Kroondal Platinum Mine: Not Using Whittle Four-D – A Case Study

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Abstract

This paper explores the reasons why Whittle Four-D could not be used to optimally design an open-pit for a client.

SRK was approached by Aquarius Exploration NL, based in Perth, Australia to undertake a feasibility study for an open-pit and underground platinum mine in South Africa.

SRK were assisted by Snowden Associates in Perth, who were charged with the Resource and Reserve estimation, and the underground study.

Whittle Four-D was used to evaluate the orebody, and produce a series of nested pits. The exercise showed ideally the orebody could be mined economically, as dictated by the nested pits, but these proved impractical due to constraints of mining and processing characteristics.

The initial mining units from the first series of pits were too small and dispersed, to mine practically and efficiently. The higher quality reef was below the initial weathered cap, which was needed by the plant, due to its better metallurgical properties. Access to the underground was required as soon as possible, because of improved financial returns, but the Whittle nested pits did not allow access soon enough.

The approach, though not conventional, has resulted in a successful study, with the client having secured finance to allow the project to progress to an operating mine.

Introduction

Kroondal Platinum Mines (Pty) Ltd (Kroondal), was listed on the Johannesburg Stock Exchange in August 1998. The major shareholder, retaining 45%, is Australian-listed Aquarius Platinum NL (Aquarius), an Australian mining company based in Perth, Australia.

Aquarius undertook exploration during the period 1994 to 1997, along the strike of the UG2 reef to the east of the town of Rustenburg in the North West Province of South Africa. Very promising exploration results were obtained from a 6km strike length of UG2 reef on the farm Kroondal 304 JQ, as well as on the farm Waterval 307 JQ. In March 1997, a decision was made to undertake a full feasibility study of the mining of this deposit to bankable document standards.

SRK Consulting (SRK) were approached by Aquarius, together with Snowden Associates (Snowden) to undertake the study. The open-pit mining component of this study was undertaken by SRK's Perth office, whilst the geological modelling and underground component was completed by

The three zone models were combined to a single model for the deposit. The individual grades within the 50m x 50m x 5m blocks for each of the supplied models were weight averaged and combined to form a single grade for each particular grade label.

It was assumed that during open-pit mining, the Leader and Main seams would be mined selectively by the open-pit mining contractor. An allowance for dilution from the pegmatoid in the immediate footwall has been assumed at 10cm (750 tonnes from 7500 tonnes) at the block pegmatoid grade. A further loss of 10% was applied to the block tonnage to allow for geological losses due to potholes, structures, etc. The waste footwall was set to zero tonnage to ensure that during the pit optimisation process no footwall waste was included in the optimal pit outlines.

The 4E grade was not used for the open-pit mining model. This grade is a sum of the four main metals (Pt, Pd, Rh, and Au) and is not meaningful from an economic or pit-design viewpoint. A weight-averaged platinum equivalent grade was calculated from the four main metals using the following projected metal prices:

Platinum	=	US$ 500/oz
Palladium	=	US$ 150/oz
Rhodium	=	US$ 300/oz
Gold	=	US$ 360/oz

Weight Averaged Platinum Equivalent Grade = Σ (Grade x Price) / Platinum Price

The above prices were based on projections from a New York metal trading company.

From the initial exploration drilling and further in-fill drilling, the depth of weathering extended to 15m below surface. All reef blocks above this horizon were flagged as oxide, with reduced plant recoveries for the pit optimisation process. The oxide reef occurring in the initial 5m was treated as waste due to the excessive weathering resulting in uneconomic recoveries. The effect of this was to reduce the in-situ resource tonnage from 21.7 million tonnes (combined Leader and Main) to 20 million tonnes. This has no impact on the underground mine, but reduces the resource tonnage available to the open-pit.

Open-pit Optimisation

The combined block model with equivalent platinum grades was exported to Whittle Four-D to generate a series of pit shells for two scenarios:

Scenario 1 : Open-pit mine only.

Scenario 2 : Open-pit and underground mine.

The first scenario was investigated to evaluate the deposit as an open-pit option only. This would be the case should the underground mine not prove successful. The second scenario was selected as the base case which results in a smaller open-pit than Scenario 1, but will also include underground reef resulting in overall more reef being mined.

