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Production Drilling Performances at Kinsevere

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Abstract

This article is about the blastholes drilling productivity at the mines of Kinsevere. These mines planned to produce 60,000 tons of copper cathodes per annum, althoughthey produced around 75,000 tons in the last three years.

Drilling is the first operation in the mines, and analysis of this operations should reveal if they are working at the optimal level, or they need some improvement. The performances of the Drill Rigs, The Pantera 1500 i, are95.78 mph in average with standard deviation of 46.17, a minimum of 29.64 mph in fresh cellular siliceous rock, a maximum of 367 mph in dolomitic shale, a median of 93.64 mph in weathered cellular siliceous rock. These are quiet high compared to the 30.5 mph in standard conditions. 300 samples measures have been sampled on site, and 30 samples of utilizations and availabilities have been analyzed for these conclusions.

On the scale of standard drilled meter, with 4categories of rock amongT2 for very soft is witch free digging is executed, T2D for soft rock requiring small powder factor, T3 medium rocks required relatively high powder factor, and T3D hard rock requiring high powder factors, the standard drilled meters at Kinsevere is calculated by the formula:

$$SD = 0.21\,T2 + 0.28\,T2D + 0.36\,T3 + 0.47\,T3D$$

Keywords: Standard Drilling, Performances, Utilization, Availability.

Introduction

Drilling is the first operation on the chain of extraction in hard rock. It must be done optimally in order to minimize the cost of production, and to maximize the profit. To optimize drilling means that drilling tools are working up to their planned life, drilling performance is according to supply specifications, and utilization is at the maximum.

There is numerous equipment available for drilling operations in open-pits mines, and all suppliers claim to provide the best equipment for given mine. MMG Limited is operating with the Pantera 1500 i for its Kinsevere Mines.

The problem investigated in this article is to evaluate the drilling equipment used for operations at Kinsevere Mines, if they are performing well, and to evaluate performances according to the local environment and recommended standard.

It is an empirical research; quantitative research method is used to evaluate the drilling time on the site of Kinsevere. I need the drilling times which will be taken from the chronometer, the categorizations of the rocks drilled which will come from the Mines Technical Services Division, and specifications of equipment from the manufacturer. Statistics will be done to calculate the drilling time according to the rock category.

Mines of Kinsevere

Geography

Figure 1. Location of Kinsevere

Mines of Kinsevere are extracted by Minerals and Metals Group, MMG in Sigle, a Chinese organization with it headquarter in Melbourne, Australia. Mines are located at 35 kilometers from Lubumbashi in the Democratic Republic of Congo. Kinsevere is planned to produce copper at 60,000 tons per year. The last five years the mine produced 80,000 tons.

History

Kinsevere has been in operation since 2004, MMG acquired right in 2012. The life of Mine in estimated up to 2023 through conventional mining method. Copper is mined from open-pit with ground conditions allowing free digging, extraction without blasting. Extraction operation included grinding mill, acid-leaching, solvent extraction, and electro-winning. The production average range from 68,000 to 75,000 tons since MMG operates.

The history of the mine is the following(MMG, 2016):

- 2004:Anvil enters into joint venture agreement with Mining Company Katanga to carry out feasibility study work on the Kinsevere-Nambulwa copper-cobalt deposits owned by The General Quarrying and Mining
- 2006: Anvil announces approval for the Phase 1 development of Kinsevere and feasibility study of the Phase 2 Solvent Extraction and Electrowinning development.
    - 2006:Anvil completes acquisition of a further 15% of the Anvil Mining Company Katanga (AMCK) taking 95% ownership of Kinsevere. Payment equivalent to US$45m in cash and shares.
- 2007:Board approves Phase 2 US$238m project to build 60ktpa Solvent Extraction and Electrowinningplant – late revised to US$380m.
    - 2007:Production from Phase 1 commences in July through HMS plant.
- 2010:Kinsevere HMS plant processes approximately 300kt or ore, producing approximately 67kt of copper concentrate.
    - 2011:Construction of Solvent Extraction and Electrowinning plant complete with first production in June, coinciding with closure of HMS plant.
    - 2011:MMG announces friendly takeover of Anvil Mining for $C1.3b cash offer September 2011.
- 2012:MMG acquires remaining 5% minority stake from MCK.
- 2013:MMG divests Mutoshi project and acquires exploration and mining rights over eight tenements adjacent to the Kinsevere operation
- 2015: Kinsevere produces over 80kt of copper cathode at C1 cost of US$1.48/lb.

