THE GEOLOGY OF THE PREMIER (TRANSVAAL)
DIAMOND MINE.

BY

E. GERRYTS.

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Science in the Department of Geological Sciences, McGill University.

Montreal.

May, 1949.

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THE GEOLOGY OF THE PREMIER (TRANSVAAL) DIAMOND MINE.

I. Introduction.

a. Acknowledgements.

The writer acknowledges permission received from Dr. J. A. Bancroft, consulting geologist to the Anglo American Corporation of South Africa Ltd., to use the notes and maps compiled during the time spent at the Premier (Tvl.) Diamond Mine.

The writer also acknowledges assistance received at various times from Dr. A. E. Waters, under whose supervision the mapping was done, and from the various officials of the Premier (Tvl.) Diamond Mine, while the mapping was in progress.

Thanks are also due to Professor R. Graham, under whose direction this report was written, and to various other members of the staff of the Department of Geological Sciences from whom assistance was received at various times.

b. <u>General Statement</u>.

The underground geological mapping of the Premier (Tvl.) Diamond Mine was carried out in continuation of the mapping of the open pit and portions of the 610 level done by Dr. A. E. Waters and C. G. Stocken of the Anglo American Corporation of South Africa Ltd. The idea in mind was the mapping of different types of kimberlite which would eventually be sampled to determine any variation in diamond content. If such a variation exists and proves to be of economic importance, selective mining may be resorted to.

Mapping was done only in the northwestern portion of the mine, from the 610 level down to the 1060 level, where underground development had been completed prior to, or was being carried on during, the period January to July, 1948.

During the mapping, both walls of tunnels were inspected and features and contacts were located from mine survey pegs. All the geology was plotted on mine maps scaled at 1:1000. Some difficulty was experienced during the mapping because water was not available to wash the walls of tunnels, nearly all drilling being done without water. With a few exceptions, all the levels of the mine are 50 feet apart; all these levels were mapped.

No mapping was done in the southeastern part of the mine as no development work was being carried out there during the stated period. The results of the mapping done by Dr. A. E. Waters and C. G. Stocken in that area have been included in the map of the 610 level.

c. Location of thesis area.

The Premier (Tvl.) Diamond Mine is situated approximately 20 miles E.N.E. of Pretoria, at the village of Cullinan. A paved motor road and a railroad connects Cullinan with Pretoria.

d. History.

The kimberlite pipe was discovered by Thomas Cullinan and, after systematic prospecting, mining operations started in 1902. The pipe was mined in open pit fashion until March, 1932, when the mine closed down temporarily, some parts having reached a depth of 610 feet. The mine remained idle until 1946 when a start was made with unwatering the pit and preparing the property for underground mining.

Transvaal System.

Rooiberg Series.

Pretoria Series.

Dolomite Series.

Black Reef Series.

Ventersdorp System.

Lower Witwatersrand System.

Crystalline Schists.

Igneous Rocks.

Kimberlite Occurrences.

Volcanic Breccia.

Nepheline Bearing Rocks.

Syenite, Diorite and Allied Rocks.

Diabase and Allied Rocks.

Bushveld Igneous Complex.

Older Granite.

Of these only the following are present in the area surrounding the Premier Mine.

Recent.

Alluvium.

Waterberg System.

Transvaal System.

Rooiberg Series.

Pretoria Series.

Magaliesberg Group.

Intrusives.

Kimberlite.

Diabase.

Felsite.

Syenite and Foyaite.

Waterberg System.

The Waterberg System is found in the northern and western parts of the area, where it forms a thick succession of reddish-brown and purplish felspathic sand-stones and grits with bands of conglomerates at the base. In the north, it underlies comparatively elevated plateau-like areas. It overlies the Pretoria Series of the Transvaal System unconformably.

Rocks of the Waterberg System also occur as foreign inclusions in the kimberlite of the Premier Mine.

Transvaal System.

The Transvaal System is represented in this area by the Rooiberg Series and by the Magaliesberg Group of the Pretoria Series.

The Rooiberg Series is found in the northwest corner of the area, where it overlies the Pretoria Series with slight unconformity. It consists of felsite underlain by conglomerates and quartzites with shales, sandstones, and eruptive breccias.

The Magaliesberg Group covers the major portion of the area and consists of three members.

Upper Quartzites, Shaly Sandstones, and Shales.

Magaliesberg Quartzites.

Shales.

The quartzite members form most of the prominent ridges of the area while the shales underlie the valleys and low-lying areas.

Intrusive Rocks.

The intrusive rocks found in the area around the Premier Mine consist of four groups:-

a. Diabase.

b. Intrusive Felsite.

c. Syenite and Foyaite.

d. Kimberlite.

a. Diabase.

Intrusive sheets of basic igneous rocks which can be classed as diabase occur in all the formations of pre-Karroo age in the area under discussion. These sheets are held to be of the same age as the Bushveld Igneous Complex. One large intrusion occurs southeast of the mine and stretches for a distance of five and a half miles from the farm Beynestpoort

520 to the farm Doornkloof 431. Various other sheets occur at other places in the map area.

b. Intrusive Felsite.

A sheet-like body of intrusive felsite surrounds the Premier Mine and extends from Beynestpoort 520 to Doornkloof 431. For some distance, the base of the sill consists of dolerite which grades upward into felsite. At its top, the sill contains abundant inclusions of quartzite. It is this intrusive felsite which makes up the "wall rock" surrounding the kimberlite of the Premier Mine.

c. Syenite and Foyaite.

On the farm Leeuwfontein 320 there is an occurrence of syenite and foyaite and on Franspoort 420 an occurrence of nepheline-bearing rock, both intrusive into the Pretoria Series. These intrusives have been said to belong to the Bushveld Igneous Complex, which occurs farther to the north.

d. Kimberlite. (Wagner, 1914, pp. 92-95)

The following kimberlite occurrences are found within a radius of eight miles from the Premier (Tvl.) Diamond Mine.

