef beds, but resembling those that occur to the south. The dip is very various, a shallow dip at the surface becoming vertical below, and *vice versa*, and the existence of numerous small faults is shown in the mines. None of these beds, however, can be traced far eastwards, while the Main Reef cannot be traced westwards. Taking all these points into consideration, it seems highly probable that these reefs to the south of Krugersdorp are dislocated portions of those lying south of the Main Reef, and that they are cut off eastwards by a strike-fault which is an extension, or a branch, of that running up the Banket Spruit. The Main Reef Series should, unless the thinning-out shown in the Durban Roodeport and Princess Mines represent an actual dying-out in the beds, be met with to the north-west of Krugersdorp.

On the map two nearly north-and-south faults are represented as cutting off the Main Reef Series to the east and west. The western fault has just been referred to, and the evidence for the existence of the eastern fault is nearly identical in character. At Boksburg the reefs are found to be turning sharply to the south, and finally to end off against a mass of diorite. In the Chimes Mine, 3 miles N.N.E. of Boksburg, a reef is worked, which, if mineralogical composition can be relied on as indicating identity, is one of the Main Reef Series. Even if the Boksburg reefs belong to those lying south of the series just mentioned, still the reef in the Chimes and Van Ryn's ground lies too far north to be one of the Main Reef beds, unless brought into its present position by faulting.

The great east-and-west fault behind Johannesburg can be easily detected by its cutting off one member after another of the quartzites and red shale-bands in going from west to east. My reasons for supposing this to be a reversed fault have been already given, as have also those for placing a fault up the Klip Riversberg valley.

Throughout the Randt the result of the faulting has been to cut up the country into a series of strips striking east and west. How much of the sequence of the beds is concealed, and how much of the apparent thickness is due to repetition, the writer is unable to say.

Very few instances occur of igneous rocks intruding into the

Main Reef Series. In the Vogelstruis Mine (see Map, Pl. XI.) a diamond drill cut into a dyke of diorite. The dyke, however, proved to be nearly vertical, so that boring was stopped before the thickness of the dyke could be ascertained. In the eastern portion of the same mine a nearly vertical dyke about 30 feet thick was drilled through. The composition of this diorite is unlike that of any other igneous rock in the Transvaal. A large proportion of the felspar is decomposed, and the lime has separated out in the form of calcium carbonate. From the evidence of the surface dumps of the Percy and Jumpers Mines it appears that a dyke of the same material has been passed through there.

With the exception of the thin grey ash-beds, already mentioned as occurring near Germiston and Boksburg, nothing else of a volcanic or igneous nature is associated with or interferes with the Reef Series.

In the western portion of the Princess Mine a dyke filled with blue clay, about 40 feet thick, runs nearly vertically across the beds. The clay is very much compressed, and seems to have filled up an open fault, the sides of which afterwards closed in. So far as seen there appears no tendency in the dyke to narrow as it descends.

None of the southernmost reefs are pierced, so far as I am aware, by any igneous rock, though they are in close proximity to a thick mass of basalt.

In the quartzites and red shales lying below the gold-bearing series there are abundant intrusions of igneous rock. In the second valley north of Auckland Park (see fig. 5, p. 421) a sheet of very fresh-looking diorite, with the crystals of hornblende but little decomposed, pierces the beds, sending veins into both the quartzites and the shales; and in the northernmost, or fourth, ridge of quartzite, previously described, thin sheets and small veins find their way along the joints and bedding-planes.

Igneous material, but of a totally distinct type, occurs locally at the surface and intrudes into the conglomerates and other beds constituting the hill behind Jeppe's Township (see fig. 4, p. 419). The rock is a quartz-amygdaloid lava of an intermediate character, containing porphyritic crystals of a dirty-white felspar. This rock also fills up a large portion of the valley east of Doornfontein.

Both these types of igneous rocks very strongly resemble in their general characters the dominant igneous material of the Southern Transvaal. They are but little altered, and have not been affected by the movements that have tilted, shifted, and often ground up the associated strata.

It is certain therefore that the upheaval, dislocation, and folding of the Witwatersrandt strata occurred before the grand eruptions or intrusions of igneous rocks, and that these eruptions and intrusions took place at least at two distinct periods. It seems equally certain that it was not the granitic base which moved, but that the overlying rocks were thrust over an underlying and much older crystalline series.