Geology

At June 2019, Mineral Resources are(MMG, Mineral Resources And Ore Reserves Statement As At 30 June 2019, 2019):

Table 1. Kinsevere Resource

Table 2 : Mineral Resources of Kinsevere

Resource	Values (Mt)	Cu %	Co%
Oxide Copper			
Measured	1,4	4,2	0,17
Indicated	7,2	3,3	0,08
Inferred	0,9	2,4	0,09
Total	***9,5***	***3,35***	***0,09***
Transition Mixed Copper ore			
Measured	0,5	2,5	0,21
Indicated	2	2	0,14
Inferred	0,3	1,9	0,09
Total	***2,8***	***2,08***	***0,15***
Primary Copper			
Measured	1,2	2,8	0,28
Indicated	19,5	2,3	0,13
Inferred	2,4	1,9	0,12
Total	***23,1***	***2,28***	***0,14***
Oxide-TMO Cobalt			
Measured	0,03		0,61
Indicated	0,3		0,59
Inferred	0,1		0,56
Total	***0,43***	***0,00***	***0,58***
Primary Cobalt			
Measured	0,01		0,33
Indicated	0,2		0,31
Inferred	0,1		0,29
Total	***0,31***	***0,00***	***0,30***
Stockpiles			
Measured			
Indicated	12,9	1,8	
Total	*12,9*	*1,80*	*0,00*
Total	**49,04**	**2,32**	**0,10**

The geology of Kinsevere is the same as all the mines in the Copperbelt of copper in central Africa, The Democratic Republic of Congo and The Republic of Zambia. Mineralization is located in the Katangan Supergroup, within the series of mines or Roan Group. Resource in 2014 were 19.7 Mt at 3.4 % Cu of supergene oxide deposit, and 24.6 Mt at 2.5 % Cu hypogene sulfide

deposit. There are three fault offset orebodies from northwest to southeast: Mashi, Central, and Kinsevere Hill along the Kinsevere fault. Hypogene mineralization occurs largely as quartz ± carbonate ± apatite veins with chalcopyrite ± bornite ± carrollite emplaced into carbonaceous shales, siltstones, and dolomites.

The stratigraphy is following:

Table 3.Lithostratigraphie de Kinsevere

Formation	Unit	Lithology	Comments	Mineralisation	Thickness
Kambove Dolomite CMN	Upper R2.3.2.	Pale coloured dolostone; evaporitic breccia	Stromatolites		40
	R2.3.2.		Pink brown-white massive; mineralised	THIRD OREBODY (lenticular) Mineralised at Kinsevere	
	R2.3.1.	Grey or black dolostone & shales	Laminated, locally carbonaceous		70
R2.2 Dolomitic Shales SD	S.D.3b	Dark dolomitic, silty & carbonaceous shale	Simplest sub-division by Francois consists of 3 units pale grey dolomitic siltstone overlain by carbonaceous shale. BOMZ & SDB not defined or developed at Kinsevere		50-100
	S.D.3a	Grey dolomitic siltstone			
	S.D.2d	Carbonaceous silty shale			
	S.D.2b+c	Stromatolitic dolomite & dolomitic silty shale		UPPER OREBODY	
	S.D.2a	Carbonaceous siltstone & dolomite			
	BOMZ	Carbonaceous shale/dolomite			
	SDB	Grey dolomitic siltstone	Evaporitic texture		
R2.1	RSC	Silicified dolomite	Vuggy; stromatolitic	ABSENT AT KINSEVERE	
	RSF	Finely banded laminated argillaceous dolostone	Hardly silicified at Kinsevere	LOWER OREBODY	<2
	DSTRAT	Fine >coarsely banded, planar bedded shaley/silty dolomite	Distinct 1-5cm nodules replaced by silica/dolomite or sulphides		3
	Grey RAT	**Chloritic & dolomitic argillite siltstone**	**Massive, occasionally sandy. Reducing environment**		1-3