1. A pipe on Louwsbaken 85.
2. The Beynestpoort pipe on Beynestpoort 520.
3. The Zonderwater pipe on Zonderwater 173.
4. An occurrence on Franspoort 426.
5. The Pienaarspoort pipe on Pienaarspoort 500.
6. The Montrose No. 1 pipe on Vryneb 74.
7. The Montrose No. 3 pipe on the boundary line between Vryneb and Rooikopjes 209.
8. The Schuller or National pipe on Rietfontein 501.
9. The Schuller-Kaalfontein pipe on the boundary between Rietfontein 501 and Kaalfontein 406.

All these occurrences, except that on Beynestpoort, have been proved to contain diamonds but not in economic quantities.

PLATE I.

A view of the Premier Mine, looking northwest.

III. GEOLOGY OF THE PREMIER (TRANSVAAL) DIAMOND MINE.

The kimberlite pipe which constitutes the orebody of the Premier Mine is the largest occurrence of its kind in South Africa yielding diamonds in economic quantities. In surface outcrop, the pipe has the form of an ellipse, with the long and short axes approximately 2900 feet and 1500 feet respectively. It is sharply defined by its "wall" rock, which consists of felsite. The felsite is part of an intrusive sheet occurring in the area.

The Material Occupying The Pipe.

1. Foreign Inclusions in the Pipe.
2. Kimberlite.
3. Dykes.

1. Foreign Inclusions in the Pipe.

The foreign inclusions in the pipe vary in size from small fragments to immense masses of rock. To the latter, the name "Floating Reef" has been given at the Premier Mine.

a. The "Floating Reef".

Stretching across the centre of the pipe is a large mass made up of red quartzite and conglomerate evidently belonging to the Waterberg Series (du Toit, 1939, p. 383). The

Waterberg Series has now been completely stripped from the area surrounding the mine, the nearest outlier being found about three miles to the north on the farm Louwsbaken 309. The mass of rock dips steeply to the northwest. It has been encountered on the 1060 level and part of it probably extends some distance below this level.

Blocks and boulders of quartzite are nearly always found in the kimberlite adjacent to the main mass of the "floating reef". Up to the present, these zones have only been found in the Normal Kimberlite.

During its collapse into the pipe, the mass of rock was evidently bent and broken up into two more or less separate blocks and numerous smaller pieces. Parts of the upper block extend only to just above the 810 level whereas the lower portion continues, in part at least, below the 1060 level.

The rocks making up the "floating reef" have the typical red colour of the Waterberg formation and are intruded in some places by diorite and quartz-porphyry. These intrusions evidently took place before the eruption of the kimberlite because the diorite and porphyry have been fractured with the quartzite and conglomerate and are sometimes found as boulders in the kimberlite.

b. Other Foreign Inclusions.

Boulders of metamorphosed limestone have occasionally been encountered in some parts of the mine but these rocks, probably derived from the walls of the pipe much deeper down, are rare.

2. Kimberlite.

A. General Description.

Two main classes of kimberlite have been recognized by Wagner.

i) A basaltic variety poor in mica, and

ii) A lamprophyric variety, rich in mica.

The kimberlites of the Premier Mine, when considered as a group, can properly be classified with the basaltic variety. This is a kimberlite rich in olivine, with only occasional phenocrysts of phlogopite mica, and with scattered grains of ilmenite, enstatite, pyrope, and chrome-diopside in a groundmass of secondary minerals. The groundmass is generally rich in perofskite, apatite, chromite, and iron oxides. Phlogopite never plays an important part as a constituent of the groundmass. The chemical composition of this type proves it to be related to the deep-seated peridotites, from which it differs in structure as pointed out by Carvill Lewis (Wagner, 1914).

The chemical composition of the Premier Mine kimberlite is compared with that of an average peridotite in the following analysis:-

	Kimberlite (1)	Peridotite (2)
SiO_2	42.36	39.04
TiO_2	2.54	0.36
Al_2O_3	2.22	2.89
Fe_2O_3	6.81	2.80
FeO	3.10	7.78
CaO	4.20	2.11
MgO	31.31	39.99
K_2O) Na_2O)	1.09	0.65
H_2O	4.22	3.62
CO_2	0.69	---
P_2O_5	1.46	---
MnO	---	0.24
Cr_2O_3	---	0.45
Insol.	---	0.31
	100.00	100.24

1) Average of three analyses of kimberlite, recalculated disregarding combined water, given by Wagner P. A. Diamond Fields of Southern Africa. Anal. M. Dittrich and P. A. Wagner.

2) Peridotite. Barkval Rum. Anal. Pollard. Analysis cited by Iddings. Description of Igneous Rocks, Pt. 11, p. 338.

Wagner (1914, pp. 97 - 98) gives the following mineralogical composition for the kimberlite of the Premier Mine:

