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Strategic Mine Planning: A SWOT Analysis Applied to KOV Open Pit Mine in the Democratic Republic of Congo

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***Abstract*—**KOV pit (Kamoto Oliveira Virgule) is located 10 km from Kolwezi town, one of the mineral rich town in the Lualaba province of the Democratic Republic of Congo. The KOV pit is currently operating under the Katanga Mining Limited (KML), a Glencore-Gecamines (a State Owned Company) join venture. Recently, the mine optimization process provided a life of mine of approximately 10 years withnice pushbacks using the Datamine NPV Scheduler software. In previous KOV pit studies, we recently outlined the impact of the accuracy of the geological information on a long-term mine plan for a big copper mine such as KOV pit. The approach taken, discussed three main scenarios and outlined some weaknesses on the geological information side, and now, in this paper that we are going to develop here, we are going to highlight, as an overview, those weaknesses, strengths and opportunities, in a global SWOT analysis. The approach we are taking here is essentially descriptive in terms of steps taken to optimize KOV pit and, at every step, we categorized the challenges we faced to have a better tradeoff between what we called strengths and what we called weaknesses. The same logic is applied in terms of the opportunities and threats. The SWOT analysis conducted in this paper demonstrates that, despite a general poor ore body definition, and very rude ground water conditions, there is room for improvement for such high grade ore body.

***Keywords*—**Mine planning, mine optimization, mine scheduling, SWOT analysis.

I. Introduction

The KOV pit is located in the Republic Democratic of Congo in Central Africa, and it is located 10 km from Kolwezi town. The KOV deposit is geologically categorized as a sedimental deposit in the so-called "Lambeau Geologique de Kolwezi", in a substantial portion of the Copperbelt geological structure. KOV pit is essentially composed of three well known ore bodies; Kamoto, Oliveira and Virgule, best known under the acronym of KOV. Oliveira stands for the discoverer's name of the deposit, a geologist called Oliveira and virgule stands literally for comma (due to the comma shaped ore body on the south of the deposit). KOV pit is essentially recognized to be one of the biggest relatively high graded copper ore deposits and was first started to be mined in the late 1950`s by the state owned company, Gecamines. KML joint venture is currently operating the KOV pit since 2006 to present, under the Kamoto Copper Company (KCC).

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A. Location and Geological Settings

KOV pit deposit is located in the Democratic Republic of the Congo side of the copperbelt sedimentary deposit and it is predominantly a copper-cobalt deposit, a subdivision of what so called Lambeau Geologique de Kolwezi. Note that the KOV pit deposit is located in the Lufilian Arc, in which most of the DRC copper cobalt's rich deposits are also located.

Figs. 1-3 show the location and the geological settings of the KOV pit

B. Property Ownership

The KML assets have been acquired since 2006, especially the KCC mining's rights that include mining and exploitation rights. KML currently owns a 75% stake in KCC, while Gecamines (GCM) and La Société Immobilière du Congo (SIMCO) owns 25% of KCC. Table I summarizes the various licenses that KML acquired in the Democratic Republic of Congo in order to operate legally. Reference [8] shows the property aspects with more details.

TABLE I
KCC Licenses That Include the KOV Open Pit Mine and the Mashamba East Open Pit Mine

Property	Exploitation permit number	Valid until
Kamoto underground mine and Mashamba East open pit	PE525	03/04/2024 Renewable
KOV open pit	PE4961	03/04/2024 Renewable
Kananga Mine	PE4960	03/04/2024 Renewable

In [12], we mentioned that during the prefeasibility stage, the SRK consulting company had led several geomodelling analysis using available drill holes information and came up with what was called the SRK bloc model. Later on, grade control geologists found themselves in a very difficult situation because of some little but substantial discrepancies that occurred when reconciling data from the SRK model and the grade control bloc model. Although the situation is under control and other better techniques are currently used, it is still relevant to consider when conducting a SWOT analysis.