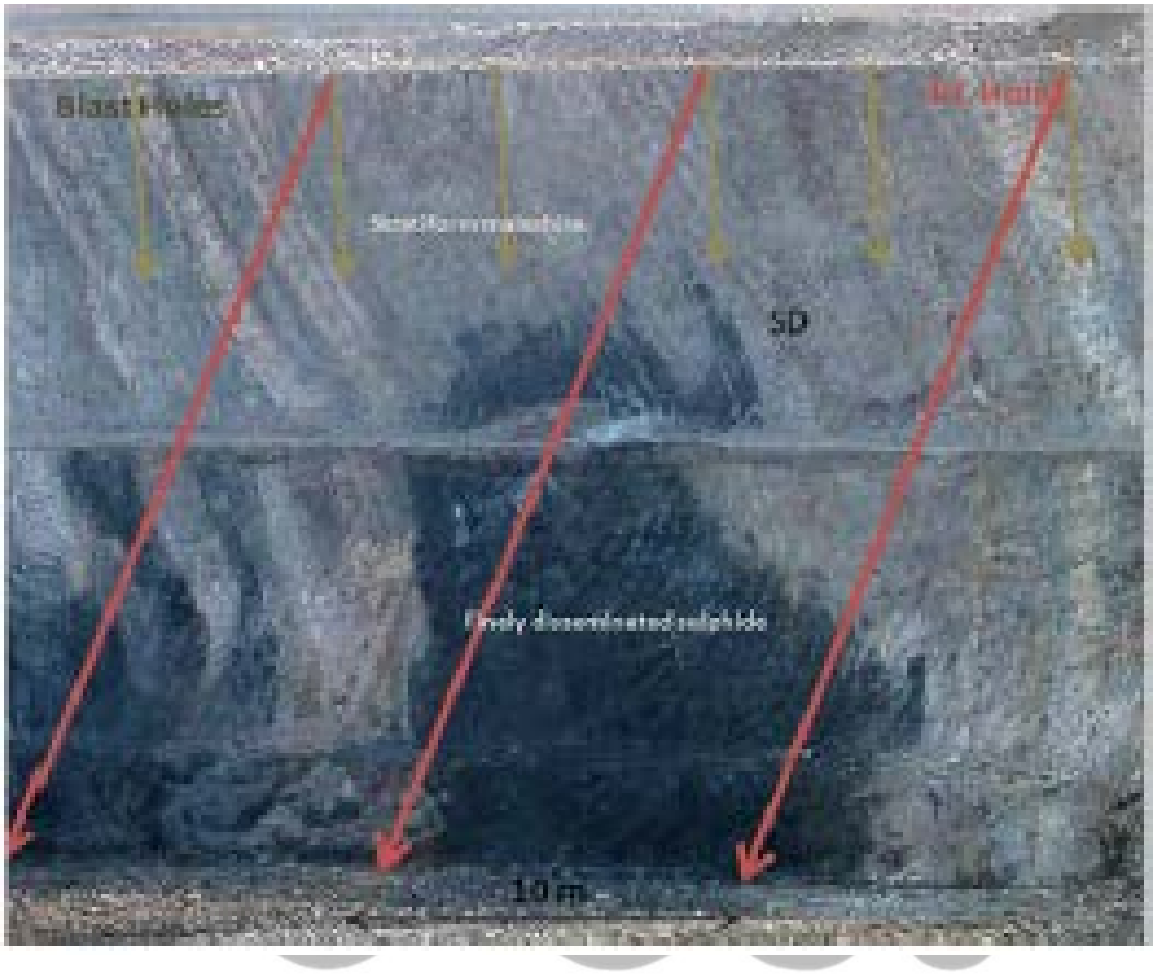

Figure 2. Rocs in the wall of Kinsevere

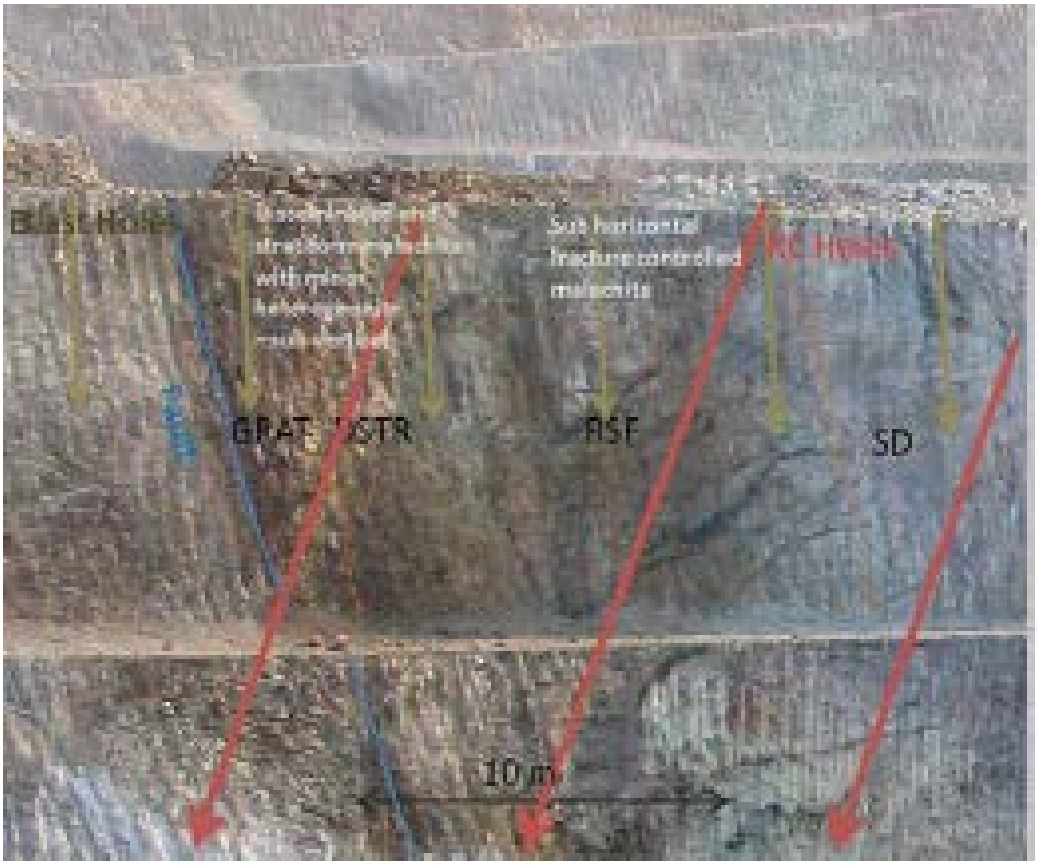

Figure 3 Stratigraphy of Kinsevere.