4. *Summary of Observations and Conclusions respecting the Physical Relationships of the Gold-bearing Conglomerates and Associated Rocks.*

The facts brought forward in the foregoing account of the more important sections within the limits of the typical Witwatersrandt district seem to the writer to show conclusively (*a*) that the Witwatersrandt strata have been subjected to great lateral pressure acting from south to north; that (*b*) they have been locally dislocated, and the dislocated masses have been driven forward over each other along more or less oblique thrust-planes. The crust-movements have not only induced overfolding and overthrusting to such an extent as in many cases to considerably alter the original relationship of the beds, but have frequently changed, almost completely, the original petrological character of the rocks.

It has not been possible, with such knowledge as the writer has been able to obtain, to determine with certainty the true geological succession of the beds of the district as a whole. So far as we are at present acquainted with the facts it appears possible to hold either of the two following views with respect to the sequence generally:—

First, that the observed order is a naturally ascending one, but is more or less disguised by faulting, folding, and thrust-movements. If this be so, and if further we assume that the igneous rocks of the Eagle's Nest repose on nearly the summit of the conglomerate series, and that the quartzites and shales overlying the schists of the Houghton Estate are the base, we have presented to us a group of strata which, trusting only to the apparent dip, would seem to be at least *three miles* in thickness. Moreover, this apparent sequence of quartzites and shale, quartzites and conglomerate, suggests an oscillating but gradually shallowing area of deposit. In this case the basal conglomerates of the series may lie farther to the north, and have yet to be discovered.

Second, that the apparent order of the strata of the district is the reverse of the true order. The quartzites, shales, and conglomerates forming the Main Reef Series will then be the highest, and will represent the deep-water deposits, of which the coarser conglomerates composing the southernmost reefs are the shallow-water equivalents.

Which of these views is the nearer to the actual truth remains at present an open question. So far, however, as our present knowledge goes, the conclusions to which the observations of the writer within the typical district definitely point may be briefly stated as follows:—

- (1) The gold-bearing conglomerates, together with the quartzites and shales of the Witwatersrandt, form one definite geological series; but neither the base nor the summit of this series can as yet be fixed.

- (2) This series is certainly much *newer* than the locally eroded schists, granites, and gneisses which now underlie it. On the other hand, the gold-bearing conglomerates and associated rocks are very much *older* than the horizontal coal-bearing beds which overlie them unconformably.
- (3) The occurrence of pebbles of red sandstone in some of the reefs shows that there must have been a still older series of sandstones from which these pebbles were derived. This older sandstone series may yet be discovered.
- (4) The entire series of beds associated with the gold-bearing conglomerates has been (at least locally) thrust over the gneisses and schists, and was not originally deposited in its present position.
- (5) The movements to which the beds have been subjected have taken place in two directions—the more intense movement being from *south to north*, and a less effective one from *east to west*. The result of these two movements is that the beds now occupy a basin-shaped area, along the margins of which the strata have everywhere given way; while the rocks have been crushed, overthrust, and altered locally into schists, quartzites, pseudo-quartzites, and gneisses.
- (6) After the cessation of these earth-movements the strata were injected with igneous material of basic and sub-basic types; and much of the country was flooded with lavas of the same character. The presence of the iron pyrites, so abundant in the quartzites and conglomerates, has probably some connexion with this volcanic outburst.
- (7) The conglomerates seem to have been formed mainly at the expense of the underlying granites and schists, which may have contained numerous veins and larger masses of auriferous quartz.
- (8) Some of the newer schist in the conglomerate-bands seems certainly due to metamorphism arising from pressure and movement acting since the conglomerates were deposited.

III. GEOLOGY OF DISTRICTS OUTSIDE THE TYPICAL WITWATERSRANDT AREA.

1. *The Chimes Mine and Heidelberg Districts.*

As the rocks of the typical area have been described somewhat fully, the strata of similar age met with in other parts of the Transvaal will be treated of in a more cursory manner, sufficient details only being given to throw light upon the general structure of the country.

Although the geology of these outlying districts looks at first sight far more complex than that of the Johannesburg area, their structure is really much simpler. It soon becomes evident on examination that the strata have been thrown generally into shallow

folds, and afterwards pierced in all directions, and often overflowed by igneous rocks.

It has been previously mentioned that the reefs are cut off to the east near Boksburg by a mass of diorite, and that they come to the surface again, about four miles to the N.N.E., in the Chimes and Van Ryn properties (see Map, Pl. XI.). A true conglomerate with associated quartzite is here exposed, the strata striking nearly due north and south, and dipping to the west.

