THE SOUTH RAND COAL-FIELD,

AND ITS CONNEXION WITH THE

WITWATERSRAND BANKET FORMATION.

A PAPER READ BEFORE THE FEDERATED INSTITUTION OF MINING ENGINEERS.

BY

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Part I.—Coal.

(1) *General.*—The writer read a paper on the South African coal-formation before the North Staffordshire Institute of Mining and Mechanical Engineers in 1889, in which he fully described the coal-seams which he had seen in the Transvaal, and discussed their origin and geological position.*

It is now his object to describe a portion of this immense tract of Coal-measures, which he has named the "South Rand coal-field," one which he has explored personally, and in which he has discovered a very valuable coal-seam, quite above the average.

The coal-bearing measures which were formed during the Triassic age were deposited in numerous more or less basin-shaped depressions and hollows. These depressions and hollows were formed by the denudation of older rocks of different ages. The deposits, though of contemporaneous formation, are distinct coal-fields, separated from each other by the old rocks which have survived denudation.

These coal-fields are of two kinds: larger ones in which the coal occurs at depths of some hundreds of feet, and smaller ones in which the coal occurs at shallow depths of from 40 to 200 feet.

If the coal be of subaqueous origin, as believed by the writer, the vegetable matter of which it is composed will have been carried further from the margin of the basin in a large coal-field than the mud which has been carried into the basin at different times. In smaller coal-fields, the distance from the margin being so small, the vegetable matter will be very much more mixed with mud. In proof of this contention, the coal found on the farm Modderfontein, which is close to the margin of the South Rand coal-field, is of very inferior quality, and the coal-seam is thin. The usual characteristic of South African coals, from shallow formations, is that they consist of alternating laminæ of coal and impure carbonaceous matter, which further supports this view.

* *Trans.*, vol. x., page 161.

The writer may also state that the coal-field which he is about to describe, and which is contained in a basin of large extent, viz., 400 square miles, compared with coal-fields at present worked, contains in its centre a thick coal-seam in which the coal is practically free from the usual carbonaceous laminæ. This coal-field lies, as shown in Fig 1 (Plate XIV.), between the so-called Upper and Lower Rooi Kopjes (Red Hills) about 16 miles south of the town of Heidelberg. It is bounded on the east by the Upper and on the west by the Lower Rooi Kopjes, and to the north in part roughly by a range of quartzite-hills. To the south, as will be shown later on, the Coal-measures are disturbed near the Vaal river, where numerous dykes of basic igneous rocks occur.

Coal-measures have been found in the Orange Free State across the Vaal river, by the writer, at Viljoen's Drift, where he advised a borehole to be put down for Messrs. Lewis and Marks. The Vereeniging is distinct from the South Rand coal-field, and is about 25 miles distant from it.*

A borehole, which had been put down at Kroonstad to a depth of 800 feet was continued by the writer's advice, and a coal-seam was found at a depth of about 900 feet (about 8 feet thick), but this was of very inferior coal and quite unworkable.

Historical.—A description of the South Rand coal-field would be incomplete without a short history of the South Rand Gold Corporation, Limited, which corporation practically owns and controls it. In 1893, the writer acquired property in this locality, in conjunction with Mr. James Heath, M.P., having previously formed the opinion that an important coal-field lay between the Upper and Lower Rooi Kopjes. The writer obtained the coal rights over this area, and he issued a plan showing the boundaries of what he supposed to be the coal area, dated September 6th, 1894, which was printed. The Witkleifontein Syndicate was formed in London, mainly through the instrumentality of Messrs. Heath and C. G. Sawyer. The Heidelberg Union Land Co. was subsequently formed to acquire the interests of the Witkleifontein Syndicate, and to enlarge its holding so as to obtain the control of this coal-field. The South Rand Gold Corporation, Limited, was afterwards formed to acquire all the assets and interests of the Heidelberg Union Land Co., Limited. The writer has acted as sole representative of and engineer to the Syndicate, the Heidelberg Union Land Co., Limited, and to the South Rand Gold Corporation, Limited, in Africa.

* *Trans. Fed. Inst.*, vol. xii., page 186.

The first borehole, to prove the writer's opinion as to the presence of a valuable coal-seam in this coal-field, was put down on the farm Modderfontein on the outskirts of the coal-field. The next borehole was put down in the centre of the coal-field at Beerlaagte. At 102 feet 8 inches from the surface, a mass of igneous rock was encountered. Finding it on examination to be dolerite, and believing it therefore to be a sheet, the writer continued boring until he was through it, although its total thickness was found to be 340 feet 4 inches. At a depth of 550 feet, a seam of good coal, 25 feet thick, was intersected.

A third borehole was put down at Grootvlei, with the result that he there found the igneous sheet to be only 25 feet thick and the coal-seam 60 feet thick, the coal being of excellent quality, better than any he had seen in South Africa. On the strength of these results, a circular shaft was sunk, 11 feet in internal diameter, 1,600 feet distant from this borehole. Substantial colliery buildings were also erected. These works were supervised by Mr. Evan Williams, colliery manager.

Coal-measures.—These Coal-measures are part of the extensive coal-bearing formation overlying the Karoo formation in the Orange Free State and Cape Colony.

In this locality, they rest, as shown on the accompanying sections (Fig. 2, Plate XV., Fig. 3, Plate XVI., and Appendix A), on gneissoid granite in the centre, and on rocks of the Witwatersrand Banket formation at the sides. The rocks consist of sandstone, grit, conglomerates, clay-slate, shale, limestone, and ironstone.

The sandstone occurs laminated and compact, occasionally as flagstone. In some instances it is fine and in others coarse-grained. It is more or less micaceous, the mica causing it at times to split up into laminæ, and at other times to form a mica-schist. The sandstone exhibits well-marked false-bedding, while some bands of it contain nodules of perfectly globular iron pyrites, up to 4 inches in diameter. These balls occur occasionally joined together. At a depth of about 300 feet in the shaft, a bed of open and friable sandstone occurs, which contains good sized waterworn quartzite-pebbles. The sandstone is occasionally calcareous.

The grit is dark and coarse, and contains pebbles.

The shale is at times dark, carbonaceous and micaceous.

The limestone occurs occasionally in thin white bands.

The ironstone occurs in the shaft in a lenticular mass and resembles blackband ironstone. It also occurs in masses on the surface near the

centre of the coal-field; this deposit has not yet been proved. It also occurs in thick deposits resembling bog iron-ore.

Breccia.—At the bottom of the Coal-measures, a more or less thick bed of breccia occurs, but does not extend invariably all along the edges of the coal-field. It varies in thickness from a few feet to 251 feet, but its average thickness is about 60 feet (Figs. 3 and 4, Plate XVI., and Appendix A).

The blocks and pebbles consist of quartzite and quartz (derived from the Banket formation), gneiss, shale, etc. The occurrence of brick-red grains is characteristic. The pebbles are sometimes rounded. The breccia is in some places interstratified with thin beds of shale and sandstone, and at other places it rests immediately on the gneiss, and on the Banket formation at the edges. It occurs in the centre of the coal-field at depths of from 388 to 704 feet, and it is thickest where it lies deepest. The matrix consists in part of quartzite-grains and fireclay. Traces of gold occur in this breccia, where the blocks and pebbles consist of quartzite derived immediately from the adjoining auriferous beds.

The writer has alluded to the possibility of this breccia being contemporaneous with the Dwyka Conglomerate, in his report to the Cape Government on the *Mineral Resources of the Division of Prince Albert* in 1893, and the results lately obtained by him have not caused him to change his opinion.

It appears that Prof. Schmeisser found a rock near Boksburg which he correlates with the Dwyka Conglomerate.* At Viljoens Drift, in the Orange Free State, a similar bed occurs at depths varying from 510 to 580 feet in which the pebbles are more flinty. The matrix is dark grey and white. It rests on grey and slightly pink dolomitic limestone.

Dolerite.—As in other portions of the Coal-measures of South Africa, dolerite occurs in this coal-field, but, as will appear presently, under peculiar circumstances.

Two dolerite-sheets occur. The upper dolerite-sheet varies in thickness from a few feet at Rietvlei to 341 feet at Beerlaagte. It has a long lenticular form, and its highest horizon is at Beerlaagte near the centre of the coal-field, where it crops out along the sides of a large circular "pan" (hollow or depression). From this point, it slopes down slightly on either side. To the west, at Beerlaagte, it is found in No. 2 borehole at 103 feet

* *Trans. Fed. Inst.*, vol. xi., page 400.

from the surface, and at No. 7 borehole at 109 feet, but owing to the configuration of the ground, at a really lower level. The sheet also apparently thins out on either side as it leaves the pan, but much more rapidly to the east, where at Grootvlei, in the shaft, it is about 34 feet thick, and farther east, at Rietvlei, it dwindles down to 2½ feet. Westwards, the decrease in thickness is not so great: at No. 2 borehole (Beerlaagte) it is 341 feet thick, and at Witkleifontein 262 feet thick (Fig. 2, Plate XV.).

The lower dolerite-sheet is only 8 feet thick at Beerlaagte and evidently thins out westwards, as it has not been found in No. 7 borehole at Witkleifontein. It extends eastwards and is 7 feet 6 inches thick at Grootvlei; it then thins out, as it is not found at Rietvlei. (Fig. 2, Plate XV.).

In conformity with the accompanying strata, the upper sheet has been found to rise slightly eastwards from Grootvlei, as seen in the section of the shaft and No. 5 borehole (Fig. 3, Plate XV.). It also rises, but more abruptly at Rietvlei. It evidently crops out in places towards the Vaal river, owing to surface-denudation due to its tributaries.