Fig. 1 (a) Location of the KOV pit (by SRK consulting)

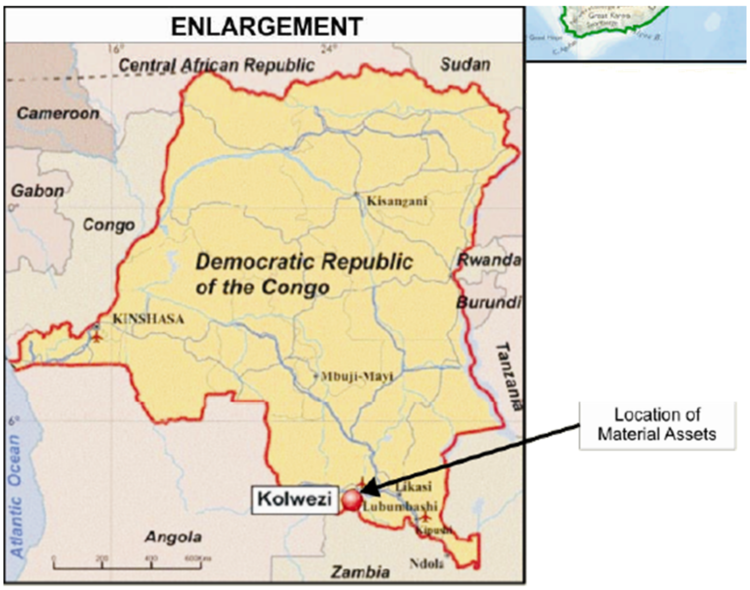

Fig. 1 (b) Location of the KOV pit (by SRK consulting)

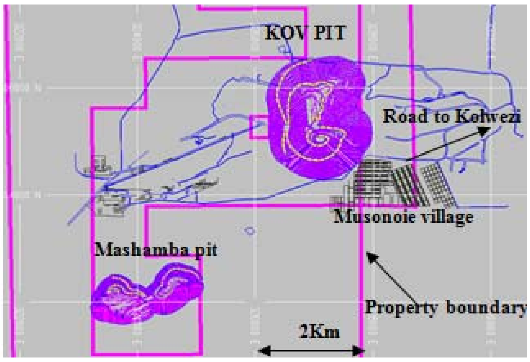

Fig. 2 Location of the KOV pit and Mashamba open pit

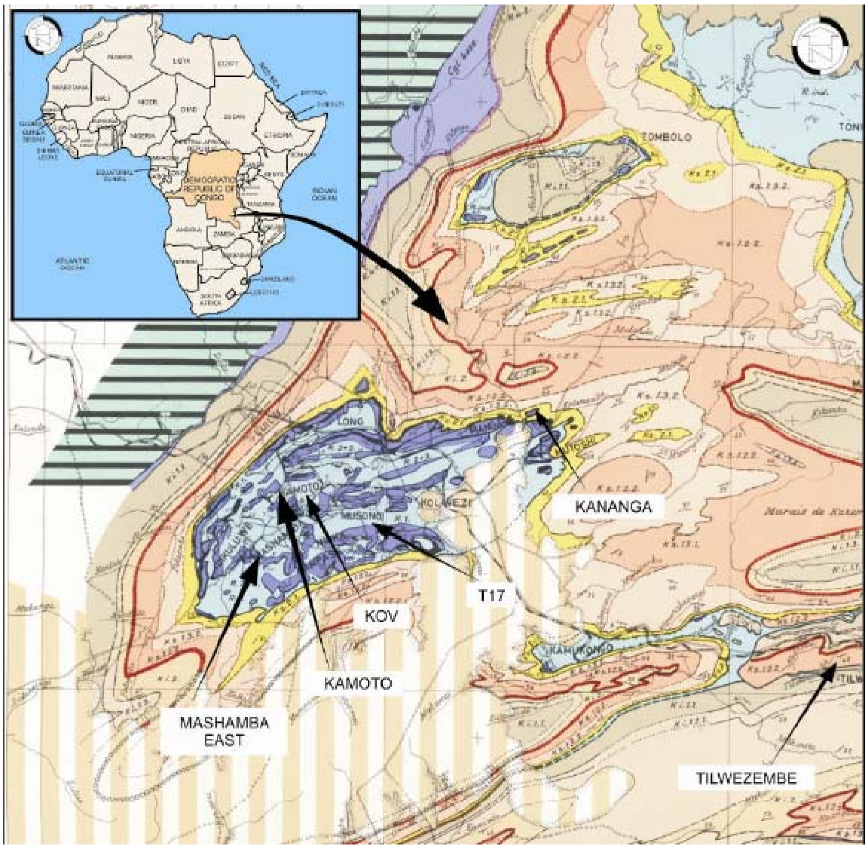

Fig. 3 (a) KOV geological settings (by SRK consulting)