The conglomerate-beds also crop out about 15 miles S.S.E. of Boksburg, and are worked for gold in the Nigel and adjoining properties. In the Nigel Mine (see fig. 7) the lowest reef is under-

Fig. 7.—Section across Nigel and Romola Gold-mines.

lain by red shale, about 60 feet thick; while the bed immediately above this reef is sandstone. The reef has an average thickness of 2 feet. Traced downwards the underlying rock approaches more and more in character to a slate or schistose rock, while the sandstone above it changes into a quartzite. The dip is 30° N.; the strike due east and west. The dip of the overlying conglomerates gradually decreases northwards, till in about a mile they become perfectly horizontal. Traced westwards the strike of the beds gradually assumes a southerly trend, while the dip is eastward. In the Remboro, Lavers-Nigel, and other properties towards the east, the Reef series changes its strike to a northerly one, the dip being then westward. Evidently the strata have been folded to form a basin.

In the eastern portion of the Nigel Mine and in the adjoining properties the reef is very thin. In the Lavers-Nigel a shaft sunk in the associated shale showed that this becomes intensely hard and schistose lower down, the usual red surface-colour changing to blue. The soft nature of the shale at the surface is due to oxidation. The banding and colouring in these oxidized shales are marvellous, tints from the brightest red to the dingiest brown, with deep and light blues streaked with orange and gold, predominating. Some of the colours may justly be likened to the cloud-colourings of an autumn sunset.

The reef at the surface is in all cases very narrow; but in a shaft sunk quite recently on the Remboro property, at some distance

from the outcrop, the reef below is found to be 2 feet thick. Here, as in the typical area, we find that the strata have suffered considerable disturbance.

Fig. 8.—*Diagram-section, east of Nigel Mynpacht.*

About 2 miles south of the Nigel Mine a reef, underlain by shale, has been struck in the Romola and Florida Mines; the dip is south. The intervening ground between these mines and the Nigel is thus seen to be occupied by strata forming the summit of an anticline. Unfortunately there are no exposures to be found. In the section (fig. 7, p. 430) it is made to appear that the low dip can be accounted for by denudation having removed the larger part of the anticline. The schistose nature of the rocks, where these are not decomposed, shows that disturbance has taken place. The ground between the Nigel and Romola Mines is occupied by a valley, north and south of which the strata gradually flatten out.

Near Heidelberg, about 9 miles S.S.W. of the Nigel Mine, conglomerates and sandstone crop out, forming the rocky foundation upon which the town is built. The same beds also compose the hills lying behind it. In the town section the beds are almost horizontal, but westwards the dip increases to an average of about 15° . On the eastern side of the town, however, immediately after crossing the Bloesbok Spruit, the strata are observed to have a very high dip.

A little farther to the N.E., in the Marais-Nigel Mine, a reef underlain by red shale, identical with that in the Nigel Mine, dips at an angle of 30° W. These frequent changes of dip and strike suggest very forcibly to the mind of the observer the fractured and disturbed state of the country.

The sandstones are exposed west of Heidelberg, along the Johannesburg road, for about 2 miles, when they are covered up by a quartz-amygdaloid lava. From this point westwards, all up the Klip River valley—and how much farther it is impossible to say,—the whole country is flooded by volcanic rocks. In one or two places, however, as in the Black Reef Mine, the quartzite-and-conglomerate series comes to the surface with a very gentle southerly dip. The writer had no opportunity of examining these beds carefully.

About 35 miles south of Johannesburg, on the Kimberley road, some high hills are composed of quartzite, dipping to the south at a small angle; but volcanic country soon comes in, and the strata

are covered up. Farther on along the same road—three stages from Potchefstroom—horizontal olive shales and some sandy beds are exposed on the roadside; they are probably of Karoo age. Volcanic country again prevails as far as Potchefstroom.

On the banks of the Vaal, at the farm called Strykfontein (see Pl. X. fig. 1), 35 miles south of Johannesburg, thin conglomerate-bands and quartzites are shown dipping northwards at a low angle; it is said that these reefs can be traced as far as Heidelberg. Following the banks of the Vaal in the direction of the stream, a thick sheet of compact undecomposed basalt soon conceals everything.