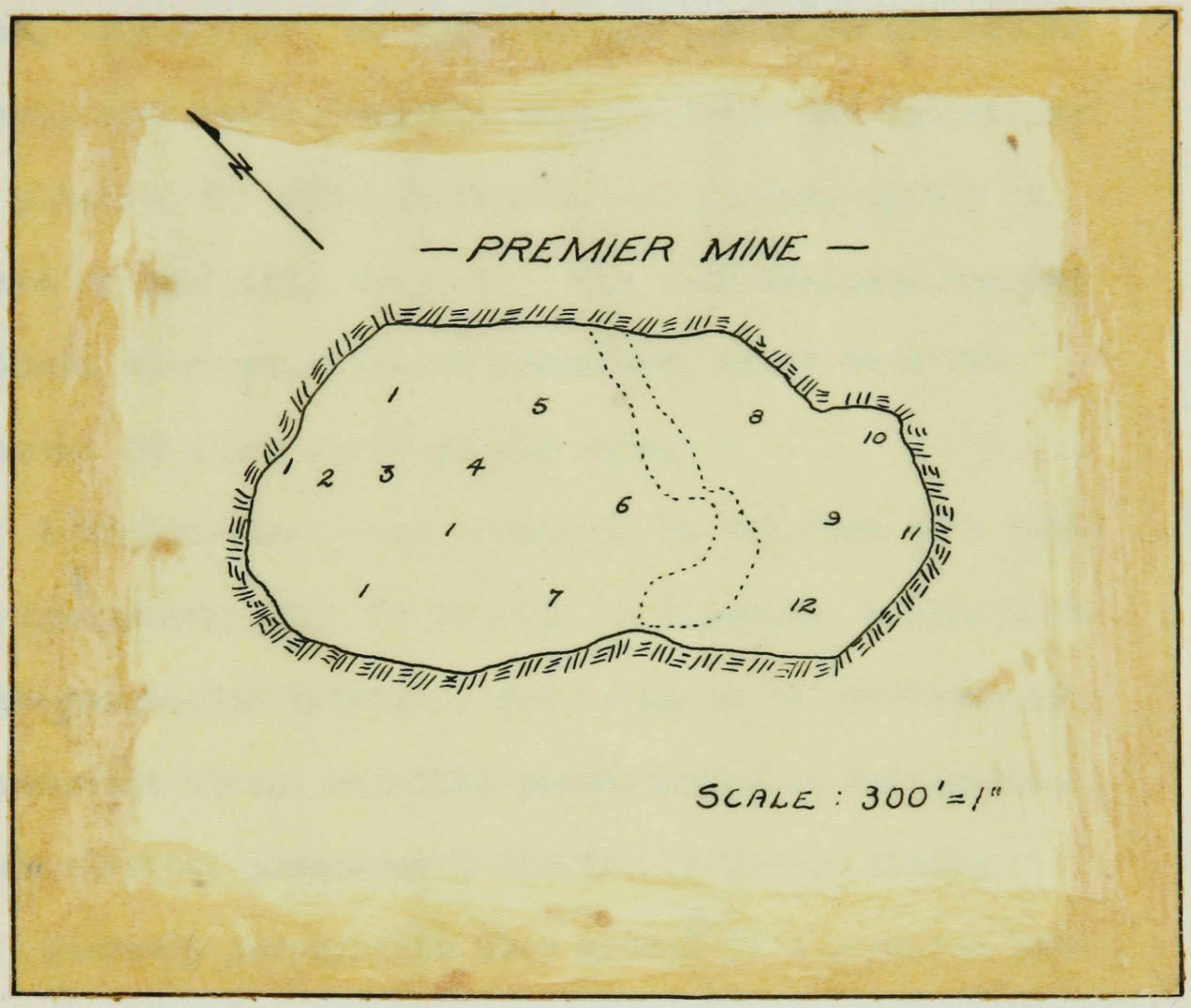
"Large and small pseudomorphs, after olivine, are invariably found to constitute the bulk of the Premier blue ground. These may consist of antigorite, iddingsite, or the weakly pleochroic and birefringent variety of iddingsite previously described. Of the common megascopic kimberlite accessories, ilmenite, as we have already seen is abundant, and phlogopite and pyrope rare, and diopside very rare. In addition to the foregoing, sharp-edged octahedra of picotite and magnetite are occasionally found on the sorting tables; and pyrite, in fine cubical and dodecahedral crystals, is very common in some parts of the mine. The latter mineral is clearly of secondary origin. The microscope also reveals the presence of occasional xenocrysts of brown hornblende and diallage. Perofskite is fairly abundant in some sections; as a general rule, however, the mineral appears to have suffered alteration into minute granules and turbid granular aggregates of titanite (leucoxene), which, together with grains of magnetite and very diminutive flakes of mica, are often seen to be concentrated around the margins of the serpentine pseudomorphs. The latter also occasionally enclose minute, egg-shaped and elongated granules of what appears to be, a very light-coloured variety of titanite. Apatite in prismatic crystals is a very common microscopic constituent of the blue ground, though the distribution of the mineral is somewhat irregular.

"The different minerals above enumerated are always embedded in a minutely fibrous ground-mass of chrysotile, with which a certain amount of chlorite is generally associated; while calcite, though rarely abundant, is nearly always present. In some specimens, the fibres of chrysotile have been aggregated into minute spherulites, giving rise to the variety of serpentine known as picrolite."

Wagner (1914, p. 95) distinguished twelve varieties of kimberlite when the mine had an average depth of 200 feet. It is doubtful whether all these represent distinct types. Analysis of his brief descriptions, and comparison, with the eight types, differentiated during recent mapping, indicates that Wagner's twelve varieties can be grouped together under four types. These four types can be correlated with the Normal, Blue-Grey, Blue-Black, and Pale-Grey Kimberlite. Reasons for these correlations will be enumerated under the description of the individual types.

Wagner describes the following twelve types, which are indicated by numbers on the sketch plan. (Figure I.)

Figure 1.



Sketch plan of the Premier Mine. The varieties of kimberlite distinguished by Wagner are indicated by numbers. After Wagner.

"1. A bluish-grey variety of blue ground which breaks with an uneven fracture and is slightly unctuous to the touch. Phenocrysts of ilmenite and enstatite are rather common; and nodular aggregates of olivine and enstatite; and olivine, diopside, bronzite, and pyrope, appear in places to be fairly abundant. The rock encloses rounded boulders of recrystallised limestone, which were not observed in other parts of the mine.