For a given set of economic parameters, the difference between the two optimisation scenarios is the reef that lies between the "open-pit only" mine (Scenario 1) and the "combination" mine (Scenario 2) that can be mined at a lower cost-to-metal by the underground mine. If this reef is mined by the open-pit a positive cash flow will still result, but it will be lower than if the reef was mined by the underground mine. Since marginal costing is used in the analysis the difference between the "combination" mine and the "open-pit only" mine will be small. It should be noted that this analysis makes no allowance for the capital required to establish the underground mine.

million tonnes reef (approximately the first 18 months of plant feed).

- The higher quality reef, available for underground mining would provide higher returns than the lower quality open-pit reef due to the metallurgical properties of the reef associated with the weathering. When considered as a separate product, the oxide reef (5m - 15m) is uneconomical to process, due to the low yield. The open-pit would therefore be planned to mine the reef that could not be mined by underground (within 30m depth of cover limitation).
- Access for the underground mine would be from the open-pit highwalls, which would dictate the start locations for the open-pit boxcuts.
- The limited down dip extensions within the final pit shell will preclude an open-pit mining sequence that includes a number of cutbacks/pushbacks.
- The reef mined from the open-pit can be blended in pit by mining a series of strike cuts that expose the total reef available for mining in the cut. Deeper higher quality reef can be blended with shallower lower quality reef during the mining cycle to provide a consistent blend to the plant.
- Each 50m wide cut is mined to final limits and can be considered as a separate pit. The extent of the cut will be determined by the cost-to-metal at the time the cut is mined. The mine will therefore be able to rapidly react to fluctuations in price by altering the depth of the cut and since several cuts will be mined in a year this will reduce the exposure of the mine to price risk.

The pit optimisation was undertaken to determine the limits of open-pit mining and the location of the 20m barrier pillar between the open-pit highwall and the underground workings. The base case pit was selected using the expected metal price, approximately US$400/oz platinum equivalent.

The results from the optimisation runs for both scenarios investigated are presented in Table 1 and Table 2, and Figure 3 and Figure 4.

Reference to these results indicates the following:

- For the given operating costs, there is no reef worth mining below a price of US$246/oz platinum equivalent.
- At the base case price (US$400/oz platinum equivalent) the Scenario 1 pit (open-pit only) yields 5.3 million tonnes at an average grade of 4.0 g/t platinum equivalent, with 71.4 million tonnes waste. The corresponding Scenario 2 pit (open-pit / underground combination mine) yields 4.1 million tonnes at 3.9 g/t platinum equivalent, with 44.0 million tonnes waste.
- For the Scenario 1 case (open-pit only) a 10% decrease in price from US$400 to US$360 results in a decrease of 23% of the reef tonnage and 32% in waste tonnage. The effect is less for the Scenario 2 case in which the underground mine, was limited to sulphide reef.

The optimal outlines at the base case price are shown in Figure 5. The Scenario 1 pit indicates the maximum profitable pit for the selected economic parameters. If there were no underground mine this would be the optimum pit limit. The Scenario 2 pit is smaller and the reef between the two pits can be mined at a lower cost by underground methods. For the optimisation runs the Scenario 2 underground mine was not constrained by the 30m depth of cover.

Open-Pit Mining Methodology

The project area has been divided into three blocks defined by the access requirements for the underground mine, the Centre block, the Eastern block and the Western block.

- The practical pit limits were controlled by the limits of the Scenario 2 pit unless the depth of cover was less than 30m. In this case the pit limits were extended to either the Scenario 1 pit limits or the 30m depth limit (which ever occurs first).

The pit design for this project consists of a starter pit mining from 15m to 30m, the initial 18 months and a final pit, which will be mined as a series of 50m wide cuts. Figure 6, shows the final practical design pit outline, mining to a depth of 30m.

Mining Schedule

The mining schedule was developed in conjunction with the underground mine. The tonnage profile provides the necessary feed to the plant, the majority of which is supplied by higher-quality underground reef. The lower-quality open-pit reef supplements this. The mill capacity is nominally 1.2 million tonnes per annum and the tonnage split is shown in Table 3. Figure 7 shows how the open-pit mine develops, and Figure 8 details how the underground mine develops.

Conclusion

This paper has described the process that was followed during the feasibility study for the Kroondal Platinum Mine Project. Subsequent to this, further drilling has been done of the reef to identify geological structures and for further grade interpretation which has been used in the detail design work which is presently on-going.

Having secured finance, Kroondal Platinum Mine has now moved into the detail design phase of the mine and plant. Preliminary work has started with the clearing of the site and preparation of foundations and roads. It is planned that the commissioning will be complete by the end of 1999, and full production will start in 2000.