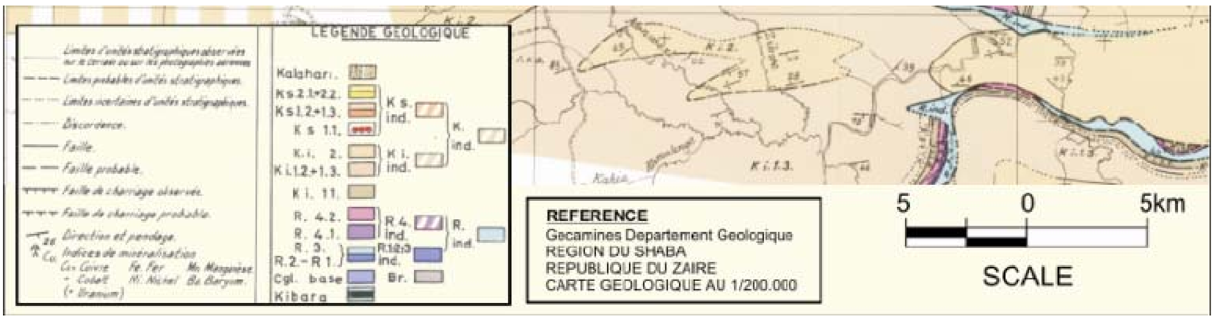

Fig. 3 (b) KOV geological settings (legend)

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II. Methodology

The methodology we are going to apply in this analysis will be by definition, descriptive, illustrative and also, comparative, on different aspects related to the KOV pit mine environment. The KOV pit mine environment will be described on its various aspects and will be confronted to the mining value chain, so that findings and conclusions that will be integrated in the SWOT analysis will be clearly identified and discussed more accurately.

A. Mine Optimization

The mine optimization process is essentially, a process driven by an algorithm (generally, the Lersch-Grossman algorithm), in which, the size of the future mine or pit, is determined in accordance of various parameters, as in [10], such as slope angle, commodity price, direct costs, the cutoff grade, and also by physical constrains such as the processing plant location, the waste dump location, river, town, etc.

B. Net Present Value (NPV)

The Net Present Value of a mining project as defined in [5]-[7], is often defined as the expected future profit actualized to today's value of money. It is something, or profit that the investor is looking at, when optimizing a mining project and the higher is that NPV, the better is for the investor. It is always good for the investor to look at the early higher NPV (early returns on investment) especially when the investment is considered to be at risk in certain countries.

C. Bloc Model

The bloc model is a 3D database that describes the ore body of the mine. The bloc model is discretized into smaller blocs that will contain the value of the bloc in terms of revenue and expenses, the blocs are generally discretized into smaller mining unit or SMU that represent at best the deposit. According to the bloc value (profit), the bloc will be considered to be a waste or ore bloc and will be included into the optimized pit at a certain slope angle. The value of a bloc is often stored at the center of mass of the bloc, and it is generally, a cutoff grade, as in [9], dependent value.

D. Bloc Model and Drill Holes

The bloc model is itself created using geostatistical methods of interpolations such as ordinary Krigging, nearest neighbor methods, and the information that is used in the geostatistical approach is coming from the exploration drill holes, which allows, when properly georeferenced into a database, to have a well-defined grade distribution along the mineralization. As with every statistical approach, the more drill holes we have, the more data we have, and the more accurate will be the ore body definition. It is important to remember in this case that, CAPEX is one of the first limitations and source of problems when defining the ore body of a given deposit because of the cost incurred when conducting exploration drilling.

E. Pit Dewatering

Pit dewatering is an operation or process by which rainfall water and groundwater is removed from the pit. It is and one of the sources of direct costing in large scale copper deposits, especially in KOV pit with an average of 3,500 m^3/hr of water inflow. The dewatering involves heavy infrastructure such as slurry sumps, heavy duty pumps, HDPE pipes, maintenance, etc. Dewatering can be classified as one of the important constrains that slows down the mining process into an open pit mine. It is good to know that KOV pit is located in Central Africa in a location where there is six to seven months of rainy season, and sometimes, 120 mm of rainfall is allowed; meaning that almost two to three quarters are usually affected every year in the mine planning process (Low sinking factor).

III. Relevant Issues for KOV Pit

A. Bloc Modeling Issue

We mentioned precedently that in one of our studies, we described how the geological information could have been impacted the mine planning process, below is an example of three different versions of bloc models that we had to be dealing with at the KOV pit.