"2. A bluish-black rock occurring in the form of a column intersecting 1. It is rich in ilmenite, breaks with a sub-conchoidal fracture; and owing to the presence of innumerable black, wax-like pseudomorphs of antigorite, after olivine, possesses a distinctly greasy lustre.

"3. Coarsely porphyritic blue ground of a peculiar bluish-purple colour, exposed in the so-called 'main tunnel development'.

"4. A brecciated variety, of a very pale bluish-grey colour, rich in ilmenite.

"5. A bluish-grey rock, which only differs from 1 in being richer in phenocrysts of garnet. Nodular aggregates are again in places fairly common. Along the pipe wall, and at its contact with the great bar of 'floating reef', the blue ground is crowded with large boulders of Waterberg quartzite.

"6. Blue ground, of pale bluish-green colour, distinctly greasy to the touch. Ilmenite in large rounded grains is much in evidence, and phenocrysts of phlogopite are more common than in any other portion of the pipe.

"7. A dark bluish-green variety, in which phenocrysts of ilmenite, and of the remaining accessory constituents of kimberlite, are fairly abundant.

"8. Dark blue ground, somewhat resembling 2. Along the pipe wall, the rock is crowded with sub-angular and rounded xenoliths of Waterberg quartzite. No nodular aggregates were observed in this portion of the pipe.

"9. A bluish-grey rock somewhat resembling 1. Rounded boulders of Waterberg quartzite give rise to columns of rubble.

"10. Very 'clean' blue ground of bluish-grey colour, made up of dark pseudomorphs after olivine set in matrix of grey colour. Ilmenite is rare and the remaining accessory minerals of kimberlite hardly ever seen.

"11. Similar to 10, but contains more foreign matter, Nodular aggregates appear to be exceedingly rare.

"12. Bluish-grey variety containing far more ilmenite than 10 and 11. The rock is crowded with sub-angular inclusions of dark greenish-grey colour."

B. Detailed Description.

During the present mapping it was only possible to distinguish eight varieties in so far as megascopical characters are concerned. Some of Wagner's twelve varieties are very similar in character, while some of the types here described display a certain amount of variation within their boundaries. The various types of kimberlite are arranged in rudely concentric pattern northwest of the "floating reef" and are as follows:-

a. Normal Kimberlite.

b. Intermediate Kimberlite.

c. Blue-Grey Kimberlite.

d. Blue-Black Kimberlite.

e. Eclogite Xenolith Kimberlite.

f. Pale-Grey Kimberlite.

g. Piebald Kimberlite.

h. 1060 Pale-Grey Kimberlite.

a. Normal Kimberlite.

This is the most abundant type observed and is the only type of kimberlite occurring southeast of the "floating reef". It is not known how far it persists in depth in this part of the mine, but it certainly extends as far as the 1060 level.

Northwest of the "floating reef" it occupies a zone of varying width, the outside of which is in contact with the felsite. As a whole, this type encloses all the other types of kimberlite.

Where it has been observed, the contact of this type with the felsite is always sharp, and usually it is slickensided. The contact with the other kimberlite types, however, is generally of a gradational character and seldom easy to map.

Adjacent to the contacts the felsite appears more vitreous than farther away, and under the microscope more grains of clear quartz can be seen in sections taken close to the contact. Whether any bulk alteration of the felsite was caused by the eruption of the kimberlite is not known at present.

The groundmass of the Normal Kimberlite consists mainly of serpentine with a dull greenish colour, usually pale, with some local darker phases. Scattered through the groundmass are found occasional phenocrysts of diopside, phlogopite, enstatite, and pseudomorphs of dark serpentine, after olivine. These phenocrysts give the rock a porphyritic appearance. Garnet is present but very seldom seen in hand specimens. While chrome-diopside is not a typical constituent of this type it is sometimes found, as scattered grains, near the contact with the country rock, and occasionally in the darker phases of this type. Another constituent which may locally be of some importance is ilmenite. It is usually found in rounded grains and, like the other resistant minerals, it appears more conspicuous in the open portions of the mine, where the kimberlite has been exposed to the atmosphere for some time.

At all depths in the mine, the Normal Kimberlite includes fragments of other rock, chiefly shale. The shale fragments are generally small and show hardly any alteration, except for a narrow corona which is sometimes present around their edges. Most of these shale fragments are of a greenish-grey colour, but some are black. It is conceivable that these fragments were derived from the Pretoria Series of the Transvaal System through which the kimberlite must have passed to reach its present position. Another possible source is shales of the Karroo System which once covered this area, and through which the eruptions of the kimberlite must have taken place, unless prior erosion had already removed this covering.

Small pieces,and, occasionally large boulders, of limestone, usually somewhat altered, are sometimes encountered in the Normal Kimberlite. These, however, are much rarer than the shale fragments. As in the case of the shale, the limestone may have been derived from an underlying source, in this instance probably the Dolomite Series of the Transvaal System, which underlies this area at a probable depth of five miles.

In contrast with material brought up from some depth are the inclusions of Waterberg Quartzite, which range in size from the smallest possible fragment to an enormous mass like the "floating reef", weighing thousands of tons.

The Waterberg System originally overlay the mine area and from the relationship seen in the mine it is fairly obvious that the first explosive eruption caused a large portion of the "roof" of Waterberg Rocks to collapse into the unconsolidated kimberlite breccia.

That the Normal Kimberlite was erupted in the form of an explosion breccia seems clear from the nature of the rock and the inclusions it contains. This mode of eruption is apparently the only one that can explain the presence of inclusions, some derived from depth and others from formations once overlying the area, on the same mine level. This type of explosive eruption was also postulated by Wagner (1914, p. 41). To get this juxtaposition of inclusions with the slow upwelling of a magma as seen by Williams (1932, pp. 236 - 237) seems highly improbable.