2. The Vredefort and Potchefstroom Districts.

Crossing the Vaal River at Vaal Pont, and going in a direction a little to the west of Heilbron, we find gently undulating, grass-covered prairie land extending on either hand as far as Vredefort. Outcrops are very rare; where the rock is seen it is almost invariably of an igneous character. But in one spot, about 6 miles from Vaal Pont, in a S.S.W. direction, a section is exposed of conglomerates dipping at an angle of a few degrees to the west. As at Strykfontein, however, the strata are soon buried beneath igneous rocks. West of Vredefort, and in the immediate vicinity of the town, gneisses, schists, granites, and gabbros form the low hummocky ground, and large blocks of these crystalline rocks are scattered about the town and its neighbourhood. Possibly these blocks may be erratics; but it is much more probable that they are simply unweathered fragments of the underlying rocks. One fact bearing out this conclusion is that after travelling for about 4 miles to the west of Vredefort the ground rapidly rises into high and rugged hills, which are found to consist of quartzites and conglomerates, dipping at a very high angle to the west. This looks as if some disturbing influence had acted in the neighbourhood; and from what we know has happened on the Randt, as well as from other evidence, it seems reasonable to believe that the quartzites have been pushed up against a bank of crystalline rocks. So far as the writer is aware, there is no evidence of glaciation so far north in South Africa.

The hills just mentioned as lying west of Vredefort present precipitous slopes and bristling hog-backed summits; the beds of which they are composed are admirably displayed, and their twists and curves are easily traceable by the eye for several miles along the strike, which is roughly north and south. For some distance westwards the dip continues to average nearly 90° ; but farther on in the same direction it is slightly less and to the west. This high dip is continued as far as Lindequifontein, a distance which may be roughly estimated as 10 miles. Here the strata again form high hills, but the dip, although still high, is now to the east. Up to Lindequifontein the beds are composed of red shales and quartzites, with here and there a thin conglomerate-band. The whole series is identical with the Quartzite-and-Shale Group lying beneath the Main Reef.

To the west of Lindequisfontein the strata consist of quartzites and thick conglomerates, the latter being poorly auriferous, and some of them being immediately underlain by a thin shale; these conglomerates and quartzites strike across the Vaal River near Schoeman's Drift; but they soon become covered up westwards by igneous rocks of a basic type. The series comes to the surface again a few miles west of Potchefstroom, and both easterly and westerly dips are frequent, showing that the beds are thrown into small folds. The country is again very much flooded with igneous rocks until the Buffelsdoorn Estate is reached, when quartzites and thin conglomerates with red shales come in, dipping at about 45° E.

The diagram-section (Pl. X. fig. 3) shows the probable structure of the country from Vredefort to Buffelsdoorn. That it is very much faulted and folded is unquestionable; but the actual details of the movements and disturbances can only be surmised.

3. The Klerksdorp and Kroonstad Districts.

South of Buffelsdoorn the country is again flooded with igneous rocks; but about 9 miles to the S.S.W. the conglomerate series comes to the surface around the town of Klerksdorp. The diagram-section (Pl. X. fig. 2) will afford a rough idea of the disposition of the rocks here exposed. The folding of the beds is unmistakable.

From Klerksdorp the conglomerates are seen to strike across the Vaal in a S.S.E. direction; but they are soon buried beneath horizontal white sandstones and coal-beds.

Exposures of conglomerates are found on the farms Damspruit, Er-is-geluk, and Welt-de-vreden, about 18 miles west of Kroonstad. The conglomerates are associated with yellow sandstones; they are said to be slightly auriferous, though from a few 'pannings' made by the writer no gold was obtained. The strata are thrown into a series of very sharp folds; but few outcrops are visible, and the beds are covered up on the west by igneous rocks and on the east by Coal-measures.

The same conglomerates, associated with similar yellowish sandstones, are exposed on the roadside, about 6 miles south of 'Kopje-Alleen.' The pebbles in these conglomerates are sometimes very large.

That the conglomerates around Klerksdorp are portions of the Witwatersrandt series the writer has no doubt, as the beds occur in the same order, and are associated with strata of the same kind. With reference to the conglomerates west of Kroonstad there is no proof of age, and they may possibly belong to a newer series than the Witwatersrandt beds. From a consideration of the facts, however, especially that the conglomerates seem identical in composition with some of those of the Witwatersrandt, and that the beds near Klerksdorp strike across the Vaal River towards Kroonstad, it seems far more likely that they belong to the same series.