Coal has thus been discovered for the first time beneath dolerite-sheets, in the Transvaal. The sheets are, however, so far distant from the coal-seams that they have had no effect whatever upon it. Calcite and pyrites in large cubes occur frequently in the cracks of the dolerite, enclosing pieces of the igneous rock. The dolerite contains numerous vertical or nearly vertical joints (columnar structure) which frequently show a coating of silky-black serpentine. This dolerite is mostly ophitic, and consists of augite, lath-shaped crystals of plagioclase-felspar, dust magnetite and labradorite (glomero-porphyritic groups), olivine, and small quantities of ilmenite. The crystals of augite are often larger, but include so many crystals of labradorite that they appear quite fragmentary (ophitic). The olivine is often very much cracked, and has been replaced along these cracks by serpentine. Olivine-basalt also occurs with a ground-mass of radiating and matted lath-shaped felspars, with granular augite and dusty magnetite, in which are porphyritic crystals of labradorite and serpentinous pseudomorphs after olivine.

The question arises, are these sheets sub-aerial (interbedded) or intrusive? The description of the rocks in the borehole section (Appendix A) is given as they first presented themselves to the writer, and from this it would be thought that he considered these sheets to be intrusive (which was his first impression), but after systematizing all his facts he believes that they point more to a volcanic origin, and that

these sheets are sub-aerial. His principal reasons for this view are :— (1) They appear to conform with the bedding of the rocks among which they are intercalated ; (2) the overlying strata are not broken into or disturbed ; (3) their lenticular shape and the relative position of the upper sheet at various localities, pointing to a flow downwards in either direction from the pan, where possibly the vent may be situated ; the rise of the sheets eastward from Grootvlei is due to a subsequent curvature of the measures which the sheet shared ; (4) their uniformity : they present a pronounced and very frequent columnar structure ; (5) they are associated with bands of tuff, and the upper and lower beds of sandstone in which they occur are mostly interlaminated with tuff ; these tuff-laminæ the writer at first mistook for indurated shale, hence his first opinion that they were intrusive, but he considers that they afford indications of feeble intermittent volcanic explosions whereby light showers of dust were discharged, which settled down quietly amidst the sand accumulating at the time.

Another reason, for his first view, was that the dolerite was more crystalline in the central portions of the sheet, but he now attributes the more close-grained texture at the top and bottom of the sheets to an intermixture of tuff. The fact that the dolerite was very rarely cellular or amygdaloidal also influenced him in his first opinion.

Should the writer's view be the correct one, and the presence of a vent established at the pan, it would be interesting to know what effect the great heat and pressure which must have accompanied the outflow of this immense mass of lava had on the thick seam of coal, which it passed through, at the contact. The character of this dolerite is identical with that of the dolerite-sheets surrounding the diamantiferous pipes at Kimberley, and some of the dolerite in the boreholes had a very bluish appearance.

In connexion with this matter, the occurrence of a disturbance on the farm Rietvlei (near the Vaal river) should be mentioned, where Coal-measures sandstone has been tilted up so as to dip at an angle of 30 degrees. This sandstone is laminated, quartzitic in part, and forms excellent building-stone, which is quarried. It dips away from a pan, which is situated about 1,200 feet from it, and around which yellow clay, waterworn pebbles, and loose pieces of indurated clay occur.

Coal.—Reference has already been made to the coal-seam occurring in the South Rand coal-field. There is actually only one workable coal-seam, with a thin rider about 30 feet above it, and a 1 foot seam beneath

it. This seam is somewhat broken up, and loses in quality, to the north, on the farm Modderfontein. Its average thickness is 25 feet, but it is 60 feet thick at Grootvlei, where the colliery is established.

If all carbonaceous bands were deducted from the estimated thickness of most South African coal-seams, this coal-seam would be found to be far and away the thickest.

Trials of this coal taken direct from the mine, without any sorting, were made at the Robinson gold-mine by Mr. Seymour, engineer to the Rand Mines, Limited, and his report is appended hereto (Appendix B). The coal was stated by him to be 29 per cent. better than the best coal used at the Robinson gold-mine. It is remarkably free of sulphur, and contains very little ash.

The colliery consists, at present, of a single shaft 11 feet in diameter. It is 582 feet 4 inches deep, including a sump 20 feet in depth. The iron headgear is 60 feet high, and a proper staging is also erected. The coal-seam is being opened out, and the coal so produced is being sold. Part of the shaft is lined. There is no large feeder of water, and that made in the mine is easily wound to the surface.

Breaks and Faults.—There does not appear to be a single break or fault in the whole coal-field. The formation lies practically horizontal, except at Rietfontein as previously mentioned. This horizontality is a marked characteristic of the South African coal-formation.

Fossils.—A fossil tree was found in the shaft at Grootvlei, but it was too much broken up to enable anyone to decide definitely as to its nature. A few impressions of leaves were found in a clay-shale bed and some lepidodendroid fossils in the coal-seam, but otherwise the formation has so far proved very barren palæontologically.

Prof. De Launay has pointed out that the Transvaal Coal-measures are older than the Stormberg Series, and he consequently describes them as Karoo beds. He stated that Mr. Goldmann had put on record the find of *Lepidodendron* and *Favularia* at Vereeniging; the writer thinks it due to himself to state that it was he who discovered these two fossils, and he mentioned the fact in a paper on "Mining at Kimberley," read before the North Staffordshire Institute of Mining and Mechanical Engineers in 1889.* These fossils are in the museum of Hanley, Staffordshire.

Fire-damp.—The writer only knows of one instance in which fire-damp has been detected in any South African coal-mine. This occurrence took place on April 21st, 1892, whilst he was examining the colliery of

* *Trans.*, vol. x., page 85; and also in *Trans. Fed. Inst.*, vol. xiii., page 122.

Messrs. Lewis and Marks at Vereeniging. The seam is about 100 feet from the surface. A borehole had been put down in the workings to a lower depth, and plugged to prevent the outflow of water. The writer held his candle to this hole and had it unplugged, when a large blue flame about 3 feet long issued forth and was immediately extinguished. This was repeated several times. No fire-damp has been so far discovered in this coal-field, save a small quantity at the Grootvlei colliery.

Small Collieries.—A few small outliers of the Coal-measures are shown in Fig. 1 (Plate XIV). These consist of shallow deposits extending along the spruits or streams. The coal which they contain occurs at depths varying from 40 to 60 feet, and it is worked at one or two small collieries.

Part II.—Gold.

General.—Prospecting for gold has been vigorously carried on by the writer around and in the South Rand coal-field. His opinion that the coal-field merely covered a large area of Banket or gold-bearing formation has been borne out, and numerous auriferous reefs have been intersected.*

Banket Formation.—The geological plan and section (Fig. 1, Plate XIV. and Fig. 2, Plate XV.) show the extent of this formation, both as regards area and depth, in the locality.

From the section (Fig. 2) it will be seen that the formation consists of two sides of an anticlinal, the top part of which has been removed by denudation before the Coal-measures were deposited. These rocks were originally thrown into an anticlinal fold through the pressure of the granitic base beneath them. A comparison between this section (Fig. 2, Plate XV.) and the one accompanying the writer's paper (Fig. 1, Plate XX.) read before this Institution† will show a remarkable similarity between this formation at the Rand and in this locality. In both localities, a large anticlinal fold produced through the elevation of the granite base occurs. The thickness of the formation is about the same, and in both cases the formation is topped by a thick sheet of amygdaloidal diabase. There is no doubt whatever in the writer's mind that the western side of this anticlinal is an uninterrupted continuation of the Rand formation, with the exception of dislocations. The Rand formation at its western end (Bantjes Gold-mining Company) dips 32 degrees south, it then forms an anticlinal on the farm Doornkop, No. 331,‡ and is then hidden beneath dolomitic limestone and amygdaloidal

* *Trans. Fed. Inst.*, vol. ix., page 362. † *Ibid.*, vol. ix., page 360.

‡ See the writer's remarks in *Trans. Geological Society of South Africa*, vol. ii., page 15.

diabase, forming, no doubt, several synclinals and anticlinals until it emerges again on the farm Witkleifontein, where it dips to the north-west at an angle of 15 degrees. It may be here remarked that the writer has advised a borehole being put down at Doornkop on the top of the anticlinal, with a view to intersecting the main reef at a workable depth.

The rocks forming the western end of this formation are, in the writer's opinion, about 12,000 feet thick. Only a few hundred feet of these strata crop out, and the others are hidden by surface-soil and Coal-measures. The formation here dips north-west 15 degrees, and the occurrence of a thickness of at least 4,300 feet of strata has been demonstrated by boring.

The thickness actually proved in the upper portions of the formation is about half of that estimated.

The rocks forming the eastern end of the formation are also about 12,000 feet in thickness, and they are entirely hidden by Coal-measures in the line of section. The formation here dips at an angle of 45 degrees to the east, and the occurrence of a thickness of at least 6,000 feet has been demonstrated by boring. The thickness actually proved by boring is about 400 feet. The rocks at the eastern end differ lithologically from those at the western end: they resemble more the clay-slates and quartzites of Hospital Hill, which are older.

The Banket formation at the eastern end, beneath the Coal-measures, is shown in Fig. 4 (Plate XVI.). The determination of the contact between the quartzites discovered in No. 6 borehole and the slates discovered in No. 4 borehole was a work entailing much consideration.