Further work is being done in order to move the underground production forward and smooth the open-pit tonnage profile, as well as scheduling changes associated with the geological anomalies identified with the recent drilling. Tenders for the open-pit and underground mining contractors have been adjudicated and contracts are being negotiated at present. These are likely to be awarded during the early part of 1999.

The feasibility financial analysis shows that the project will be a success story for Kroondal, Aquarius and the shareholders.

Acknowledgements

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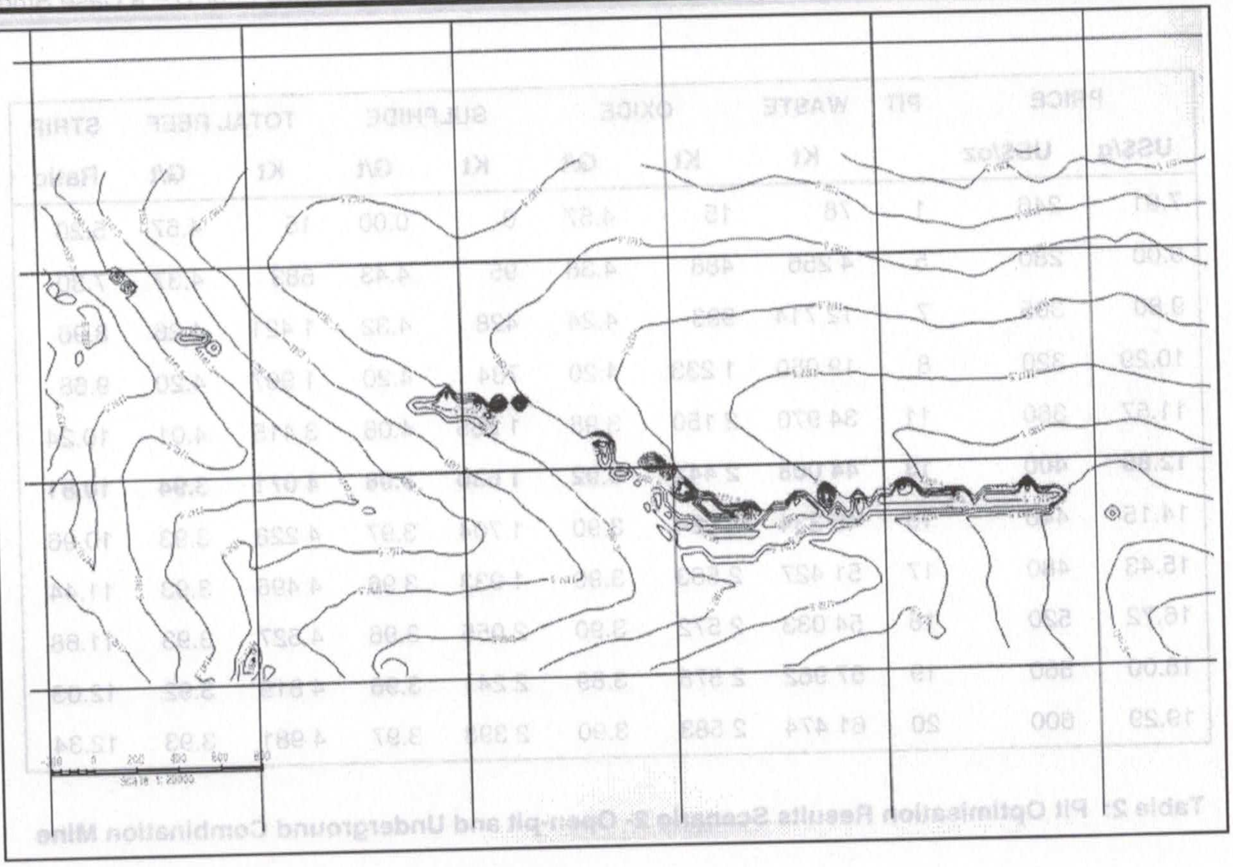