4. *The Igneous Rocks of the Southern Transvaal.*

The description of the igneous rocks of the Transvaal generally is outside the object of the present paper. Those intimately connected with the Main Reef Series have already been discussed. The amount of volcanic activity displayed is enormous; the whole of the stratified country seems to be floating in igneous rocks, the chief varieties of which are dolerites, diorites, quartz-amygdaloid lavas, and basalts.

In Dunn's map of South Africa (2nd ed. 1887) these igneous rocks are represented as one vast sheet. Mr. Penning, in Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 451, represents the dolerite as contemporaneous and interstratified with the Witwatersrandt beds. Now the types of igneous rock in the Transvaal are similar to those that pierce the Karoo Beds of the Orange Free State. Moreover, the oldest sedimentary beds of the Transvaal are greatly altered, while the igneous rocks, where not weathered, are as fresh-looking as if they had cooled but yesterday. The volcanic rocks of the Gats Randt are not, in the writer's opinion, interstratified, but appear to have come up an east-and-west fissure, and overflowed the Witwatersrandt beds at the time when the main movement and faulting of the country took place.

So far as the writer's observations enable him to judge, the igneous rocks of the Southern Transvaal are much posterior in date to the formation of the Witwatersrandt beds. But whether the eruption of igneous material took place before or after the deposition of the Karoo Beds, or was contemporaneous with the laying down of the Upper Karoo Series, is uncertain. If similarity of type is of value in correlation, then, as previously mentioned, these igneous rocks are very probably of the same age as those of the Orange Free State, which certainly appear to be of Upper Karoo (Stormberg) age.

5. *Summary of Conclusions respecting the Relation of the Strata of the Neighbouring Areas to those of the Witwatersrandt Series.*

(a) Our examination of the beds in the districts lying more or less immediately outside the Witwatersrandt area thus shows them to be thrown into numerous folds, which vary greatly in intensity. Sometimes the beds form shallow basins (as in the Nigel Mine district), but more often the strata are bent into sharp anticlines and synclines, the axes of which run either north and south or east and west. On the whole the beds are of a similar lithological character throughout the Southern Transvaal, being composed of sandstones, shales, and thin conglomerates, variously arranged, and more or less locally altered into quartzites and schists.

(b) The direct local superposition of the conglomerates on shales shows that the beds were either laid down by currents varying greatly in strength, or that they were deposited in areas undergoing rapid changes of level.

(c) The subsequent outpouring of igneous rocks has been enormous. This extrusion was certainly later in date than the deposition of the conglomerate series, and may possibly be posterior to that at which the faulting and crumpling of the strata took place.

(d) The apparent base of the sedimentary series, where seen (as at Vredefort), clearly overlies granites, gneisses, and gabbros; but the sedimentary beds dip towards the crystalline rocks, often at high angles.

(e) Most of the conglomerates are more or less auriferous, though there are notable exceptions.

(f) The coal-bearing strata overlying the Witwatersrandt series rest unconformably upon the eroded edges of all the beds below, and are the newest stratified rocks of the district.

[The present paper deals essentially with the facts bearing upon the stratigraphy of the Southern Transvaal. It was the Author's intention in a second paper to give a detailed account of the lithology of the gold-bearing conglomerates, and to describe in this connexion various microscopic slides which he had caused to be prepared, and also to discuss the mode in which the gold occurs and the question of its origin. Before, however, he was able to complete this part of his work, Mr. Gibson had to leave England for Equatorial East Africa. His second paper is therefore necessarily deferred.]

EXPLANATION OF THE PLATES.

PLATE X.

Diagram-sections across the Gold-bearing beds of the Southern Transvaal.

PLATE XI.

Geological Sketch-map of the Witwatersrandt Gold-fields.

DISCUSSION.

The PRESIDENT hoped that many papers similar to that just read would be offered to the Society, now that so many of its members were scattered over the world. Dr. Exton, who had sent specimens which were exhibited on the table, had noted the difficulty of accounting for the gold in the conglomerates. He (the President) had not exactly understood, from the reading of the paper, how the Author accounted for the mode of occurrence of this gold, further than that it was derived from the auriferous quartz-veins in the gneissose rocks, and he would be glad to hear the views of those who had made a special study of the distribution of gold.

Prof. GREEN pointed out the difficulty, in the present state of our knowledge, of correlating the beds described in the paper with the beds older than the coal-bearing rocks of Cape Colony. He thought that the intrusive masses of dolerite might belong to the same complex of dykes and sheets which form so marked a feature in the country to the south. He hazarded the opinion that the conglomerates were old alluvial gold-bearing deposits, and maintained that the mode in which the gold occurred was compatible with this view.