The Normal Kimberlite is the only type seen to enclose fragments of the Waterberg Quartzite. This observation, and also the fact that it surrounds all the other types, seems to indicate that this type was erupted first.

Correlation of the Normal Kimberlite with types 1, 5, 8, 9, 10, 11, and 12 of Wagner (see pp. 16 - 17) seems possible for the following reasons:-

i. Type 5 is in contact with the felsite and contains fragments of the Waterberg Quartzite. The Normal Kimberlite is the only type making contact with the felsite and containing Waterberg Quartzite inclusions.

ii. Types 8, 9, 10, 11, and 12 of Wagner are found in that portion of the mine, southwest of the "floating reef", where only Normal Kimberlite is known to occur.

iii. The general description given for all the above types agrees with that of the Normal Kimberlite.

b. <u>Intermediate Kimberlite.</u>

The Intermediate Kimberlite occupies a zone just inside the Normal Kimberlite. It may form a complete ring around the other types on the 610 and 660 levels, but on the 710, 760, and 843 levels, and possibly also on the remaining levels, it occupies two crescent shaped areas only. This type makes extremely vague contacts with the other kimberlite with which it comes into contact.

In general appearance this type is intermediate between the Normal and Blue-Grey Kimberlite. It has about the same dull greenish-grey colour as the

Normal Kimberlite but differs from it in one important respect: phenocrysts are more abundant. Dark pseudomorphs of serpentine, after olivine, appear in the serpentinized groundmass as the most important mineral, and this is accompanied by grains of enstatite, diopside, and ilmenite. Garnet and phlogopite mica are present but rare, while chrome-diopside is rare but slightly more abundant than in the Normal Kimberlite.

Light and dark shale fragments occur in less important amount than in the Normal type. Limestone fragments are so rare as to be practically absent.

From the field-relations it appears that this type may have been formed by the intermixing of the Normal and the Blue-Grey Kimberlite during the eruption of the latter, and in areas where the Normal Kimberlite was not too well consolidated. This would explain the absence of a gradational contact between the Normal and the Blue-Grey Kimberlite where the Intermediate type is absent.

c. <u>Blue-Grey Kimberlite.</u>

The Blue-Grey Kimberlite occurs as a vertical, cylindrical mass which is surrounded by the Normal and Intermediate types. The mass is fairly regular in outline but generally narrower, in plan, on the northeast than on the southwest side. It is not known whether it forms a continuous zone on the northeast side as no exposures are available in this area. Contacts with the Intermediate and Blue-Black Kimberlite are generally gradational, but fairly sharp contacts were observed with the Normal and Eclogite-Xenolith Kimberlite.

This type is generally darker in appearance than the two types previously described, but the colour varies from level to level and even from one section to another on individual levels. The predominant colour, however, is a dull blue-grey.

The most abundant phenocrysts are large and small grains of olivine, now completely altered to serpentine. With these, but in lesser quantities, are phenocrysts of enstatite and ilmenite, some more than half an inch in diameter. Chrome-diopside may locally be prominent but, although practically always present, it is, as a rule, not too abundant. Neither garnet nor phlogopite have been observed; if they are present at all they are in very minor amount. As in the previous two types, the groundmass of the Blue-Grey Kimberlite appears to consist of serpentine. The rock contains occasional fragments of shale and limestone, but in general, a brecciated appearance is not prominent.

There is no actual evidence available as to when the Blue-Grey type was emplaced, in relation to the other types, but it is probably later than the Normal type and may have been the second type to be intruded. As previously pointed out, the intrusion of this type may have given rise to the formation of the Intermediate Kimberlite.

The rock corresponds very closely with Wagner's description of his "type 7" and possibly it is to be correlated with that rock.

d. Blue-Black Kimberlite.

The Blue-Black Kimberlite occurs centrally within the pipe of the Blue-Grey type and may form a continuous zone on some of the mine levels but is definitely cut off by the Eclogite-Xenolith type on the 760 level. Contacts with the Blue-Grey, Eclogite-Xenolith, and Piebald Kimberlite are gradational, but knife-sharp contacts between this type and the Pale-Grey Kimberlite were observed.

This porphyritic bluish-black rock stands in sharp contrast with the types previously described. It appears more homogeneous than the latter except where it has reached a fairly high degree of alteration, when it becomes less difficult to differentiate between the dark-greenish groundmass, the phenocrysts, and the inclusions.

Despite the fact that the rock appears much denser and harder than the other types, it can still be easily scratched with a knife and obviously the main difference lies only in the colour of the serpentine which composes the bulk of the rock.

Typically, this is a bluish-black rock with a greasy lustre. Close inspection is sometimes required to distinguish between the numerous greasy-black pseudomorphs, after olivine, and the equally dark groundmass. These pseudomorphs, which consist of antigorite (Wagner, 1914, p. 96) replacing olivine, make up the bulk of the rock. Less important in volume, but always present, are crystals and irregular grains of ilmenite, enstatite, and chrome-diopside. The ilmenite has been observed as fairly large grains, occasionally with a diameter of more than half an inch. The other phenocrysts are as a rule smaller than this.

Inclusions of foreign rock types occur but in general they are few and unimportant. These are generally so highly altered that their original composition is uncertain. It appears unlikely that this type is a volcanic breccia, although the possibility is not ruled out altogether.

It is possible to correlate this type with types 2 and 3 of Wagner, the descriptions of which, fit the Blue-Black Kimberlite very neatly.

Since there are so few inclusions in this type, a chemical analysis would give approximately the true composition of the rock. Such an analysis has not been made by the writer, but Wagner (1914, p. 98) gives the following analysis of his "type 2", which is here correlated with the Blue-Black Kimberlite.