TABLE II
KOV Pit Life of Mine and Scheduling Using the SRK Model

Year	Ore (tonnes)	Waste (tonnes)	Strip ratio
Year1	6,502,100	68,403,500	10.52
Year2	6,502,100	71,439,500	10.98
Year3	6,499,900	69,831,300	10.74
Year4	6,497,700	63,805,500	9.8
Year5	6,502,100	76,552,300	11.77
Year6	6,502,100	56,321,100	8.66
Year7	6,502,100	24,588,300	3.78
Year8	6,493,300	24,148,300	3.71
Year9	6,501,000	56,779,800	8.72
Year10	6,501,000	51,658,200	7.94
Year11	3,454,000	1,650,000	0.47
Total	68,457,400	565,177,800	8.25

TABLE III
KOV Pit Life of Mine and Scheduling Using the Other Model

Year	Ore (tonnes)	Waste (tonnes)	Strip ratio
Year1	6,504,300	86,300,500	13.26
Year2	6,501,000	96,145,500	14.79
Year3	6,499,900	78,877,700	12.1
Year4	6,498,800	71,438,400	10.9
Year5	6,496,600	69,183,400	10.6
Year6	6,506,500	38,980,700	5.9
Year7	6,495,500	44,359,700	6.82
Year8	6,501,000	39,045,600	6.0
Year9	6,496,600	45,229,800	6.96
Year10	3,331,900	2,220,900	0.66
Total	61,832,100	571,782,200	9.24

TABLE IV
KOV Pit Life of Mine and Scheduling Using the Grade Control Model

Year	Ore (tonnes)	Waste (tonnes)	Strip ratio
Year1	6,436,536	28,127,000	4.52
Year2	6,433,690	58,609,100	9.29
Year3	57,76	-	-
Total	12,927,991	86,736,100	6.87

The resulting versions of the bloc model are mostly due to insufficient drill holes available information, despite accurate geostatistical techniques that have been applied to interpolate them.

B. The KOV Geotechnical Issue

In August 2014, Call & Nicholas did conduct a geotechnical study in the entire KOV area, to provide strong recommendations on how to handle stability problems in and around the KOV pit. Below, are a few illustrations and recommendations on the Call & Nicholas findings, as in [13].

When looking at Figs. 4 and 5, the North of KOV pit was identified as very risky due to its geotechnical behaviour; water was pounding at the top of the pit 1410RL and was infiltrated in the laterite-clay ground along almost the entire North pit wall cracks. In the dry season, the water was gone and the cracks were opening and releasing all the water contained into the wall. On January 8th, 2016, seven people were killed after the collapse of the North pit wall.

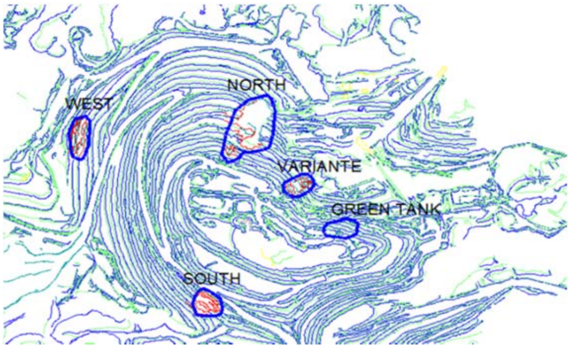

Fig. 4 KOV geotechnical areas of interest

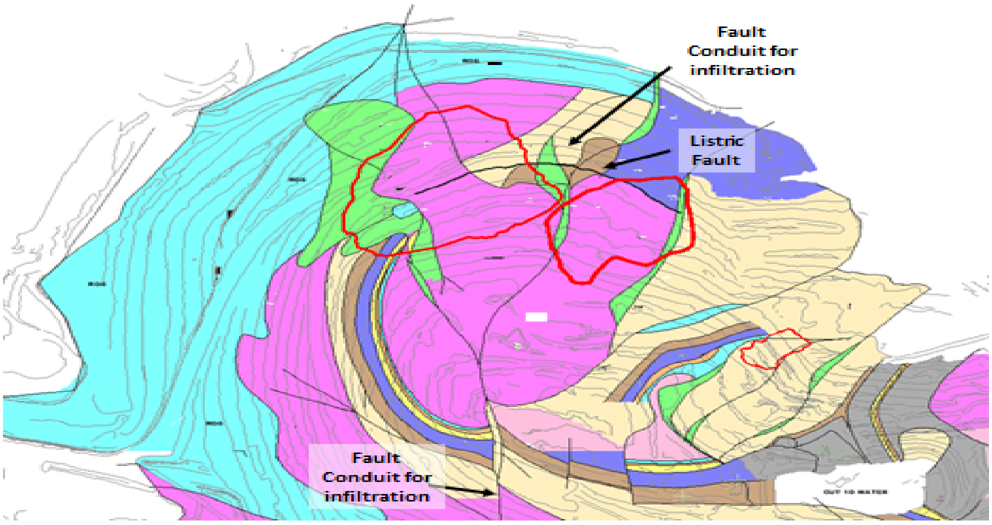

Fig. 5 KOV geotechnical and structural description of areas of interest

Fig. 6 KOV pit North wall after the Collapse in January 2016

C. The Mine Scheduling Aspect

KOV pit is one of the richest copper deposits around the world, as mentioned precedently, the mine optimization process, as described in [1]-[4], led to a life of mine of approximately 10 years with, in average a copper grade of 4% which is substantially considered as a good trend along the life of the mine.