Borehole No. 4 was first put down, and then No. 6 was put down to a depth of 250 feet. The quartzite proving very strong and the wear-and-tear in diamonds being heavy compared with that in the Coal-measures above, it was decided to try and get at the contact by putting down a few holes through the Coal-measures between Nos. 4 and 6 boreholes. No. 12 borehole was then put down: at 212 feet quartzite was encountered, it was passed through at 226 feet, and followed by breccia and conglomerate-beds to a depth of 241 feet, when slate occurred. 2 feet of core were lost just before reaching the slate. The conclusion arrived at was that the contact had been reached and a reef at the contact lost, so another borehole was put down (No. 13) 3 feet distant from No. 12 borehole. The results obtained led the writer to the conclusion that the quartzite passed through in Nos. 12 and 13 boreholes was not the solid rock, but a large block disconnected from it

and forming part of the bed of breccia which underlies the Coal-measures. No. 14 borehole was next put down. This also passed through a large block of quartzite with breccia and conglomerate beneath, and the slate was bored into. The best plan then appeared to the writer to bore No. 6 hole deeper, notwithstanding the hardness of the quartzite, and the contact was reached at a depth of 530 feet 10 inches.

What helped to influence the writer in his first conclusion on the result of No. 14 borehole was the fact that the quartzite-block showed distinct planes of stratification dipping, as in the solid formation, at an angle of 45 degrees. This dip shows that the blocks must have slid down from the solid without being otherwise disturbed.

The above description is given to illustrate the difficulties attending a correct deduction of phenomena shown in cores, and how much care is required to properly appreciate them. In order to convey a correct impression of the samples of cores assayed, they were sketched by Mr. G. Stanley Bloomer, and are reproduced in Figs. 8 to 120 (Plates XVII. and XVIII.

Description of Rocks.—The rocks forming the western end of the anticlinal have so far been shown to consist of quartzite: coarse, fine, and argillaceous, containing pebbles occasionally in greater or fewer quantities; slate: in very thin bands, more or less sharply defined; and Banket reefs: thin on the whole, with mostly small pebbles.

The quartzites and Banket Reefs are more or less pyritical. Pyrites occurs as segregations near pebbles, mixed with argillaceous matter and disseminated throughout the mass. It is invariably crystalline when visible to the naked eye. The pebbles consist mostly of quartz, milky white, smoky black, transparent, translucent, streaked; yellow, bluish, and horny (truffle colour); rounded, angular, and sub-angular. Slate-pebbles occur, as on the Rand,* though in greater quantities, soft and hardened, mostly small, but occasionally large, often elongated and flat. Pebbles of mica—transparent—occur at times. Grains of shale and flakes of mica also occur more or less throughout the cores.

The rocks forming the eastern end of the anticlinal consist, so far as proved, also of quartzites, slates, and Banket Reefs, but the character of the quartzites is different and the slate occurs as a very thick bed. The quartzite above the slate is extremely talcose, mostly compact, white, and very hard. A bed of quartzite older than the slate in

* This fact seems to have escaped the notice of several writers.

geological sequence has peculiar characteristics (Fig. 2, Plate XV.). It is talcose and argillaceous, has schistose planes, and is extremely hard in depth. It contains calcite and white quartz-veins; also pyrites in segregations.

The slate-bed, near the contact, at No. 6 borehole, presents certain peculiarities: it contains large white and smoky quartz-pebbles, bands of quartzite, specks and segregations of pyrites and black quartz-grains.

It has occurred to the writer that these slate-beds may have had an igneous origin, and have been basic igneous rocks in which cleavage-planes have been superinduced; but the presence of pebbles and quartz-grains in the slate, as described above, which by the way is an unusual occurrence, and so far as the writer knows has not been pointed out before, would seem to detract from this view. In connexion with the usual presence of a Banket Reef at the contact of slates and quartzites, it may be observed that the fact that no reef is intersected in any particular borehole must not be taken as evidence of its non-existence, as the slightest earth-movement may cause a sliding motion sufficient to efface it at any particular spot, the substance of the reef being thrust on to itself at another point.

The deposition of pyrites differs at the western from that at the eastern end of the section (Fig. 2, Plate XV.). At the western end, the pyrites is segregated more around the pebbles and also more regularly in the form of venules, whereas at the eastern end very few venules occur, the pyrites being more in the form of irregular segregations. As on the Rand, galena and zinc blende occur in veins of secondary quartz at the western end. These quartz-veins are white, and not more than a few inches thick.

Fig. 2 (Plate XV.) shows an underground connexion with the formation in which the Heidelberg Roodepoort reef occurs. The diabase-sheet, which covers and thus hides it, has been shown to have a maximum thickness of 3,000 feet.

In corroboration of this view, the writer may state that a borehole had been sunk to a depth of 1,050 feet on a certain property in the Potchefstroom district. The core consisted of igneous rock, and the writer was asked to report as to whether the boring should be stopped, as it was thought that the hole was in a dyke. He examined the core and the ground carefully and made the accompanying section (Fig. 5, Plate XVI.). He formed the opinion that the rock encountered so far was the amygdaloidal diabase-sheet and that it would be passed at a depth of about 1,330 feet; he therefore advised that boring should be

continued. At a depth of about 1,440 feet the sheet was passed through and quartzites encountered, some of which are auriferous.

Dykes.—Dykes occur in this locality, which are mostly of diabase. In one notable instance, a dyke of quartz-diabase was encountered in the borehole near Vlakfontein station. To all appearance this rock looked like a highly talcose quartzite, but the quartz-grains were dull and ill defined. The rock was hard, heavy, contained pyrites and numerous calcite and white quartz-veins. A microscopic examination showed it to be granophyric and to contain kaolinized felspar, augite, quite fresh, and exhibiting good twinning, magnetite, and iron pyrites. The spaces between these minerals were entirely filled with a beautiful granophyric intergrowth of felspar and quartz.

Part III.—Bed Rock.

Granite.—The gneissoid granite, forming the base of this coal-field, is part of the basement underlying the whole of South Africa, and is here, in the writer's opinion, distinctly anterior to the Banket formation. The writer has examined it at Cape Town and George in Cape Colony; in Mashonaland; in Matabeleland; and at Vredefort, in the Orange Free State.

In the Transvaal, the writer has examined it at Zoutpansberg; on the Rand; north of the farm Witfontein, No. 572;* on the farm Varkenskraal, No. 354; and 13 miles east of Heidelberg. He has also shown its position as a dyke at the eye of Wonderfontein.†

Regarding its occurrence on the farm Varkenskraal, a banket reef occurs, in the writer's opinion, over nearly the whole extent of the farms shown in Fig. 6 (Plate XVI.). The reef, and the quartzites and slates accompanying it, are covered over about two-thirds of the farms by dolomitic limestone and cherty detritus, produced by its denudation. The reef dips from the western side of the farms, where they are horizontal, at an angle of from 5 to 10 degrees to the east, and is, therefore, not likely to occur at a greater depth than 400 or 500 feet at the Mooi river, where the reef lies deepest (Fig. 7, Plate XVI.). From the western side of the farms, the reef dips westward into the proclaimed farms Zyferfontein and Wolvefontein, at an angle of about 5 degrees. On Zyferfontein, it forms several small anticlinals and shallow synclinals, and crops out with an eastern dip of about 10 degrees, about 3 miles west of the farms. From an examination of the country north of the farms, the

* *Trans. of the Geological Society of South Africa*, vol. ii., page 33.
† *Ibid.*, vol. ii., page 15.

writer believes that the small anticlinal which occurs along the western end of the farms, and which stretches towards Klerkskraal, is connected with a granite-intrusion, which occurs, as shown on Fig. 6 (Plate XVI.), on the farm Varkenskraal. Some of this granite contains white quartz-veins, which can be seen passing through various gradations of decomposition until they reach the final stage of Banket pebbles. On Varkenskraal and Klerkskraal, the Banket Reefs and accompanying quartzites are clearly seen resting upon the granite, and some of the pebbles occurring in the reef at its outcrop on Zyferfontein farm consist of glassy white quartz.

The reef varies in thickness and quality over the extent of country shown on Fig. 6 (Plate XVI.). It sometimes appears to form two distinct reefs. In some places it resembles a breccia, at others, and more generally, it resembles some of the best Banket beds of the Rand. It contains mostly average-sized quartzite-pebbles. In some places, large sandstone-pebbles occur, as much as 18 inches long. Occasionally the pebbles are small. The foot- and hanging-walls also vary. At Zyferfontein, and at a few other places, they consist of slate. On the other farms, the hanging-wall is usually quartzite. The writer is of the opinion that this reef more nearly resembles the Black Reef, and more especially as it occurs at Eastleigh, than any other Banket Reef that he knows. It was impossible, in view of the large quantity of banket traceable, to do more than to pan a few promiscuous samples. On the whole, the results were satisfactory, and several pannings showed 8 or 10 dwts. of gold to the ton, which, in some cases, was very coarse.

The writer has referred to his discovery of granite at a place east of Heidelberg, at a meeting of the Geological Society of South Africa.* Its position is now shown on the accompanying geological plan (Fig. 6, Plate XVI.). Granite is nowhere seen near the surface in the neighbourhood of the South Rand coal-field. It was intersected in boreholes in the centre of the coal-field at depths of 687 feet and 725 feet respectively.