Figure 2: Optimised Pit Outline – First 18 Months

PRICE		PIT	WASTE	OXIDE		SULPHIDE		TOTAL REEF		STRIP
US$/g	US$/oz		Kt	Kt	G/t	Kt	G/t	Kt	G/t	Ratio
7.91	246	1	78	15	4.57	0	0.00	15	4.57	5.20
9.00	280	5	4 256	488	4.36	95	4.43	583	4.37	7.30
9.80	305	7	12 868	997	4.24	436	4.33	1 433	4.27	8.98
10.29	320	8	20 617	1 243	4.19	823	4.23	2 066	4.21	9.98
11.57	360	11	48 317	2 152	3.98	1 942	4.13	4 094	4.05	11.80
12.86	**400**	**13**	**71 476**	**2 452**	**3.92**	**2 889**	**4.06**	**5 341**	**4.00**	**13.38**
14.15	440	15	96 634	2 533	3.90	3 829	4.02	6 362	3.97	15.19
15.43	480	17	137 574	2 564	3.90	5 144	3.97	7 708	3.95	17.85
16.72	520	18	155 063	2 572	3.90	5 647	3.96	8 219	3.94	18.87
18.00	560	19	176 738	2 578	3.90	6 225	3.93	8 803	3.92	20.08
19.29	600	20	207 855	2 583	3.90	6 970	3.90	9 553	3.90	21.76