SiO_2	---	38.29
TiO_2	---	2.00
Al_2O_3	---	2.66
Fe_2O_3	---	5.77
FeO	---	2.93
CaO	---	2.42
MgO	---	29.46
K_2O	---	1.03
Na_2O	---	0.30
H_2O -	---	3.13
H_2O +	---	10.19
CO_2	---	0.20
P_2O_5	---	1.44
Total	---	99.82

Analyst - M. Dittrich.

e. Eclogite-Xenolith Kimberlite.

This type occurs nearly at the centre of the area, northwest of the "floating reef". There is no field evidence to suggest that it in turn surrounds yet another type of kimberlite. It makes fairly sharp contacts with the Blue-Grey, Blue-Black, and Pale-Grey Kimberlites.

The Eclogite-Xenolith Kimberlite is somewhat similar, in appearance, to some phases of the Blue-Grey Kimberlite, but, where it comes in contact with the latter type, it was always possible to distinguish between the two. The colour of the rock varies from bluish-grey to greenish-grey. In the groundmass are found pseudomorphs of serpentine after olivine. These range in colour from pale yellow to nearly black in different parts of the mass. The rock contains also phenocrysts of enstatite and diopside, but these appear to be rare. The only other constituent which is at all abundant is ilmenite. This mineral occurs in aggregates which may measure several inches across, but are usually much smaller than this.

Inclusions of shale also occur in this type but they appear to be scarce. More important as inclusions are large and small xenoliths which are invariably well rounded and smoothed. These are very resistant and stand out conspicuously in the open pit where the kimberlite has been subjected to weathering. They are very abundant on the 610 level but appear to diminish progressively in amount on lower levels. This decrease may be more apparent than real due to the comparative lack in weathering of the kimberlite in depth.

These xenoliths are always sharply outlined and were probably rounded, and in some cases actually polished, by the movement of the intruding kimberlite in which they were caught.

Their mineralogical composition is very heterogeneous but nearly all contain two or more of the following: garnet, pyroxene, bronzite, and olivine with other minor constituents, some of which are evidently alteration products.

Some of these nodules definitely show the typical mineral assemblage of the eclogite facies (Turner, 1948, p. 104) but most of them lack this parallelism with true eclogites and show a closer relationship with peridotitic rocks. Wagner (1914, pp. 128 - 130) points out that these inclusions, which appear also in other occurrences of kimberlite, may be genetically related to the kimberlite.

Of interest is the age relationship between these nodules and the kimberlite. Holmes and Paneth (1936) found, by using the helium ratio method of age determination, that, while the kimberlite is of late Cretaceous age, these inclusions are actually much older.

This would clearly indicate that these xenoliths have been derived from the shattering of some older rock, probably deep-seated, judging by their composition and texture and the fact that no such rocks are known to outcrop in the district or even farther afield.

These age relations also seem to throw some doubt on the genetic relationship between the inclusions and the kimberlite as postulated by Wagner.

Wagner (1914, pp. 117 - 118) vizualised a re-melting of rocks with a composition similar to that of these inclusions to explain the genesis of the kimberlite. He is opposed in this, however, by Williams (1932, pp. 206 - 207), who thinks that the kimberlite was produced from a residual magma, rather than from the re-fusion of already solidified peridotitic rocks.

One of the many questions that comes to mind when regarding these nodular inclusions is, why they should be concentrated in one particular type of kimberlite. Actually, it is quite possible that all the other types may include these xenoliths but at different levels in the earth's crust, not all types having reached the same elevation during the various intrusions.

f. Pale-Grey Kimberlite.

The Pale-Grey Kimberlite is at the centre of the area, northwest of the "floating reef". It always shows sharp contacts with the Blue-Black Kimberlite whereas contacts with the other types are generally less sharp. This type occurs as three separate masses on most levels, the segments being separated by the Carbonate Dykes and Piebald Kimberlite. As far as the present development has exposed it, this type appears to occupy progressively smaller areas on lower levels.

Typically, the rock is pale-bluish to bluish-grey, very dull, soft, and somewhat porous. It appears to have reached a stage of alteration seldom approached by any other type, even where these have been exposed to the atmosphere for some time.

Phenocrysts are not at all conspicuous, except those of ilmenite. Olivine and enstatite do appear but have been completely altered to serpentine, large grains of enstatite sometimes giving rise to fibrous blebs of what appears to be chrysotile.

Pale-purplish to pale-bluish fragments occur abundantly as inclusions in most exposures of this type. Even these have been altered to such an extent that one is left in doubt as to their original composition.

In contrast with the other types of kimberlite, this type displays a remarkable pitted surface upon weathering. On such a surface, the pits appear in the groundmass while the tough inclusions form the projections.

From the highly altered nature of this rock it seems obvious that it must originally have been very porous to give access to circulating waters which caused the alteration.

g. Piebald Kimberlite.

The Piebald Kimberlite can, nearly always, be found adjacent to the Carbonate Dykes but it also occurs more or less in the centre of the northwestern portion of the mine, where it is apparently not connected with any of these dykes. This type has gradational contacts except where it meets the 1060 Pale-Grey type of kimberlite with which its contacts, wherever observed, are invariably very sharp.

The rock displays two quite different facies, the one very dark and the other pale-grey. The dark facies usually forms an outer zone to the light facies. It is not always present, however, and in its abscence the light facies makes direct contact with the other types of kimberlite.

i. <u>The Dark Facies.</u>

The dark facies can be seen grading into the Blue-Black Kimberlite and the bulk of it appears to have been formed from that type by some alteration which caused the inclusions to assume a lighter colour and which also gave the rock a more vitreous appearance.

In hand-specimen, white and greenish inclusions and grains of ilmenite are the most conspicuous constituents.

Under the microscope this type appears as a coarsely porphyritic rock with a glassy groundmass. The composition of the groundmass cannot be discerned but distributed through it are pale-greenish spherulites and brownish patches.