This granite is pink in appearance. Rock-slides of samples of these latter gneissoid granites were made, and these were seen to resemble the protogine gneiss of Mont Blanc. The minerals thus found were :— Felspars (monoclinic and triclinic) and quartz, all more or less abraded at their edges, cemented together by thinnish bands of chlorite (secondary from brown mica), fibrous hornblende, and protogine (a secondary white mica). A porphyritic pink crystal (beautiful microclines), also abraded

* *Trans.*, vol. i., page 36.

at its edges, was observed ; on examination, under polarized light, it was seen that large pieces of this crystal had been broken off by crushing agencies, and yet only slightly moved before being cemented together to the main portion of the crystal by protogine.

The writer is indebted to Mr. P. D. Durell, who kindly drew all the illustrations reproduced in Plates XIV., XV., and XVI. attached to this paper.

APPENDIX A.—Section of No. 5 Bore-hole at South Rand Colliery, Grootvlei, commenced on September 9th, 1895, and completed on January 2nd, 1896. The Diameter of the Bore-hole is $3\frac{1}{8}$ Inches, and of the Core $2\frac{1}{4}$ Inches to the Bottom of the Bore-hole.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Yellow clay ...	16	0	16	0
2	Yellow clay and pebbles	13	0	29	0
3	Clay, gradually getting darker and more micaceous ...	35	0	64	0
4	Soft grey shale, more or less micaceous...	16	6	80	6
5	Shale...	0	10	81	4
6	Soft grey shale ..	26	8	108	0
7	Calcareous shale ...	1	10	109	10
8	Shale, more or less arenaceous ...	0	8	110	6
9	Shale, slightly calcareous and arenaceous	1	6	112	0
10	Shale, arenaceous ...	1	0	113	0
11	Shale, arenaceous and micaceous (harder)	1	0	114	0
12	Shale, arenaceous and micaceous (indurated at contact)...	4	0	118	0
13	Dolerite	25	4	143	4
14	Slate, indurated ...	0	2	143	6
15	Sandstone, indurated (quartzite) with much pyrites ...	0	6	144	0
16	Sandstone, coarse in part ...	78	0	222	0
17	Shale, arenaceous and partly micaceous ...	15	6	237	6
18	Shale, micaceous and arenaceous ...	4	0	241	6
19	Sandstone, coarse and fine, with a few thin and irregular bands of shale in places	89	4	330	10
20	Sandstone, fine, more or less micaceous in part	59	2	390	0
21	Alternating thin bands of sandstone and dark micaceous shale	13	4	403	4
22	Fine black shale slightly banded in places	15	8	419	0
23	Sandstone, coarse ...	1	0	420	0
24	Sandstone, pure white	0	3	420	3
25	Sandstone, coarse ...	0	3	420	6
26	Shale, dark	3	3	423	9
27	Fine sandstone, with shale-bands ...	2	3	426	0
28	Sandstone, coarse and fine	9	4	435	4
29	Carbonaceous shale and coal	1	6	436	10
30	Sandstone	31	2	468	0
31	Agglomeration of quartz-grains in a pyrites matrix ...	0	6	468	6
32	Shale, highly carbonaceous, with bands of coal	7	1	475	7
33	**COAL**, mostly very bright and light with duller bands ; only 7 feet of core recovered ; remainder must be better coal...	11	1	486	8
34	Carbonaceous shale-band	1	0	487	8
35	**COAL**, with carbonaceous shale ...	1	2	488	10
36	**COAL**, good ...	16	8	505	6
37	Carbonaceous shale	0	3	505	9
38	**COAL**, good ...	1	4	507	1
39	**COAL**, good ...	2	9	509	10
40	Shale, highly carbonaceous	1	6	511	4
41	**COAL**, very good ..	9	2	520	6
42	**COAL**, very good ...	6	0	526	6
43	Sandstone, coarse ...	27	6	554	0
44	Sandstone, finer, with carbonaceous impurities and quartz-pebbles	15	0	569	0

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
45	Sandstone, coarse, with carbonaceous impurities	9	0	578	0
46	Dark coarse grit, with pebbles ...	1	0	579	0
47	**COAL**, very good...	1	0	580	0
48	Sandstone, more or less fine, with bands of coarse grit ...	18	0	598	0
49	Dark coarse grit, with pebbles ...	4	6	602	6
50	Slightly calcareous grey earthy soft rock : decomposed igneous rock ...	1	0	603	6
51	Dolerite-sheet ...	7	6	611	0
52	Mica	0	6	611	6
53	Coarse grit, with carbonaceous impressions and laminæ with a few pebbles	28	6	640	0
54	Shale, carbonaceous	4	0	644	0
55	Coarse grit, more or less dark grey ...	8	9	652	9
56	Grey shale, with white bands ...	7	3	660	0
57	Breccia, with large pebbles of quartzite and shale, with small brick-red grains ...	27	0	687	0
58	Gneiss, coarse-grained, with pink felspar, jointed, 45 degrees	40	0	727	0

APPENDIX B.—Boiler test of South Rand coal begun at 12 noon on August 26th, 1897, and ended on the following day at 10 a.m. The two boilers used were coupled return tubular, with return side-flues, connected at the top and bottom by the steam-drum and mud-drum respectively, and were supplying steam to a triple-expansion vertical engine, and to a compound vertical Riedler air-compressor at the Robinson 120 stamps battery. The boilers had 2,397 square feet of water-heating surface, 58 square feet of grate-surface, 44 tubes of an outside diameter of 3½ inches, and 16 feet in length between tube-sheets.

EXPERIMENTAL DATA.

Average height of barometer, corrected, inches...	24·45
,, atmospheric pressure in pounds per square inch ...	12·014
,, draft in inches of water	0·187
,, temperature in degrees Fahr. of boiler-house ...	70·46
,, ,, ,, ,, feed-water	69·16
,, ,, ,, ,, uptake-gases ...	433·56
,, pound pressure per square inch by the steam-gauge...	119·00
,, ,, ,, ,, of the steam, absolute	131·014
Percentage of moisture in the steam	0·50
Temperature in degrees Fahr., corresponding to absolute atmospheric pressure	347·652
British thermal units in each pound of feed-water	69·1789
,, ,, dry steam	1,219·6753
Pounds of wood used to light the fires	387·00
,, coal fired	9,098·75
,, cinders remaining	143·20
,, coal consumed	8,955·55
,, clinkers in the coal	404·80
,, ashes in the coal	836·70
,, moisture in the coal	159·22
,, total refuse	1,400·72
,, combustible in the coal	7,554·83

Percentage of combustible in the coal	84·359
,, clinker ,, ...	4·520
,, ash ,, ...	9·343
,, moisture to coal consumed	1·778
,, total refuse	15·641

RESULTS.

British thermal units absorbed by each pound of feed-water...	1,150·7963
Factor of evaporation	1·1916
Pounds of water evaporated into dry steam	60,536·00
,, ,, ,, per pound of coal	6·5703
,, ,, ,, ,, combustible	7·7483
,, ,, ,, ,, coal from and at 212° Fahr.	7·8291
,, ,, ,, ,, combustible from and at 212° Fahr.	9·2328
,, ,, ,, per square foot of heating-surface per hour	1·147
Pounds of coal burned per square foot of grate-surface per hour	7·22
British thermal units per pound of coal absorbed by the feed-water	7,561·076
British thermal units in each pound of coal	10,197·79
Theoretical evaporation per pound of coal from and at 212° Fahr.	10·56
Efficiency of plant	74·14

The CHAIRMAN moved a vote of thanks to Mr. Sawyer for his paper, and the motion was approved.

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To illustrate Mr A.R. Sawyer's Paper on "The South Rand Coal-field," &c.

Vol. XIV Plate XIV

GEOLOGICAL PLAN
OF
THE ROOIKOPJES PORTION OF THE HEIDELBERG DISTRICT, TRANSVAAL.

Fig. 1.

REFERENCE.

- COAL-MEASURES, WITH EXTENSIVE SHEETS OF DOLERITE.
- DIABASE.
- WITWATERSRAND FORMATION, CONTAINING NUMEROUS AURIFEROUS REEFS, AND UNDERLYING THE COAL-MEASURES AND THE AMYGDALOIDAL DIABASE-SHEET IN PART.
- GNEISSOID GRANITE, UNDERLYING THE WITWATERSRAND FORMATION AND THE COAL-MEASURES WHERE THE FORMER HAVE BEEN REMOVED BY DENUDATION.

TO JOHANNESBURG
NIGEL G. M. CO.
BLESBOK SPRUIT
SLATES QUARTZITES ALTERNATING
SLATES AND QUARTZITE ESCARPMENT
GNEISSOID GRANITE
AMYGDALOIDAL DIABASE
HEIDELBERG
BOSCHHOEK NO. 270
MOLYNEUX WEST G. M. CO.
NOITGEDACHT
SLATE
MOLYNEUX CONSOLIDATED G. M. CO.
HEIDELBERG PLATKOP G. M. CO.
PERSEVERANCE COLLY
SANDSTONE, QUARTZITE AND SLATE
ZUIKER BOSH RAND SPRUIT
OCEANA TRANSVAAL COLLIERY
VLAKFONTEIN STATION
NATAL RAILWAY
TWEEFONTEIN NO. 98.
WILGEPOORT NO. 244.
RIETFONTEIN NO. 244.
DASPOORT NO. 120.
MISSION STATION
RIETSPRUIT NO. 223.
BLESBOK SPRUIT
WHITE QUARTZITE AND SLATE
PANFONTEIN NO. 141.
QUARTZITE RANGE
TO DURBAN
MODDERFONTEIN
HEIDELBERG ROODEPOORT GOLD MINING CO
GREYLING STAD
SOUTH RAND COLLIERY
BRAKLAAGTE NO. 187.
SEERLAAGTE NO. 256.
RIETVLEI NO. 190.
LINE OF SECTION FIG 2
PAN DOLERITE
VAAL RIVER
WITKLEI FONTEIN NO. 295.
SOUTH RAND COAL-FIELD
UPPER ROOI KOPJES
ROOIWAL NO. 295.
BARNARDSKOP
HEXRIVER GOLD MINING CO.
DYKE
KALK SPRUIT
FREESTONE QUARRY
PROBABLE RAILWAY EXTENSION TO HARRISMITH
ORANGE FREE STATE
WILGE RIVER
VILLIERS

Scale, 3·8 Miles to 1 Inch.