Table V illustrates how good the potential of the KOV pit is in terms of available ore, and the profit that may result from such a rich deposit. It is important to remember that the sinking rate has been set to one bench per month (10m), but the dewatering issue is one of the big constrains that slows down the mining speed.

The amount of the water inflow is such a constrain in the pushback1, that it becomes impossible to mine a single 5m flitch.

D. The Dispatch System

As for common big open pit mines, the KOV pit is equipped with a dispatch modular system which is an optimized tool to help improve ore and waste mining. Beside the advantages, the system is a satellite-internet dependent system that helps to maintain an optimized load and haul system much accurate than the classical dump trucks required amount, calculation methods, as in [11].

E. The Radar Monitoring (Ground Probe) System

The geotechnical aspect of the KOV pit is complex, and precedently we outlined the Call & Nicholas findings, as in [13] in the KOV pit, and in addition to that, the geotechnical department was equipped with a radar monitoring system to provide real time stability report of KOV pit walls.

TABLE V
KOV PIT LIFE OF MINE AND SCHEDULING EXAMPLE

Year	Rock (Million Tonnes)	ORE (Million Tonnes)	Waste Million Tonnes)
YEAR 1	103.17	**7.10**	96.07
YEAR 2	83.05	**6.70**	76.36
YEAR 3	54.77	**6.00**	48.77
YEAR 4	58.72	**6.30**	52.42
YEAR 5	68.30	**6.70**	61.59
YEAR 6	87.05	**6.10**	80.95
YEAR 7	39.80	**6.00**	33.81
YEAR 8	37.49	**6.00**	31.48
YEAR 9	43.59	**6.00**	37.59
YEAR10	49.03	**6.20**	42.83
YEAR11	7.22	**4.29**	2.93
YEAR12	1.43	**1.06**	0.38
TOTAL	633.64	**68.46**	565.18

TABLE VI
KOV PIT SWOT ANALYSIS TABLE

Strengths	**Weaknesses**
• The dispatch system is up and running. • The mineral potential is high (high grade ore available for more than nine years). • The geotechnical department has been equipped with a radar monitoring system. • Equipment support is good and the availability of equipment is at a good rate. • Extra ore that does not exist in the bloc model is found on the ground, thus creating a positive surprise that can be added to the production.	• The geological information is not sufficient at some areas of the KOV pit and this, lead to difficult reconciliation process with grade control geology. • Power outages are shutting down the dewatering infrastructure and create problems controlling the water inflow. • Satellite connectivity dependent for the dispatch system, which also relying to the power system with several shutdowns and problems during cloudy days in rainy season (six to seven months of rainy season).
Opportunities	**Threats**
• Geotechnical concerns have to be integrated into the next long term mine plan to mitigate the north wall risk of collapse in the long run. • Put Mashamba East open pit mine (a satellite pit) ore to contribution so that we can optimize stripping ratio in the KOV mine, while maintaining mill feed at the processing plant. • Lower power outages frequency so that we can improve dispatch efficiency as well as the dewatering system. • Increase in pit reserves by adding more drill holes information in the pit. • Increase equipments such as dump trucks and Shovels to be able to handle a Multimine approach if required (combining KOV and Mashamba East pit mining).	• Sinking rate is affected by dewatering issue in the pushback1 and may slow down the high grade ore mining. • Geotechnical areas were identified and risks of collapse still presents in other areas of the KOV pit. • High stripping ratio required for mining ore in the KOV pit to expose ore to maintain mill feed requirement. • Dewatering • Unforeseen other geotechnical problems. • Copper price volatility • Political risk in the Democratic Republic of Congo.

IV. FINDINGS & DISCUSSION

Various aspects have been outlined along this study and the major relevant aspects of the study are the ore potential of the KOV pit deposit, the length of the life of the mine, (around 10 years), while many other aspects such as dewatering, geotechnical aspects, and the lack of sufficient geological information have to be considered as disadvantages for the KOV pit mine. In Table VI, we summarize the various elements that have to be taken into account to generate the proposed SWOT analysis.

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