The phenocrysts are chiefly pseudomorphs of antigorite after olivine. They have an appreciable range in size and a fair number of them show the characteristic crystal outline of olivine.

Much less common are phenocrysts of hypersthene. These, too, show various stages of alteration to serpentine, some grains, nearly completely altered, still retaining an original schiller structure.

Small grains of magnetite are seen but these are much rarer than might be expected considering the high degree of alteration of the olivine. This may be due to the original olivine having been poor in the fayalite molecule.

ii. The Light Facies.

This facies displays a conspicuous speckled appearance due to the presence of numerous white inclusions. Contacts between it and the dark facies range from fairly sharp to gradational.

Megascopically, the rock appears porphyritic due to the presence of phenocrysts of greenish serpentine, after olivine, and locally grains of ilmenite and garnet, the latter usually of a reddish-brown colour. Phenocrysts of enstatite, phlogopite, and diopside, such as are usually present in other types of kimberlite, appear to be absent or at least have not been observed.

Examined in thin section under the microscope, it is seen that the serpentinized phenocrysts, which range in size from half an inch to one hundredth of an inch, consist chiefly of the lamellar variety of serpentine known as antigorite. Replacement of the original mineral has been complete, but from the shape and the general character of the phenocrysts it is inferred that they were originally grains of olivine. Calcite is a fairly conspicuous constituent of this type, but the irregular patches and isolated grains are practically always of microscopical size. It is usually more abundant near the contacts with the Carbonate Dykes and it appears to be a secondary mineral. The groundmass, which is very fine grained, consists essentially of fibrous serpentine together with some brownish material of unknown composition.

The white inclusions, which are responsible for the conspicuous spotted appearance of the rock, can be seen under the microscope to consist mainly of calcite. They are usually surrounded by a corona in which a pale coloured garnet is very noticeable. Small grains of what appears to be a pyroxene are also present, both in the calcite and in the corona. It is possible that these inclusions represent fragments of magnesian limestone derived from the underlying Dolomite Series of the Transvaal System.

h. <u>1060 Pale-Grey Kimberlite.</u>

The 1060 Pale-Grey Kimberlite has been encountered on all the mine levels. It has its greatest development on the 1060 level, where it has been exposed along the South Blue Haulage for a length of about 120 feet. On the other levels it appears only as a dyke from 4 to 20 feet wide. This type has not been observed on the 610 level, probably due to the fact that a rock dump now covers the area where it may outcrop.

This type stands in striking contrast with the other varieties of kimberlite due to its definite intrusive relations with them, and its tapering dyke-like form. Where it appears as a dyke -- that is, on all levels except the 1060 -- it apparently never has any great lateral extent, and it makes up only a very small percentage of all the kimberlite present in the mine. Unless the fairly large exposure on the 1060 level represents merely a local dyke-enlargement, it is possible that this type may become increasingly important as deeper levels are exposed.

The 1060 Pale-Grey Kimberlite has a greenish-grey colour and a fine grained, granular groundmass, which consists largely of greenish grains of serpentine. Larger grains of the same kind are distributed through the rock, giving it a porphyritic appearance. Calcite, in the form of large blebs and small grains, is a fairly prominent constituent of this rock. The only other phenocryst seen to attain any prominence is ilmenite. This occurs as irregular grains, scattered through the groundmass.

White inclusions, similar to those found in the Piebald Kimberlite, are present. They generally display a kernel of calcite, surrounded by a border of dirty white material. As in the case of the inclusions in the Piebald

Kimberlite, these have probably been derived from the Dolomite Series.

Economic Resources Of The Kimberlite.

Diamonds occur in the kimberlite of the Premier (Transvaal) Diamond Mine. They are of various types and grades including cleavage fragments, well crystallized diamonds, brown diamonds of inferior quality, exceptionally fine gemstones, and many other classes (Wagner, 1914, pp. 155 - 157).

There is no evidence available as to what proportion of the total yield, which is in the vicinity of 25 carats per hundred tons, is derived from any particular type of kimberlite. Sampling is at present in progress and more information should eventually become available.

3. Dykes.

Conspicuous fine-grained black and bluish-black dykes, sharply defined from the kimberlite, occur on all levels in various parts of the mine. These dykes have their major development in the northwestern part of the workings, where they branch in all directions. They generally taper out toward the contact with the felsite; some, only a few inches wide, persist for long distances.

These dykes have not been observed cutting the country rock in this particular occurrence, although similar dykes associated with other occurrences of kimberlite do enter the country rock.*

Although these dykes show some diversity in mineralogical composition they are evidently all of approximately the same age, and younger than the kimberlite. Their irregular radial distribution is highly suggestive of material occupying cracks and fissures formed in a contracting body.

Practically in every instance where these dykes have been observed they are bordered by a certain thickness of the Piebald Kimberlite. While there is a sharp dividing line between the dykes and the Piebald Kimberlite, the latter invariably shows gradational contacts with the other types of kimberlite. One exception to this association is found where the dykes traverse the Normal Kimberlite. Here, the Piebald Kimberlite is usually absent and the dykes come into direct contact with the Normal Kimberlite.

The close association of these dykes with the two varieties of Piebald Kimberlite appears to indicate some genetic relationship, which may, or may not, be proved by subsequent investigations.

* Oral communication, C. G. Stocken.

Typically developed, the dyke rock appears as a fine-grained rock, black or bluish-black in colour, and often containing greenish patches of serpentine. Small crystals of calcite give the rock a glistening appearance when fresh. In the atmosphere, it weathers to a porous rock of a reddish-brown colour.

Under the microscope, the rock can be seen to consist of crystals and grains of calcite, magnetite, and serpentine, replacing olivine.