Mining Institute of Scotland.
Transactions 1897-8

And.w Reid & Comp.y L.td Newcastle on Tyne.

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The Federated Institution of Mining Engineers.
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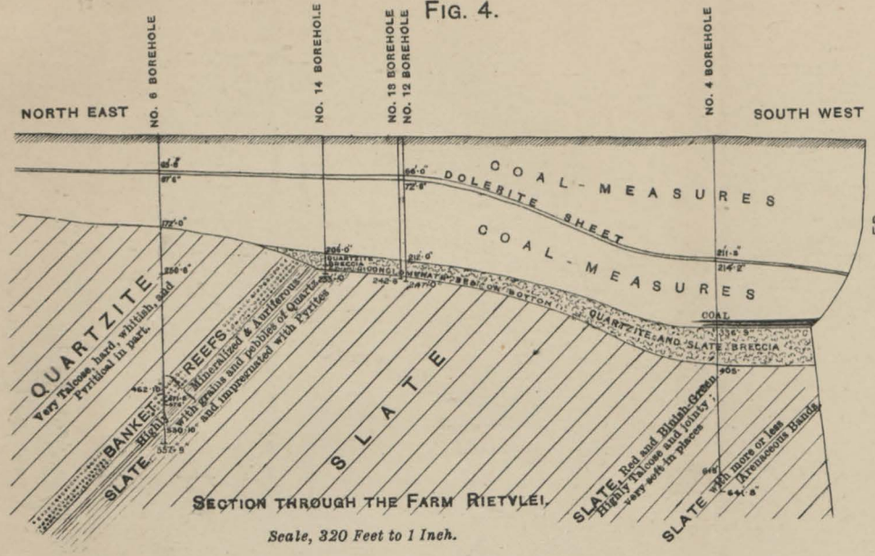
To illustrate Mr A.R. Sawyer's Paper on "The South Rand Coal-field" &c.

Vol. XIV Plate XVI.

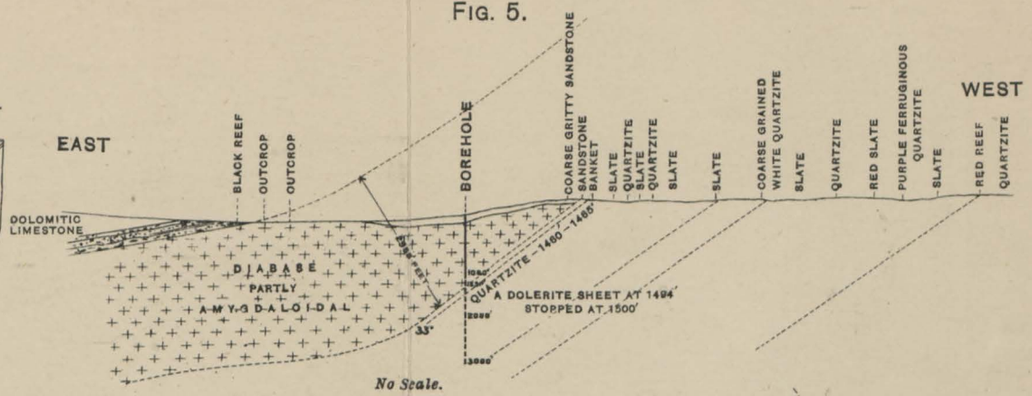
FIG. 4.



SECTION THROUGH THE FARM RIETVLEI.

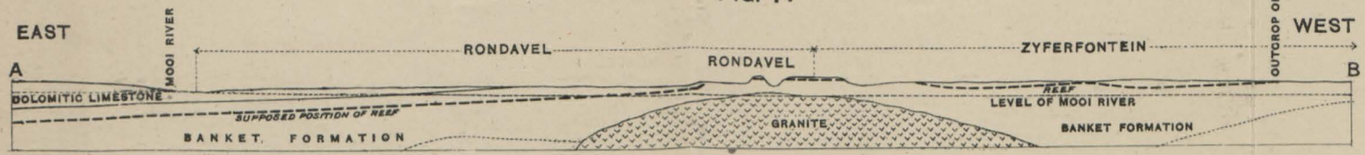
Scale, 320 Feet to 1 Inch.

FIG. 5.



No Scale.

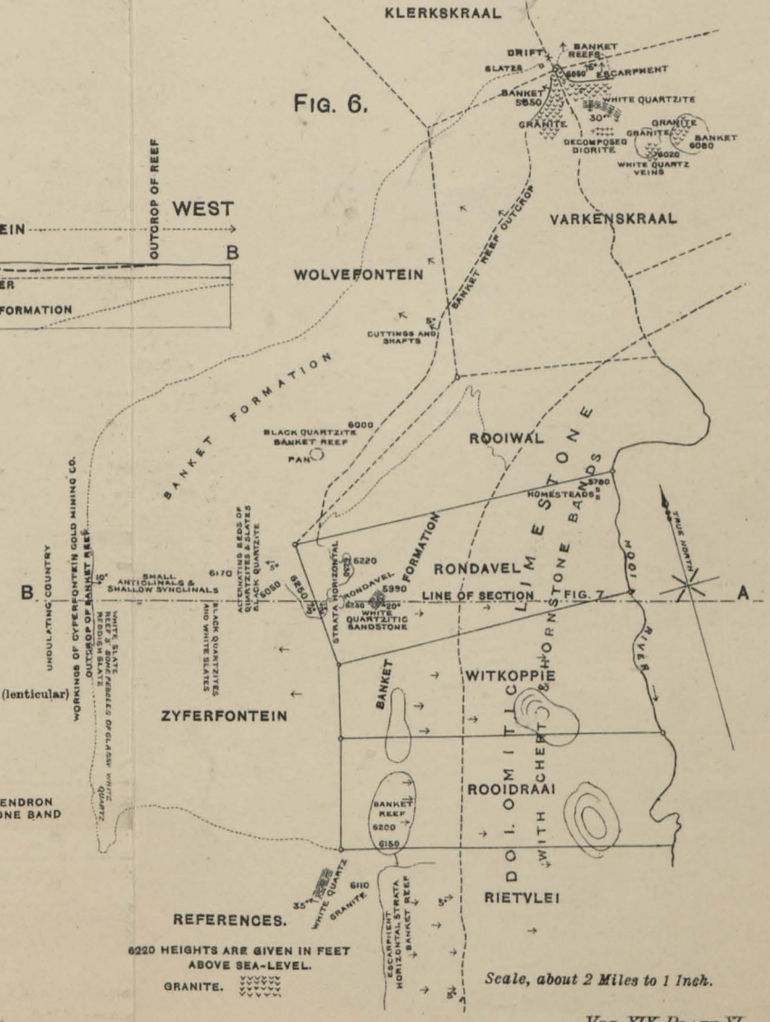
FIG. 7.



SECTION THROUGH LINE A B, FIG. 6.

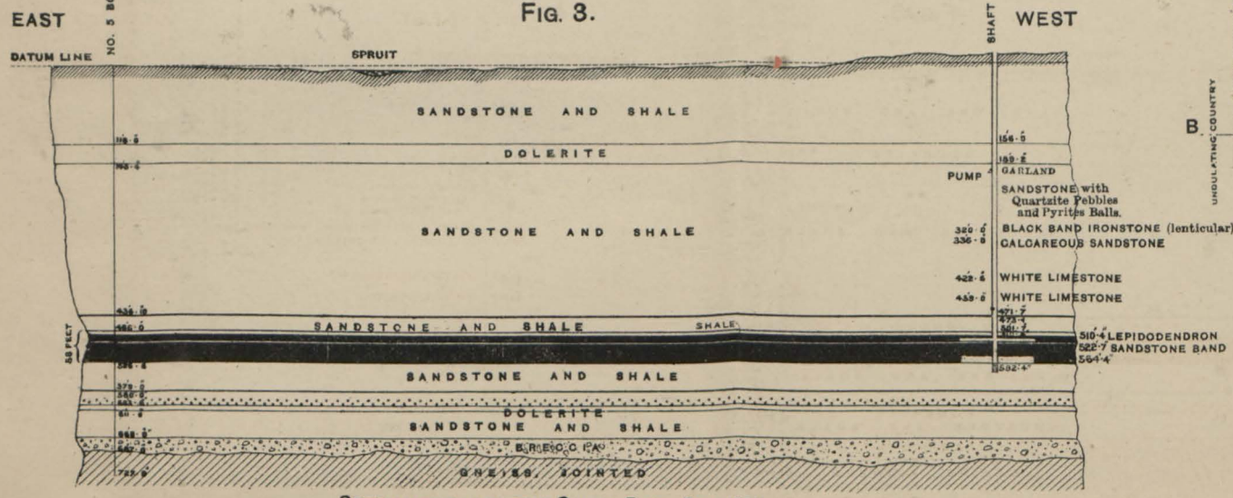
Scale, 1 Mile to 1 Inch.

FIG. 6.



Scale, about 2 Miles to 1 Inch.

FIG. 3.