Table 1: Pit Optimisation Results Scenario 1- Open-pit only

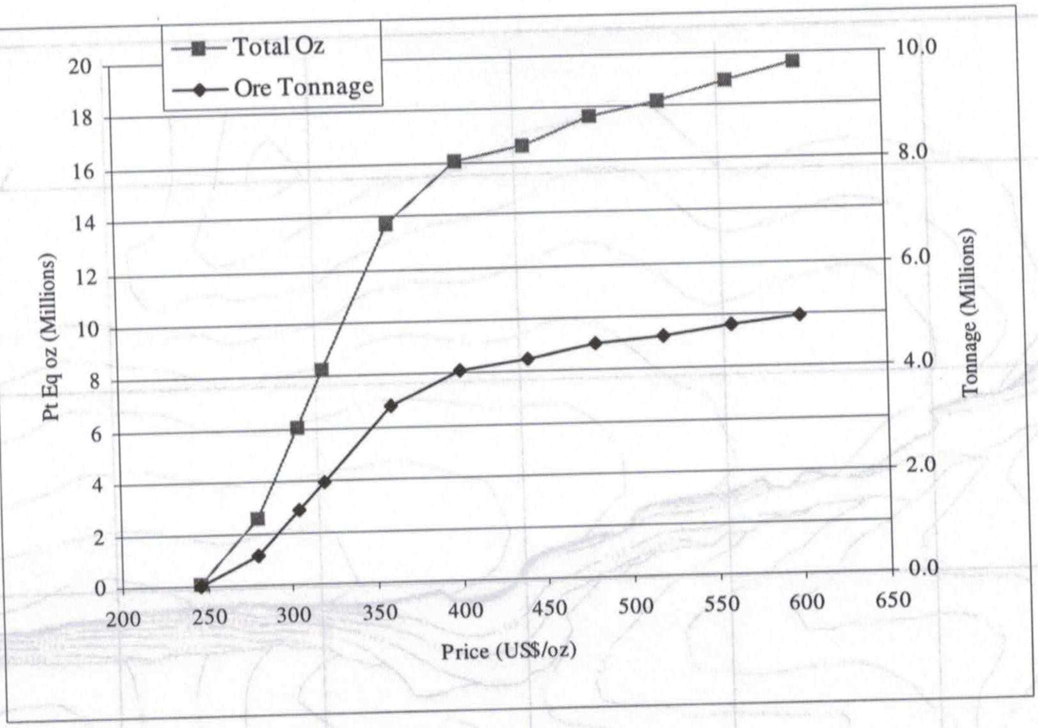

Figure 4: Scenario 2 – Selected Optimum Pit Outline

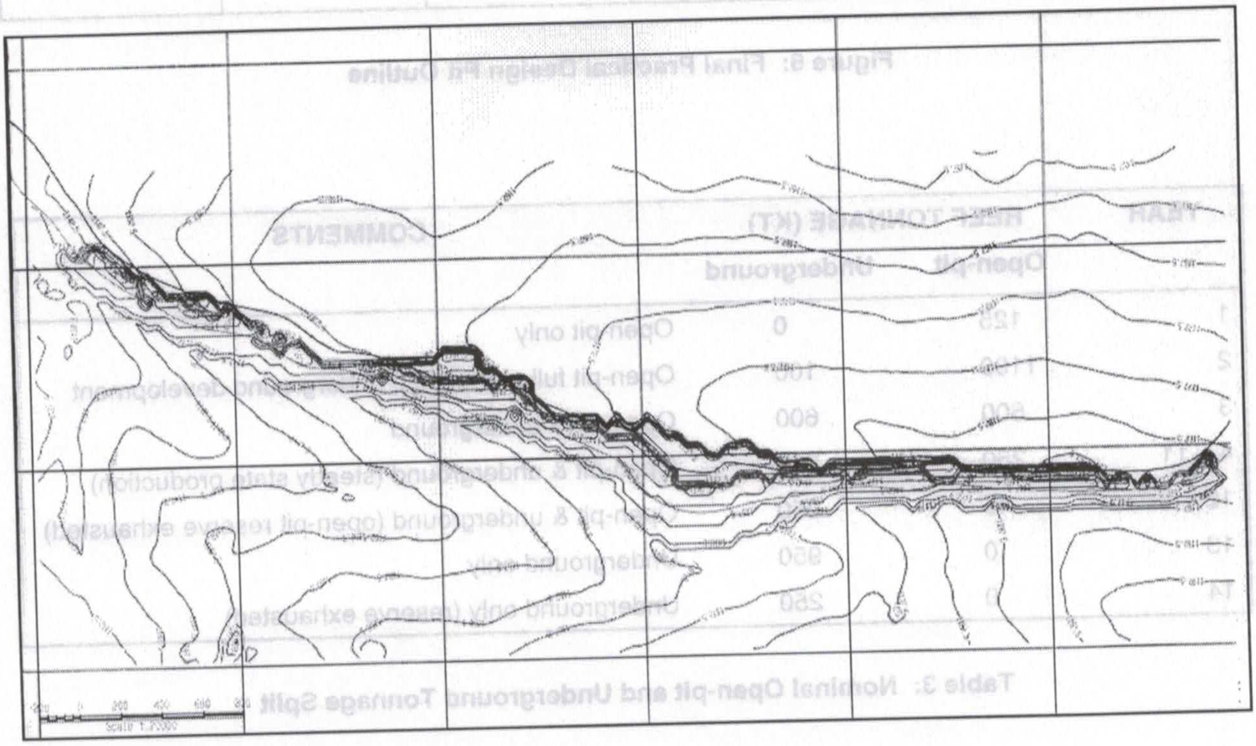