Mining Operations

There are three pits scheduled like following:

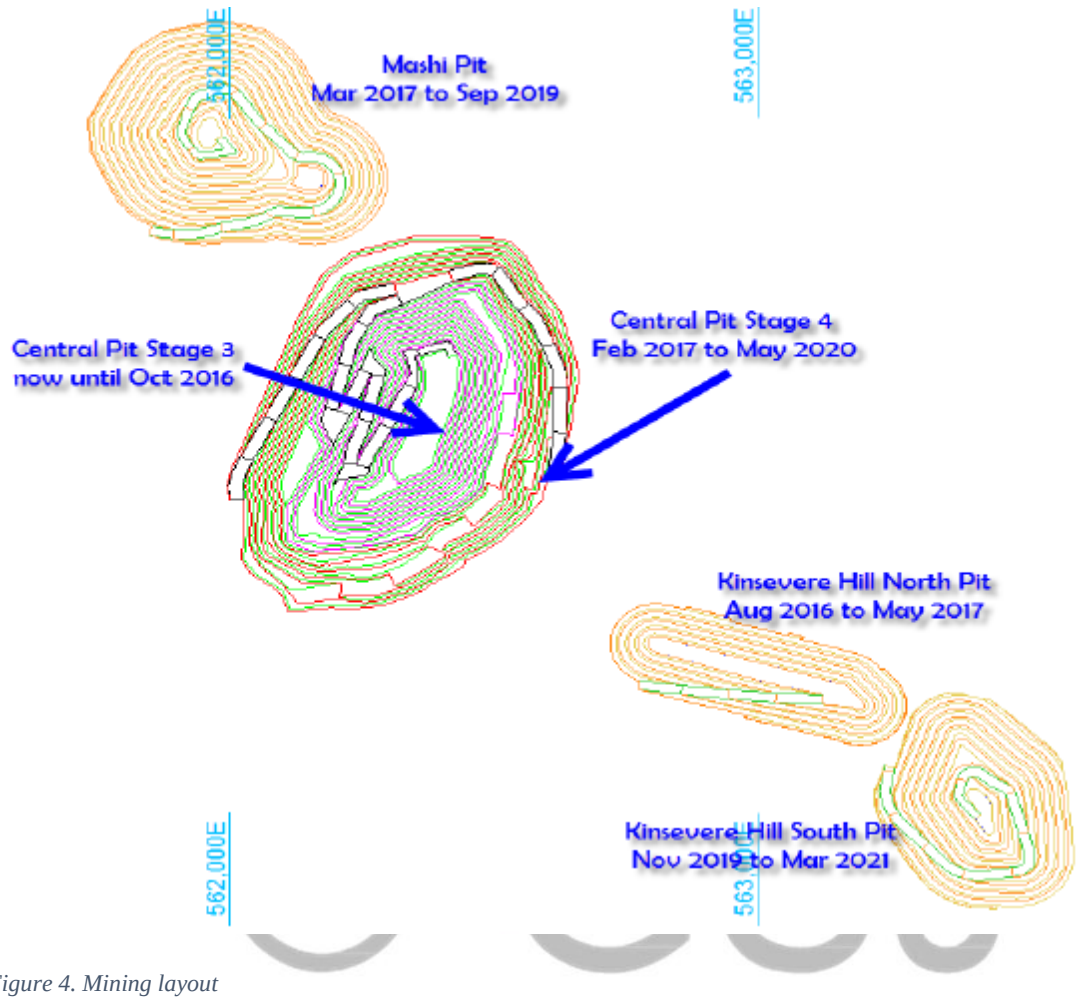

Figure 4. Mining layout

The feeding throughput is 2.2 Million tons per annum from the mines into the crusher for the production of copper cathodes. The life of mine is extended to 2023 with the current mineral resources.

Blastholes Drilling

Types of drilling

There are two types of drilling for mine production(Rostami & Hambley, 2011) :

1. Percussive drilling, depth up to 76 m.

a. smaller holes sizes, up to 150 mm or 6 inches, Impact and rotation of the bit are transmitted from the drill or top hammer to the bit through a drill rod or series of drill rods, coupled together and called drill string.
b. Larger holes sizes, from 75 mm hole diameter to 508 mm (3 to 20 in.). Hammer is located down the hole or in-the-hole at the bottom of the string immediately above the bit.

2. Rotary drilling:
    a. Drag bits: Diameter from 75 to 250 mm
    b. Tricone bits: 75 to 300 mm
    c. Larger roller bits: Diameter above 300 mm

Every drilling system demand different drilling tool. Percussion drilling bits are in various shapes, the figure 1 is giving different shapes of top hammer bits. The drill still with integral chisel bit and single TC insert is for jackhammer drills. Hammer on or screw-on cross-shaped bits with four chisel-shaped TC inserts are common. In harder rocks, chisel-shaped bits are replaced by button bits. Retrac bits is an example of button bits, used in difficult rock formation, to facilitate removal of the bit and steel from the hole, which is decisive in soft or squeezing ground.

I am recalling that the shape and the length of buttons depend on the type of rock:

1. Longer, pointed inserts for softer rocks
2. Shorter, rounded inserts for harder rocks.

Bits are selected using charts from commercial bit manufacturers; however, optimum bit geometry and button shape is usually determined by trial and error at the job site.