SECTION THROUGH THE SOUTH RAND COLLIERY.

Scale, 320 Feet to 1 Inch.

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The Federated Institution of Mining Engineers.
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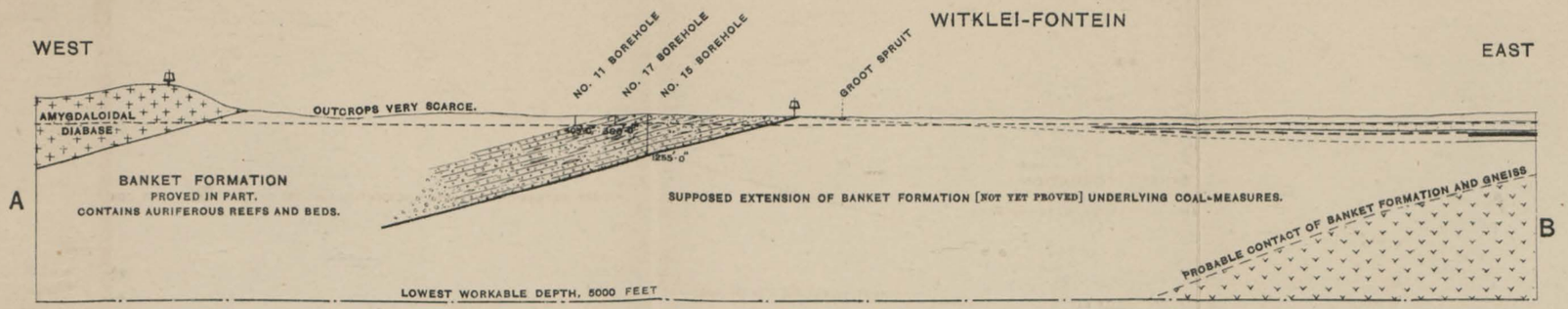
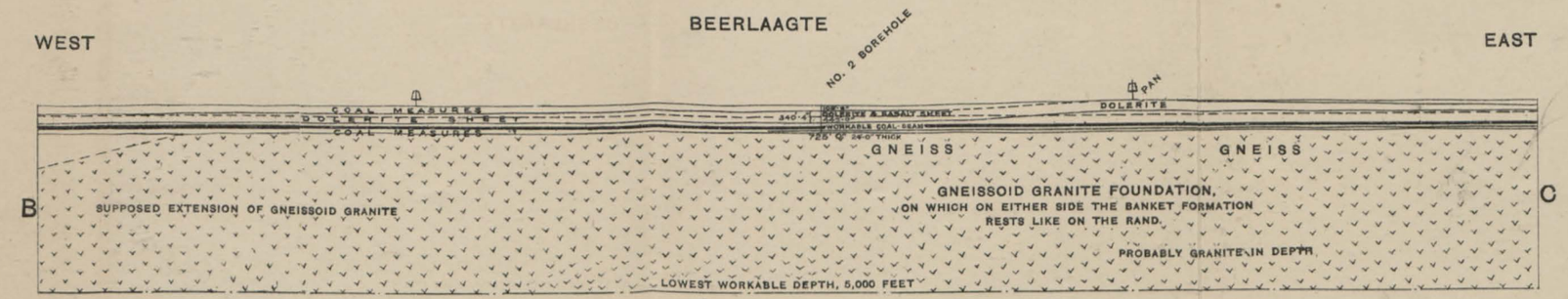
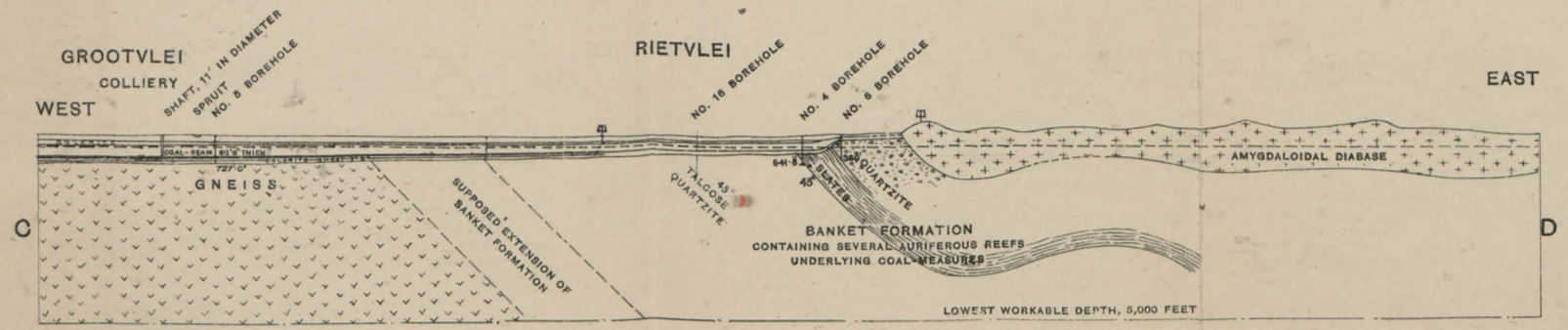
To illustrate Mr. A.R. Sawyer's Paper on "The South Rand Coal-field" &c.

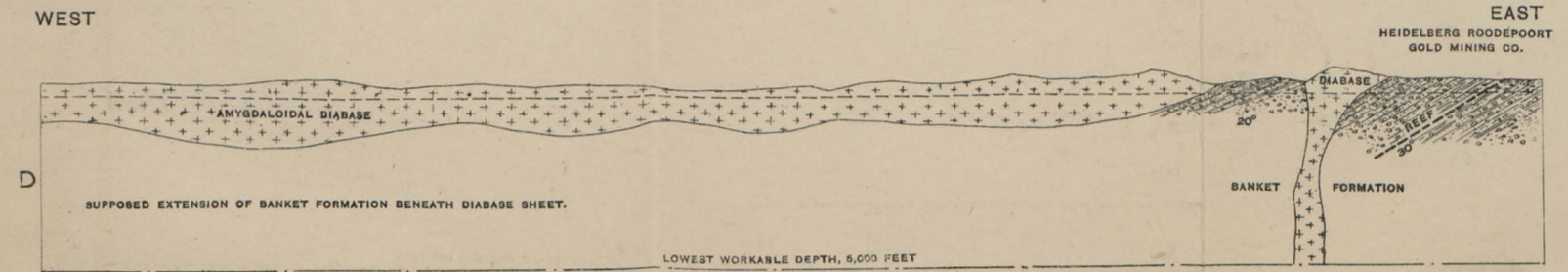
Fig. 2.

Line of Section A B on Fig. 1.









Scale, about 4,984 Feet to 1 Inch.

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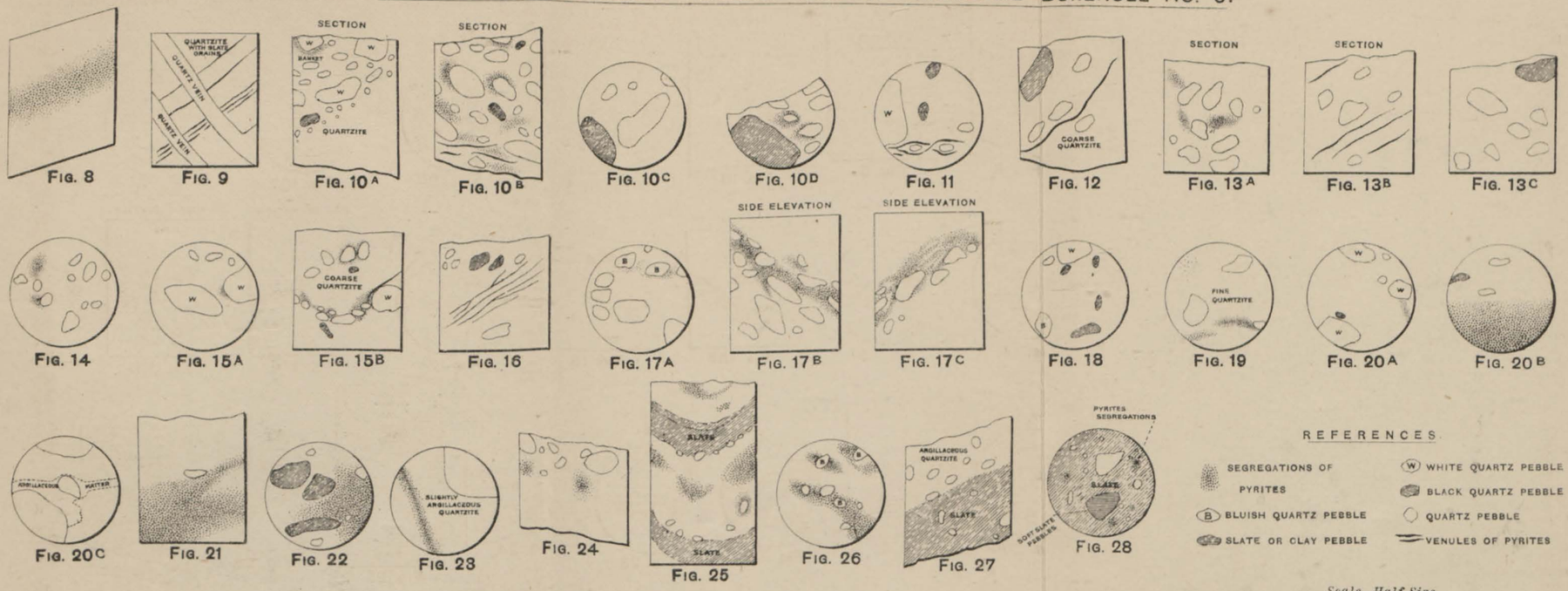
To illustrate Mr. A.R. Sawyer's Paper on "The South Rand Gold-field."