Figure 5: Optimised Pit Outline

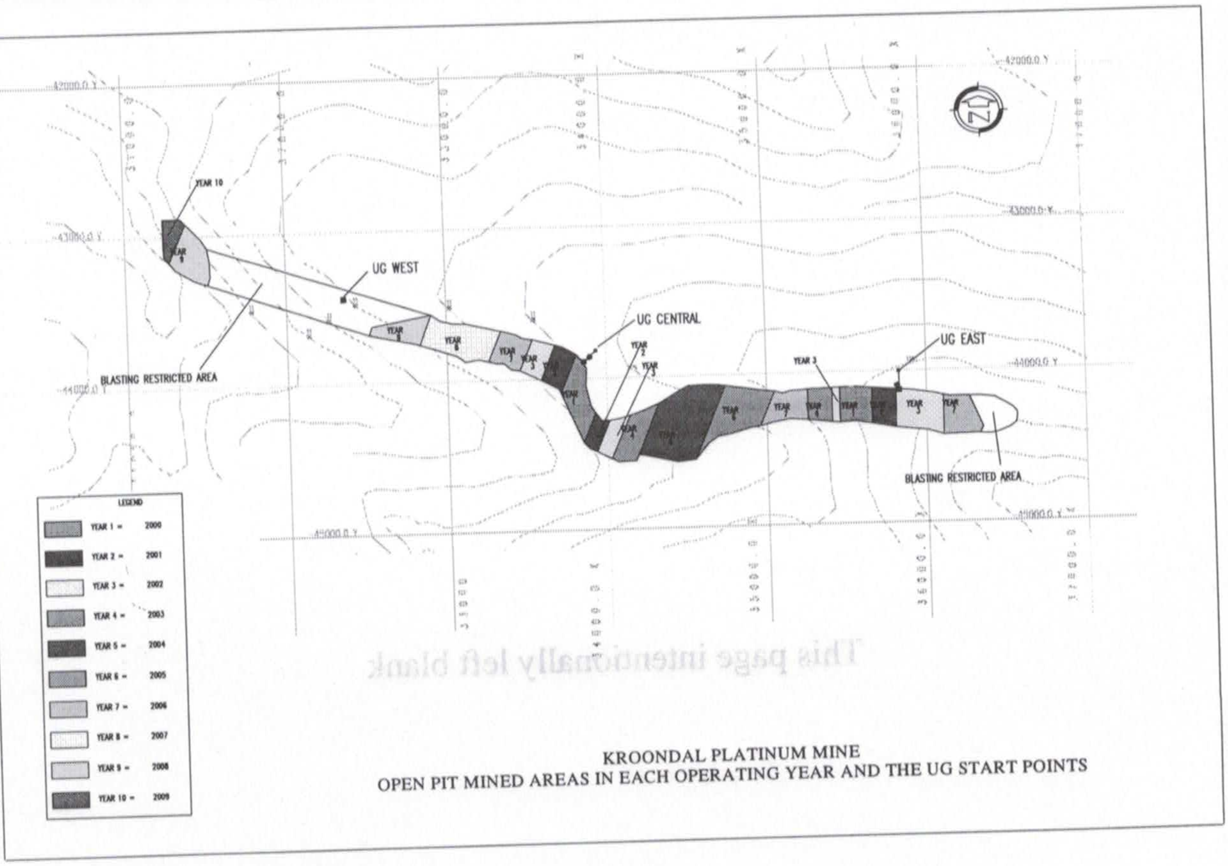

Figure 7: Open-pit Schedule

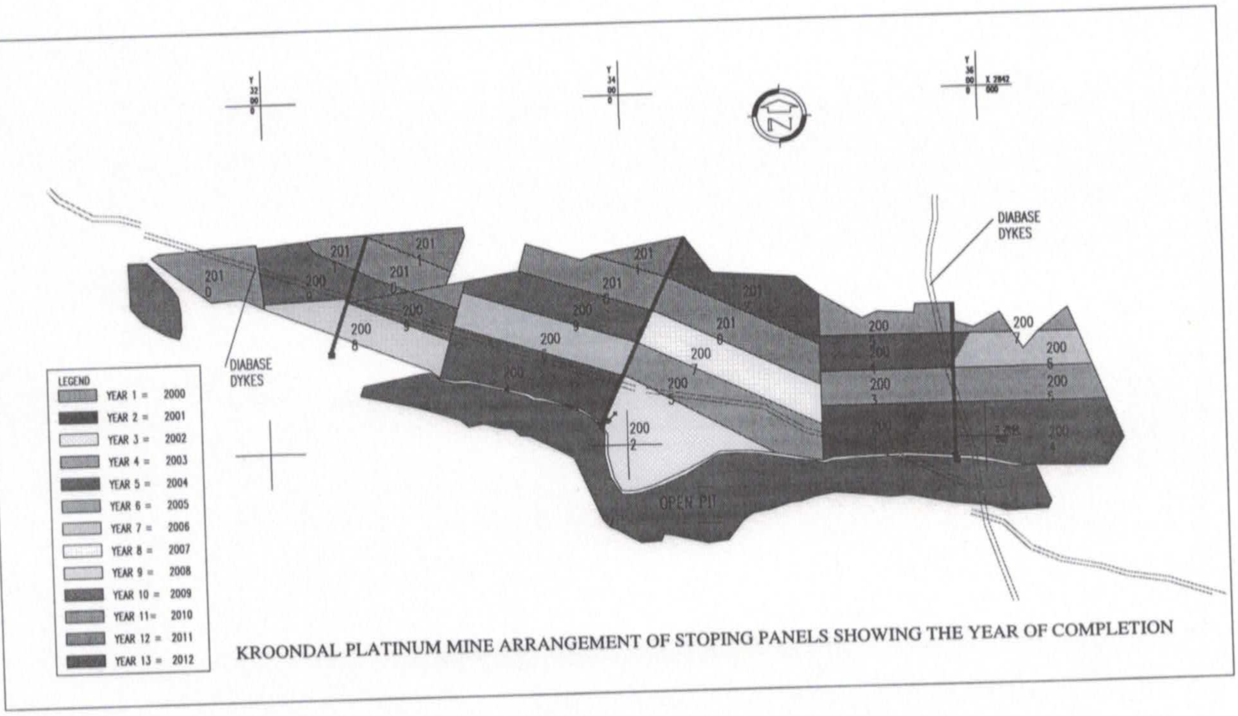

Figure 8: Underground Schedule