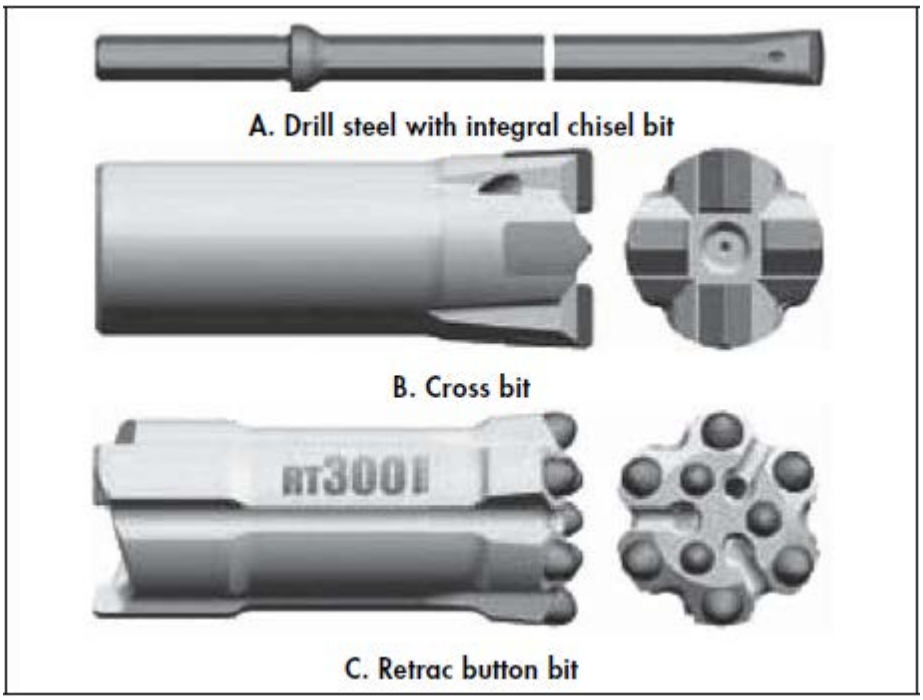

Figure 5. Percussive Drill Bits

The Down-The-Hole drilling does not evaluate to much since its introduction in 1955 by Ingersoll Rand Company. Figure 2 is an illustration.

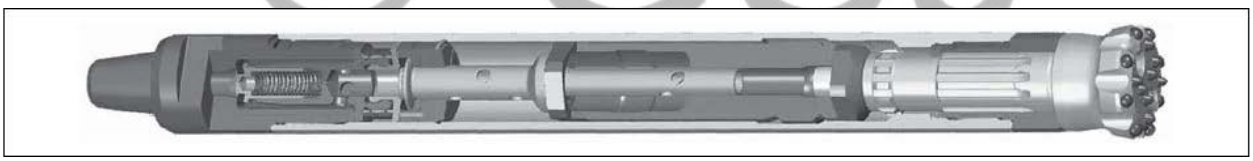

Figure 6. Cutaway view of a DTH Hammer and Bit

Penetration rate for typical surface drills vary from 2 to 80 m/h, increasing with increased power of the rig, and decreasing with increase hole diameter and rock mass strength. The table below is giving some penetration rate:

Table 4. Drilling rates for percussive systems

Drilling Method	Range of Diameter mm	Typical Depth m	Typical Drilling Rate, m/h	Accuracy % or cm/m	Application
Top hammer pneumatic jackleg	25-50	<4	60	2-5	Used in small tunnel, and drift development, small scale stopping, surface operations as starter, shallow trenching, bolt installation, etc.
Jumbo	37-100	4-10	100-200	1-3	Tunneling, Stopping, fan drilling, bolt installation, and probe drilling
Surface crawler – mounted drills	50-150	5-30	20-150	1-3	Surface and bench drilling
Top hammer hydraulic jumbo drills	37-125	4-20	30-120	2-3	Tunneling, Stopping, fan drilling, bolt installation, and probe drilling
Down-The-Hole	75-150	10-50	20-80	3-5	Surface and bench drilling

Drilling rates are for actual drilling and do not include time for drill retraction, boom relocation, collaring, etc.

Drilling rates decrease as rock mass strength increases and may increase or decrease depending on the number and orientation of joints/blocks.

The most important aspect to remember is that bit selection is based on hole size and depth, rock type, and operational requirements. Sources of information to guide selection of the proper bit include manufacturers such as Atlas Copco (Epiroc), and Sandvik for percussive drill bits, and Smith International and Baker Hughes for tricone and drag bits.

Here is some performance for drilling:

Table 5. Generalized production rate of drilling units in

Drilling conditions	Soft Rock	Medium Soft Rock	Medium Hard Rock	Hard Rock
Rock Strength, MPa	70-100	100-175	175-225	225-300
Rock Strength, 1,000 psi	10-15	15-25	25-35	35-45
Rock fabric condition	Drilling rate, m/h			
Stable, uniformly competent ground conditions	55	33.5	30.5	24.5
Competent rock, fractured collar zone (top 0.6 to 1.2 m of bench)	49.5	30	27.5	22
Rock with closed joints, fractured collar zone (top 0.6 to 1.2 m of bench)	42	25.5	23.5	18.5
Rock with open joints, fractured collar zone (top 0.9 to 2.4 m of bench)	33.5	20.5	18.5	15
Heavily jointed, poorly cemented, fractured collar zone (top 1.2 to 3 m of bench)	27	16.5	15	12

Drilling productivity at Kinsevere Mines

Drilling is done by drill rigs Pantera 1500 i.