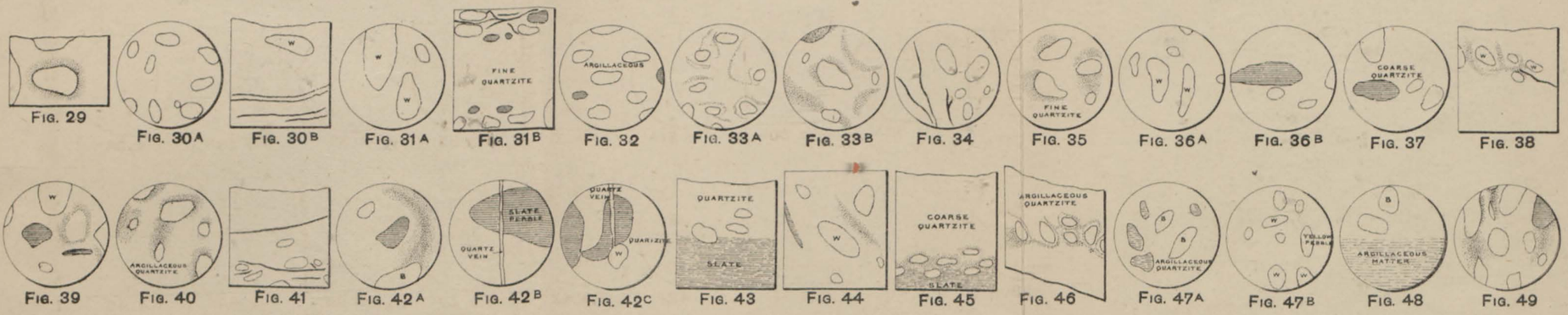
Vol. XIV Plate XVII

Typical Samples Assayed—Eastern End of Anticlinal—Borehole No. 6.

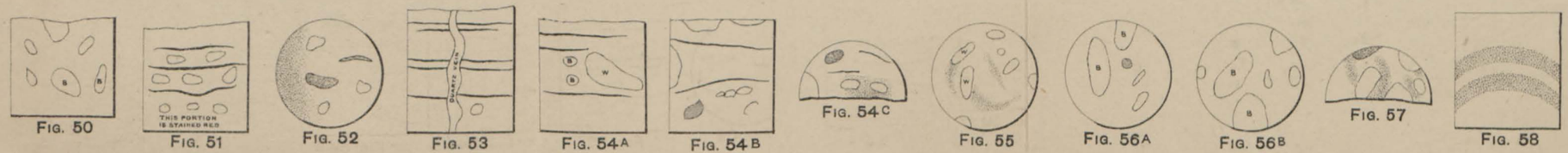


Scale, Half Size.

Typical Samples Assayed—Western End of Anticlinal—Borehole No. 10.



Typical Samples Assayed—Western End of Anticlinal—Borehole No. 11.



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To illustrate Mr A.R. Sawyer's Paper on "The South Rand Gold-field."

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Typical Samples Assayed—Western End of Anticlinal—Borehole No. 15.

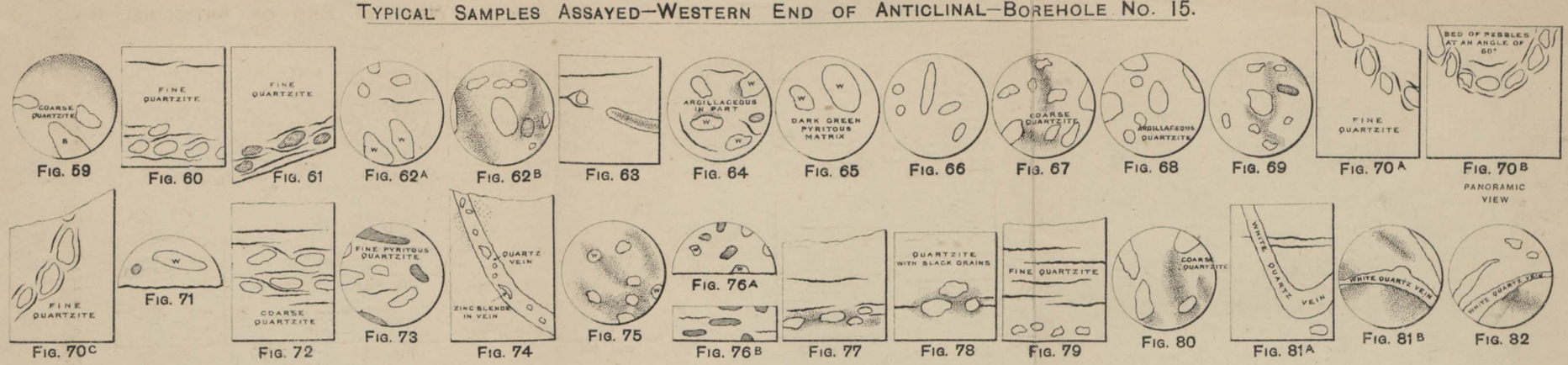

Fig. 59 Fig. 60 Fig. 61 Fig. 62A Fig. 62B Fig. 63 Fig. 64 Fig. 65 Fig. 66 Fig. 67 Fig. 68 Fig. 69 Fig. 70A Fig. 70B PANORAMIC VIEW

Fig. 70C Fig. 71 Fig. 72 Fig. 73 Fig. 74 Fig. 75 Fig. 76A Fig. 76B Fig. 77 Fig. 78 Fig. 79 Fig. 80 Fig. 81A Fig. 81B Fig. 82

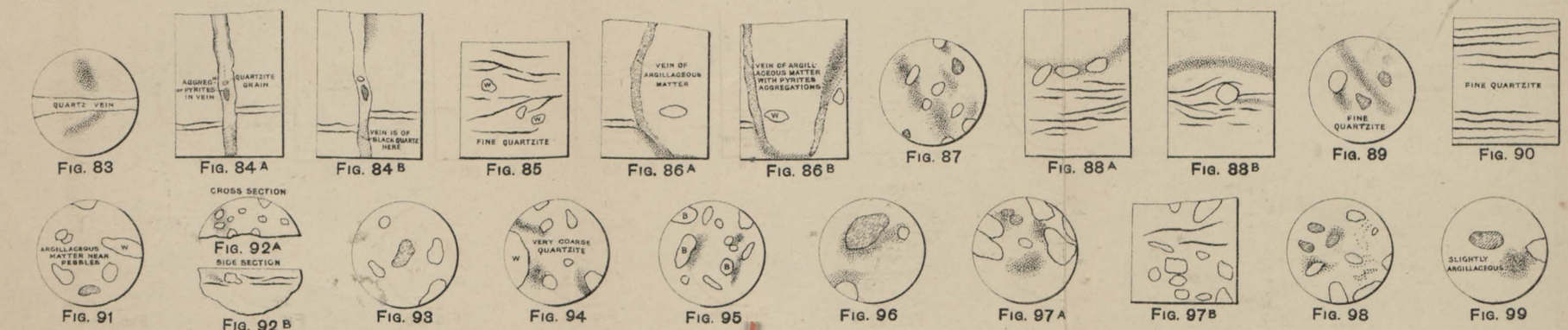

Fig. 83 Fig. 84A Fig. 84B Fig. 85 Fig. 86A Fig. 86B Fig. 87 Fig. 88A Fig. 88B Fig. 89 Fig. 90

Fig. 91 Fig. 92A Fig. 92B Fig. 93 Fig. 94 Fig. 95 Fig. 96 Fig. 97A Fig. 97B Fig. 98 Fig. 99

Typical Samples Assayed—Western End of Anticlinal—Borehole No. 17

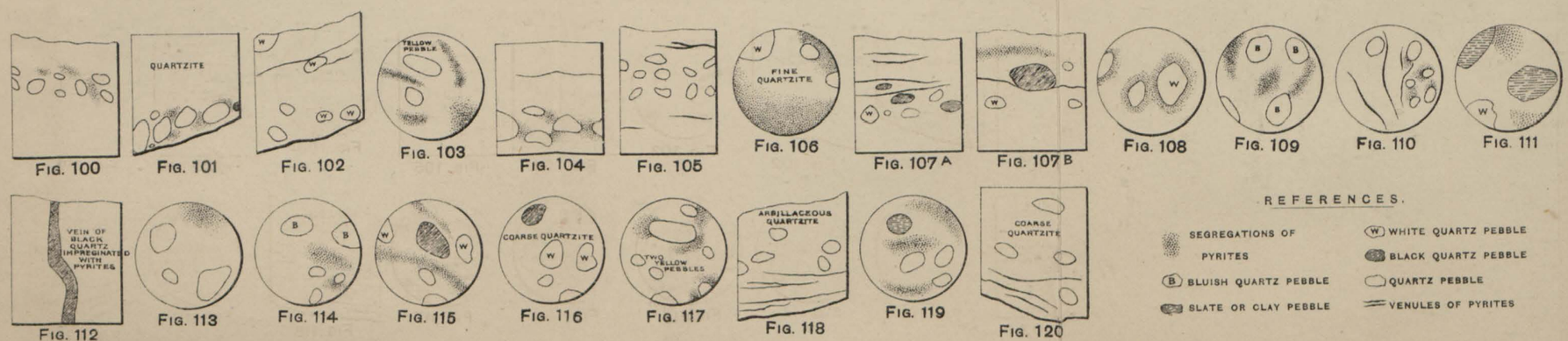

Fig. 100 Fig. 101 Fig. 102 Fig. 103 Fig. 104 Fig. 105 Fig. 106 Fig. 107A Fig. 107B Fig. 108 Fig. 109 Fig. 110 Fig. 111

Fig. 112 Fig. 113 Fig. 114 Fig. 115 Fig. 116 Fig. 117 Fig. 118 Fig. 119 Fig. 120

Scale, Half Size.