Mr. ARTHUR said he had not visited the Witwatersrandt gold district, so he found it a difficult matter to say much about the

paper which had just been read ; but as he had inspected many gold-fields in California, South America, and in different parts of the world, and obtained a practical knowledge of their surroundings, it appeared to him evident that the district now described by Mr. Gibson bore no resemblance, geologically speaking, to anything hitherto discovered, and therefore it was one of especial interest. The speaker did not think that the gold in the quartzites and conglomerates could be called alluvial gold, because from all the information he had on the subject the gold was found in a state of fine division, whilst in all true alluvial deposits the gold was found in various forms and sizes, varying from lumps of many pounds in weight to the finest dust. The only case which had come under his notice of metals being found in conglomerates (ancient river-beds being excepted) was that of the copper mines on the southern shore of Lake Superior, in Michigan, U.S.A. There the copper was found in a metallic state, sometimes in very fine dust and grains, and often in masses weighing many tons. It was most likely that the gold had been deposited in the quartzites and conglomerates, and was not derived from alluvial sources, as some would suppose.

Mr. TOPLEY remarked that the Banket deposits of the Gold Coast seemed to contain gold introduced into the conglomerate at the time of its formation ; whilst in the Witwatersrandt area the gold had frequently been deposited around the pebbles after the formation of the conglomerate.

Mr. ALFORD remarked that the paper dealt only with the gold-bearing deposits of the Witwatersrandt, and that nothing had been said about the very important series of auriferous rocks of the Barberton district, which were of an entirely different nature. The coal-bearing sandstones were by no means small deposits, as they occurred over an area of about 1000 square miles, and, although the coal-beds had not been proved throughout, there were strong indications of their existence. The coal-seam at Brakpan Colliery was 21 feet in thickness, and the output of coal at that colliery exceeded 13,000 tons per month. The outcrops of the conglomerate-reefs, though in places faulted a few feet, were traceable east and west of Johannesburg for a total distance of nearly 40 miles. They were by no means regular in gold-bearing value, which appeared generally to be greater where the beds had a high angle of dip and in the proximity of the intrusive igneous rocks. He did not consider the thickness of the quartzite-and-conglomerate series to be very great, but thought that the general break-up of the strata by the igneous intrusions had brought portions of the same beds repeatedly to the surface ; and he entirely concurred with Prof. Green in his description of the multitude of trap dykes in the Orange Free State, which also agreed with many parts of the Transvaal. The origin of the gold in these conglomerate-beds was a most interesting, but at the same time a most intricate subject. The gold occurred in the matrix of the conglomerate, and seldom in the quartz-pebbles. On taking a pebble from its resting-place in the conglomerate, both the surface of the pebble and also that of the cavity from whence it

came were often to be seen covered with minute crystals of gold, and in the pyrites it occurred in small plates on the cleavage-planes. The gold might have been in the form of alluvial gold in the gravel-deposits from which the conglomerates were formed, then dissolved, and re-deposited in its present condition ; but its primary origin had still to be accounted for. The fissure-veins in the granite, worked for copper and silver at the Albert and other mines, had not been found hitherto to carry gold in any considerable quantity. The gold must at one time have been either created or evolved from something else : could that not as well have happened in its present position as elsewhere ?

Prof. LAFWORTH noted that the Author had had unlimited opportunities of doing work in the district described. Before he went out it was believed that the district was a simple basin, the reefs margining the basin. The Author came to the conclusion that, whilst it was just possible that it was really a simple basin, it was far more probable that there had been overthrusting and shearing along the edges of the basin, and possibly great repetition in its interior ; so that these gold-bearing rocks might quite well be found eventually within the basin itself. The Author certainly believed that the beds were repeated again and again, and need be of no great thickness. He knew that the Author had avoided giving any definite idea in the paper as to the source of the gold, as he proposed to treat of this subject in a separate memoir.

Mr. TEALL also spoke.

DIAGRAM SECTIONS ACROSS THE GOLD-BEARING BEDS OF THE SOUTHERN TRANSVAAL.

Fig. 1. FROM JOHANNESBURG TO VAAL RIVER, 40 MILES.

Fig. 1. *Continued.*

Fig. 2. FROM NOOTGEDAGHT TO NOTRE-DAME, 20 MILES.

Fig. 3. FROM VREDEFORT TO BUFFELSDOORN, 30 MILES.

Fig. 3. *Continued.*