Figure 7. Drill rigs in the mines

The Characteristics of the Pantera 1500i are:

- Hole Diameter: 89 -152 mm
- Rock Tools: 51 and 60 mm, rods or 87 mm
- Rock Drill: 33 kW
- Engine output: 261 kW (Tier 3)
- Flushing air:14 m3/min up to 10 bars(depends on used rock tools)
- Production capacity: 2,0 Mt/year
- Total weight: 22 700 kg

Here isthe summary of data collected on site:

Table 6. Descriptive statistics of drilling times

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Penetratin_Rate_m	300	33,68	417,14	108,8395	52,46358	2752,427
Drilled_depth_m	300	5,50	8,10	7,5088	,56919	,324
Drilling_time_h	300	,02	,23	,0867	,04315	,002
Valid N (listwise)	300					

By Geology, and ground conditions:

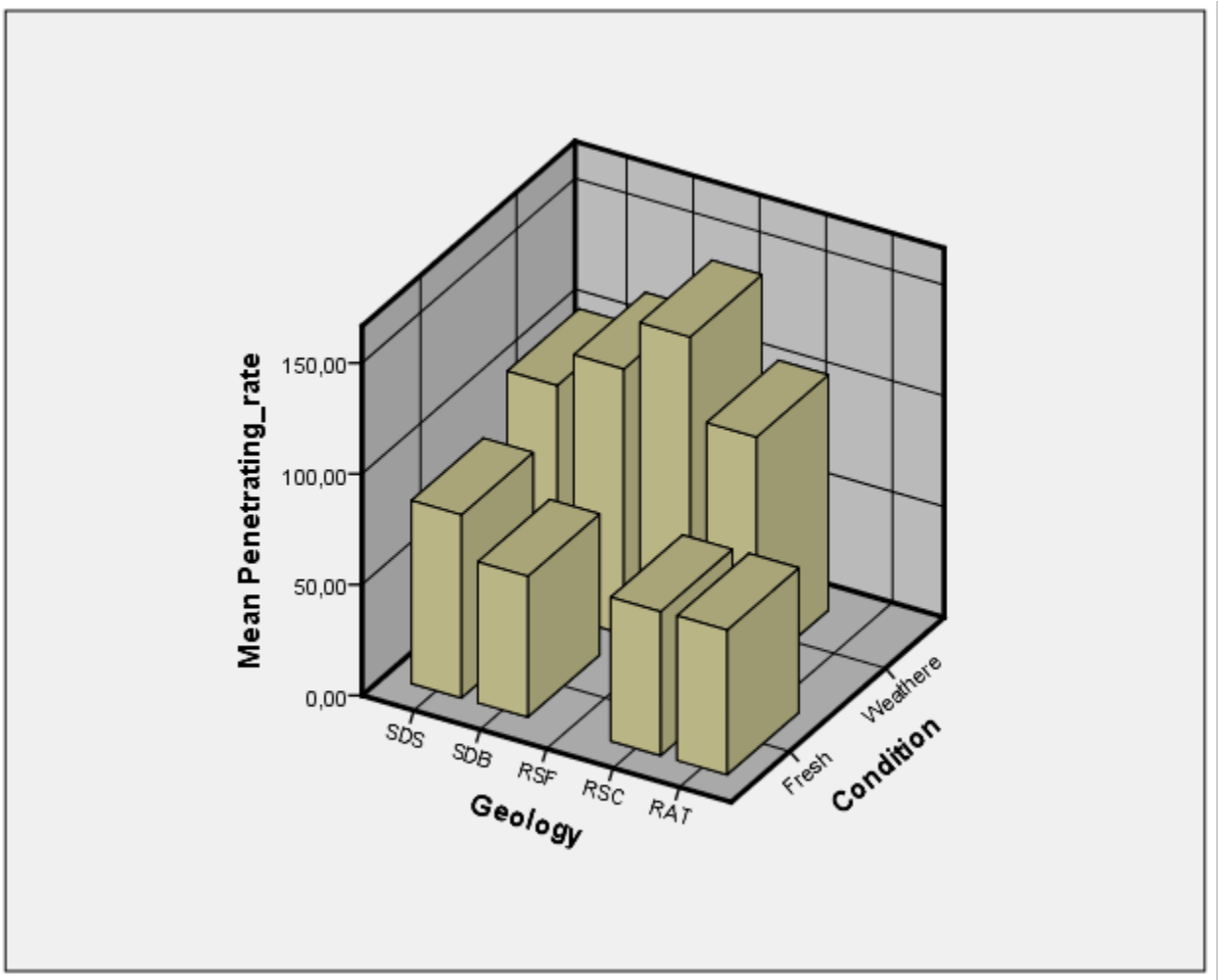

Figure 8. Graph of drilling rates

Availability and Utilization of drill rigs

30 days have been analyzed in the aim of getting availability and utilization of the drill rigs in the Kinsevere. The data collected are listed below:

Table 7. Availabilities and Utilizations

Day	Theoric	Available	utilization
1	12	11,81	11,67
2	12	10,08	11,63
3	12	11,85	9,91
4	12	11,13	11,58
5	12	11,71	11,08
6	12	11,2	10,33
7	12	11,25	11,44
8	12	12	10,14
9	12	11	11,26
10	12	11,47	11,34
11	12	11,49	11,36
12	12	11,43	11,38
13	12	11,96	11,91
14	12	11,96	11,89
15	12	11,91	9,92
16	12	11,91	11,49
17	12	12	10,85
18	12	10,95	10,86
19	12	10,5	8,75
20	12	12	11,75
21	12	10,5	10,02
22	12	11,7	7,72
23	12	8,17	7,89
24	12	11,58	10,21
25	12	10,58	10,51
26	12	11,91	10,29
27	12	10,36	9,44
28	12	11,16	8,77
29	12	11,79	10,57
30	12	11,7	10,49

The summary of these data is:

Table 8. Statistics on Availabilities and utilizations

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Utilization	30	8	12	10,55	1,136
Available	30	8	12	11,30	,813
Theoric	30	12	12	12,00	,000
Valid N (listwise)	30				

The availability ratiosare:

Table 9. Availabilities and utilizations

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Availability	30	,68	1,00	,9418	,06772
Utilization	30	,64	,99	,8790	,09464
Valid N (listwise)	30				

This mean that the overall penetrating rate will the preceding calculated times the average utilization:

$$Penetrating\ rate = 108.8 * 0.88 = 95.78\ mph$$

This means that the overall penetrating rates are:

Table 10. Penetrating Rates

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Penetrating_rate	300	29,64	367,09	95,7787	46,16811
Valid N (listwise)	300				

By geology:

Table 11. Penetrating Rates by rocks category

Average of Penetrating_rate 2	Column Labels		
Row Labels	Fresh	Weathered	Grand Total
RAT	65		65
RSC	65	106	92
RSF		143	143
SDB	64	119	92
SDS	83	103	97
Grand Total	**69**	**114**	**96**