In some sections, the rock appears very even-grained but with irregular patches of calcite always present. The groundmass is generally clear, colourless or faintly green, and isotropic. It is possible that this material consists of a meta-colloidal or colloidal form of magnesium hydrate (Daly, 1925, p.672).

In other sections, the rock appears definitely porphyritic due to the presence of numerous phenocrysts of what must originally have been olivine. These display a curious habit. Usually, a kernel consisting of serpentine, calcite, and occasionally magnetite, is surrounded by a clear, colourless border of isotropic material. The interstices between these phenocrysts are filled by grains and crystals of magnetite and an isotropic, colourless material.

Conceivably some, if not all, of the magnetite, contained in these dykes may have been derived from olivine as a product of its alteration and decomposition. In this connection, however, it is of interest to note that, in the Piebald Kimberlite, the olivine was altered without giving rise to any appreciable amount of magnetite. It seems clear from this relationship that the olivine originally contained in the dyke rock must have been appreciably richer in the fayalite molecule than the olivine of the Piebald Kimberlite. Chemical analyses of the dyke rock show an average FeO + Fe_2O_3 content of over ten per cent. It is possible that the magnetite is not pure iron oxide but is a magnesian variety, (Fe, Mg) O. Fe_2O_3 (Bowen and Tuttle, 1949, p. 454).

Origin Of The Dykes.

Wagner (1914, p. 99) came to the conclusion that these dykes were formed by "an extreme form of alteration of a porphyritic igneous rock, resembling kimberlite in structure".

Williams (1932, p. 142) supports this view and gives some comparisons between chemical analyses of the dykes and kimberlite to prove his point. Straight comparison of such analyses, however, is not of much value, as pointed out by Barth (1948, pp. 51 - 52). Also, as most of the kimberlites seen and examined during the course of this investigation are nothing but volcanic breccias containing appreciable quantities of foreign material, a chemical analysis, as such, is practically meaningless. It is hoped that a more accurate way of arriving at the true chemical composition of the kimberlite may eventually be devised, and used, in a later, more detailed study, of these rocks.

In opposition to the two cited authors, we find Daly, who regarded these dykes as essentially magmatic (Daly, 1925, p. 684).

What the controversy actually boils down to is: what is the origin of the calcite in these rocks? At this stage it is not possible to express any opinion as to whether the calcite is primary or secondary, but it is hoped that a more detailed study, at some later date, may bring forth an answer to this question.

IV. AGE OF THE PREMIER PIPE.

a. Direct Evidence.

Going on direct evidence no more can be said than that the Premier Pipe is younger than the Waterberg Series, of which it contains inclusions.

b. Indirect Evidence.

There is fairly abundant evidence of the Upper Cretaceous Age of many of the other kimberlite occurrences in South Africa, and it is possible that the Premier Pipe is of this age, as it resembles most of the other occurrences in general characteristics.

Evidence for the Upper Cretaceous Age of the Pipes.

(Williams, 1939, p. 10).

1. Diamonds similar to those found in the Kimberley mines occur in Pliocene placers.
2. Kimberlites of Kimberley contain fragments of unmistakable Stormberg Lavas (Middle Jurassic Age).
3. Fossiliferous Neocomian Rocks are pierced by melilite basalt plugs which may be consanguineous with kimberlite.
4. Holmes' work on the helium ratio of uncontaminated kimberlite from South Africa confirms a late Cretaceous Age.

V. STRUCTURE.

1. Major Factors Controlling The Emplacement Of The Kimberlite.

The group of kimberlite occurrences in the Pretoria district, which includes that of the Premier Mine, appears to be unrelated to major structural features, recognisable at surface. Other groups sometimes display a linear arrangement, which may point to a line of subterranean weakness (Wagner, 1914, p. 8). Occasionally, individual pipes may follow such structural weaknesses as igneous contacts and fracture zones.

The Premier Pipe is situated in a valley in the felsite and quartzite but a considerable amount of material must have been eroded since the emplacement of the kimberlite, so that this feature is probably of no great significance.

2. Minor Structures.

Minor structures, such as the displacement and fracturing of the Carbonate Dykes, have been observed in the kimberlite which have probably been caused by the hydration, and consequent expansion, of the kimberlite (Wagner, 1914, pp. 32 - 34).

The contacts of the kimberlite with the wall rock are, wherever observed, slickensided, with the striae and grooves mostly vertical. Slickensided surfaces can often also be observed in the kimberlite itself, generally with development of secondary minerals. One such plane can quite frequently be found in the Normal Kimberlite, within a few feet of the contact with the felsite. A certain amount of movement probably took place along many of these planes, but, due to the massive nature of the rock, the amount of displacement cannot be measured.

Open fissures have also been observed in the kimberlite in the North Blue Haulage on the 1060 level, and, on some of the higher levels, water often flows from these fissures, the amount apparently depending on the quantity of water collected in parts of the open pit during rainstorms.

VI . GEOLOGIC HISTORY.

In giving a geologic history of the Premier Diamond Mine it is fully realized that it is possible to interpret geologic facts and observations in different ways. Until further evidence becomes available, the following sequence of events appears to be most feasible:-

1. Gaseous eruption, with emplacement of the Normal Kimberlite, partly at least as a tuff, and collapse of the Waterberg Quartzite into the vent.
2. Eruption of the Intermediate, Blue-Grey, Blue-Black, Eclogite-Xenolith, and Pale-Grey Kimberlite.

Some of these also may have been erupted in the form of a tuff, while others appear to have welled up as a true magma. The actual sequence of these eruptions is still a matter of conjecture at the present moment.

3. Formation of the Carbonate Dykes and the Piebald Kimberlite.

The cutting relations of the Carbonate Dykes with the kimberlite indicate that they were emplaced after nearly all of the volcanic activity had ceased. From the field relations it would also

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