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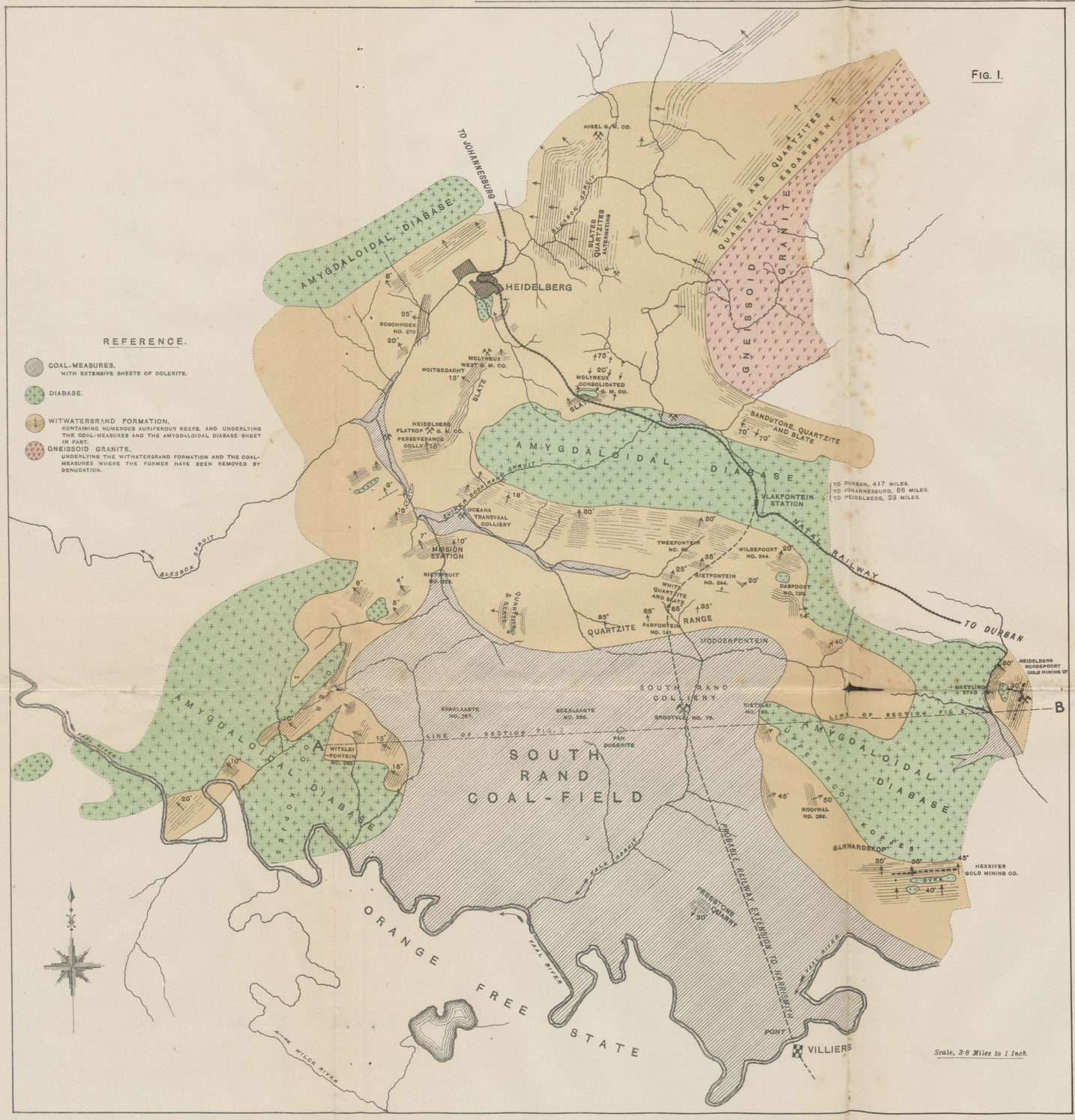
And.w Reid & Compy Ltd. Newcastle on Tyne.

Vol XIX. Plate XIII

GEOLOGICAL MAP AND SECTIONS OF THE HEIDELBERG DISTRICT, TRANSVAAL,

BY A. R. SAWYER, A.R.S.M., F.G.S., LATE H.M.'S INSPECTOR OF MINES, MINING ENGINEER.

FIG. I.



FOR PARTICULARS SEE

THE SOUTH RAND COAL-FIELD,

AND ITS CONNECTION WITH THE

WITWATERSRAND BANKET FORMATION.

A PAPER READ BEFORE THE FEDERATED INSTITUTION OF MINING ENGINEERS,

BY

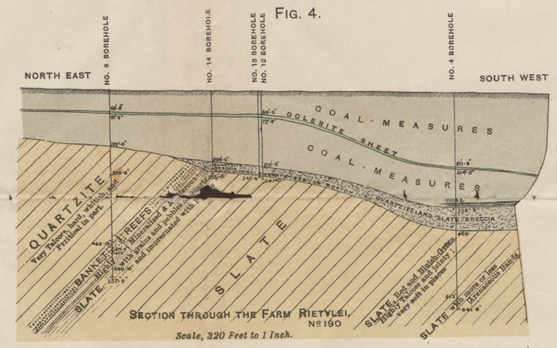
MR. A. R. SAWYER,

14TH SEPTEMBER, 1897.

No distinction is made between the Witwatersrand Beds proper and the older Hospital Hill Slates and Quartzites, but the latter are specially designated on the Plans and Sections as Quartzites and Slates.

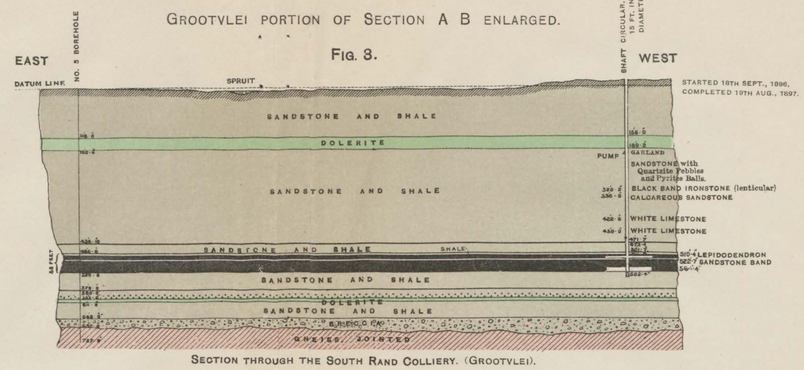
RIETVLEI PORTION OF SECTION A B ENLARGED.

FIG. 4.



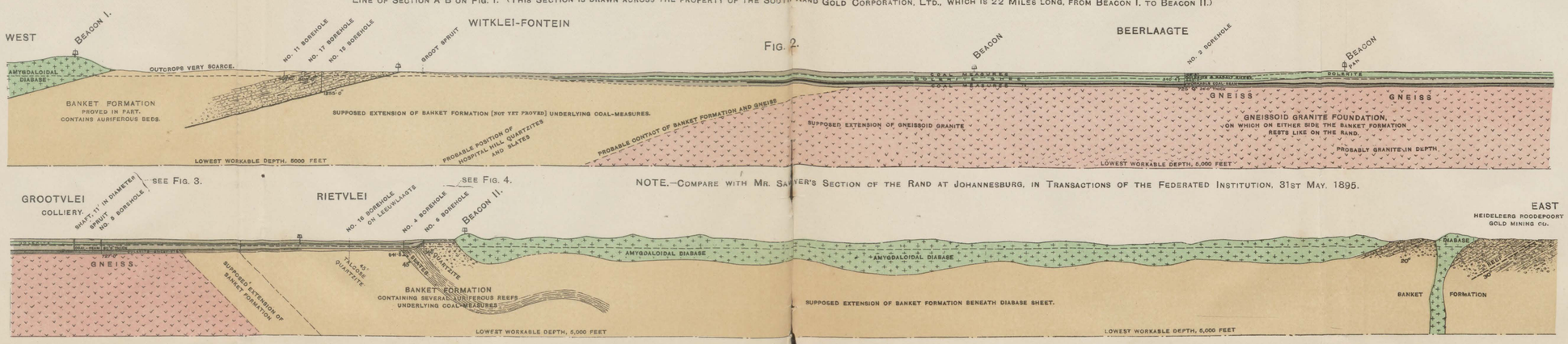
GROOTVLEI PORTION OF SECTION A B ENLARGED.

FIG. 3.



LINE OF SECTION A B ON FIG. 1. (THIS SECTION IS DRAWN ACROSS THE PROPERTY OF THE SOUTH RAND GOLD CORPORATION, LTD., WHICH IS 22 MILES LONG, FROM BEACON I. TO BEACON II.)

FIG. 2.



NOTE.—COMPARE WITH MR. SAWYER'S SECTION OF THE RAND AT JOHANNESBURG, IN TRANSACTIONS OF THE FEDERATED INSTITUTION, 31ST MAY, 1895.

Scale, about 4,984 Feet to 1 Inch.

JANUARY 1898.