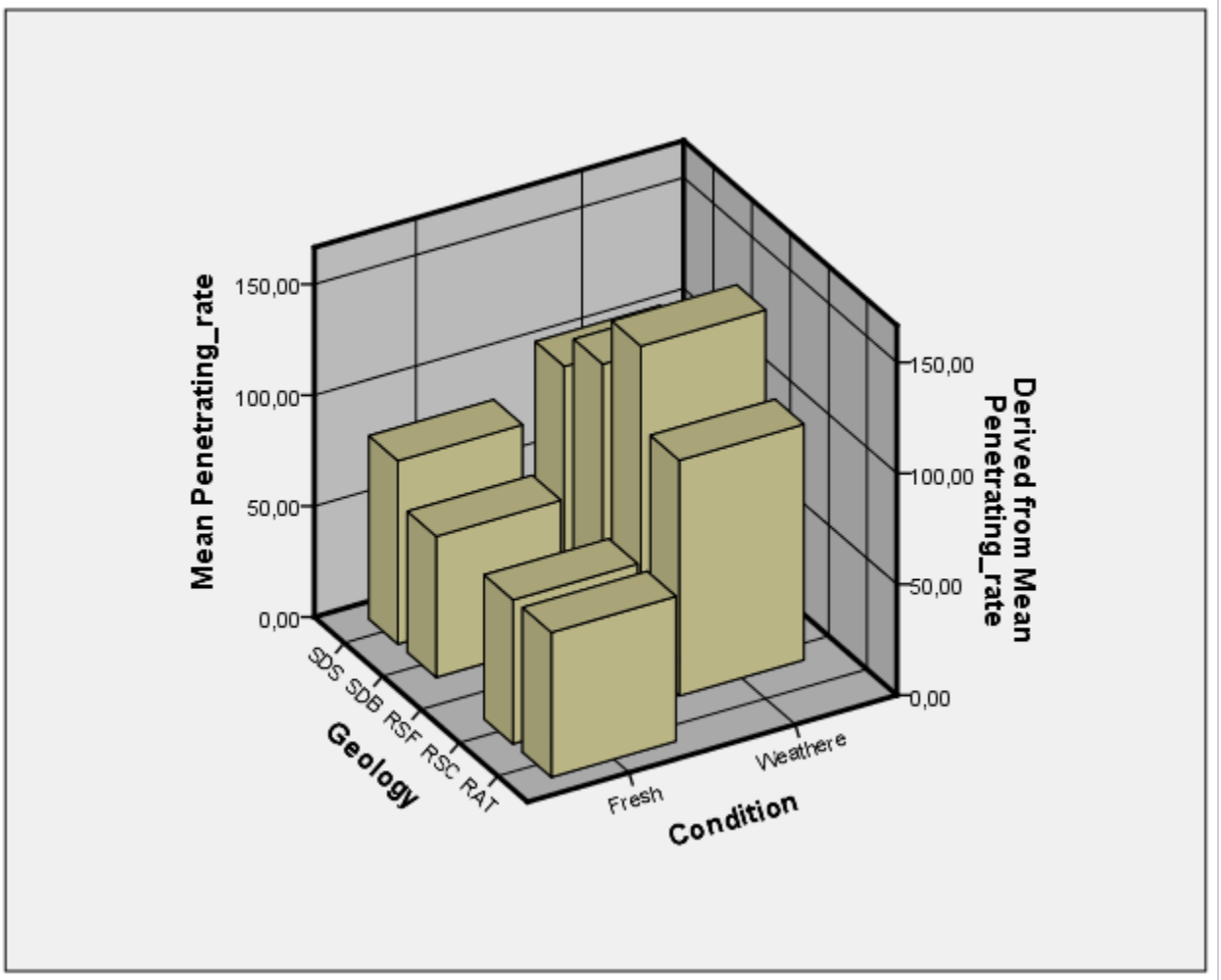

Figure 9. Penetrating Rates

Categorization of rocks in the copper belt of central Africa

The categorization of rocks in the Copperbelt of Congo and Zambia comes from the work done by the General of Carries and Mines(GECAMINES, 1976):

Table 12. Rocks Categorization from the General Quarrying and Mining

Category	Rock	French Abbreviation	Condition
2	Red earth		
2	siliceous greseuse rock	RGS	Friable
2	Cellular Siliceuse Rock	RSC	Very weathered
2	Talcose Clay Rock	RAT	Very weathered
2D	Black Ore Limestone	CMN	
2D	siliceous greseuse rock	RGS	Relatively hard
2D	Dolomitic Siliceous Shale	SDS	Black or gray
2D	Basic Dolomitic Shale	SDB	Weathered
2D	Talcose Clay Rock	RAT	Weathered and compact
3	Cellular Siliceuse Rock	RSC	Weathered
3	Talcose Clay Rock	RAT	Dolomitic
3	Basic Dolomitic Shale	SDB	Dolomitic
3	Dolomitic Siliceous Shale	SDS	Dolomitic
3	siliceous greseuse rock	RGS	Dolomitic
3	Black Ore Limestone	CMN	Homogeneous
3D	Cellular Siliceuse Rock	RSC	Dolomitic
3D	siliceous greseuse rock	RGS	Dolomitic

In this case, I am going to make the correlation with Kinsevere in the following table:

Table 13. Penetrating Rates by rocks Types

Row Labels	Average of Penetrating_rate 2
3	84,75
2D	108,81
2D-3	142,70
3D	64,91
Grand Total	**95,78**

Standard drilling

It is the comparison of drilling performances in different geologies and conditions taking into account one formation, A stable, uniformly competent ground conditions, in medium hard rock with a rock strength between 175-225 MPa, is planned to be drilled at 30.5 mph. this means that in Geology 2D, with 108.81 mph is corresponding to 30.5 mph is standard conditions. Then 1m will correspond to 0.28 m in standard condition, I have the following relationships:

2	0.21 sm
2D	0.28 sm
3	0.36 sm
3D	0.47 sm

These relationships come from the penetrating rate:

- In 2D the penetrating rate is 108.8 mph, this means that 1 meter is drilled in 0.009 h. In Standard condition, 1 meter is drilled in 0.03 h; in 2D-3, 1 m is drilled in 0.007 h; in T3, 0.011 h, and in 3D 0.015 h. Being given that 1 m in standard condition is drilled in 0.032 h, and 0.009 h is 2D. For those respective time in 2, 2D, 3, 3D; the depth drilled in standards conditions should be 0.28 m; 0;21 m;0.36m and 0.47 m. Meaning that 1 meters in 2, plus 1 m in 2D, plus 1 m in 3, and plus 1 m in 3D are equal to 1.32 meters in SD.

This means that the standard meters drilled at Kinsevere is given by:

$$SD = 0.21\,T2 + 0.28\,T2D + 0.36\,T3 + 0.47\,T3D$$

If the drill rig drilled 4 meters, 1 in T2, 1 in T2D, 1 in T3, and 1 in T3D, the total drilled depths is 4 meters at Kinsevere which are 0.21 + 0.28 +0.36 +0.47 =1.32 m in standard conditions.

Drilling at Kinsevere is in better conditions than in any recognized standard conditions.

Conclusions

Drilling at Kinsevere is done in a better condition than any place else. With the formula of standard drilling given by:

$$SD = 0.21\,T2 + 0.28\,T2D + 0.36\,T3 + 0.47\,T3D.$$

The drilling performance are:

- 142.70 mph is soft rock
- 108.81 mph in soft-medium rock
- 84.75 mph in medium-hard rock
- 64.91 mph in hard-rock

For an overall of 95.78 mph with a standard deviation of 46.17 mph, a minimum of 29.64 mph, a maximum of 367.09 mph, and a median of 93.64 mph.

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