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Approaches for Designing Extraction Methods for Randomly Occurring Pocket Formation of Gemstones: A Case of Musakashi Emerald Area, Solwezi, Zambia

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Abstract

Designing suitable extraction methods for mining randomly occurring pocket formation of gemstones has never been easy at the Musakashi emerald mine due to the limited geological information. In order to improve the productivity as well as the recovery, in this work, we undertake a detailed geological survey (airborne, surface mapping, geochemical sampling, and trenching activities), and review, analyze, and establish the appropriate extraction methods, and conduct the economic viability of the mining emeralds in the Musakashi area. A total of 51 holes are drilled in order to define the mineralization and estimate the mineral resource for the rubble ore and the in-situ ore zones using the Surpac Geovia software. The diamond drilling unravels the existence of an alteration zone enveloping the shales in an area of 150m by 100m. The emerald is localized within these reaction zones, and is estimated to extend to a depth of about 20–30m below the surface. The total mineral resource stands at 345, 290 grams for the rubble ore and 123,870 grams for the discordant veins. From the geological information obtained, a trial pit design is established with a target of increasing recovery of emeralds from the current 10 kg to 100 kg per year.

1. Introduction

Extraction of emeralds from the ground usually presents a difficult engineering problem due to the fact that unlike metallic deposits, emeralds generally occur in random pockets formations. According to Lee A. Groat, B.M. [1], the gemstone deposits are rare because the geological conditions necessary for the formation of gem-quality materials are rarely attained. Due to the random nature and occurrence in pocket formation, gemstone mining is a very complex and tedious process that requires a huge input of valuable resources such as time, workforce, equipment, and knowledge. Therefore, the entire process of gemstone mining is required to be very systematic as it costs a lot of money [2].

Traditionally, emerald mining has occurred as artisanal and small-scale mining, wherein relatively simple tools such as pick-axes and shovels are used by the individual (or small groups of) miners in order to extract the gemstones from the host rock. However, in most regions, explosives are also used to tunnel, break up the host rock and liberate the emeralds. The practice of using explosives results in a significant breakage of the emerald crystals, substantially reducing the overall recovery of emeralds of each site [3]. Anecdotal reporting suggests that 40–60% of emerald crystals are destroyed or damaged by blasting but no known studies are available to definitively determine the impact of this practice on productivity [4]. There are several methods used for mining emeralds in the words: open cast mining, terrace mining, and tunneling [5]. In addition, the manual extraction methods using simple tools such as pick and shovel are used for mining loose and semi-consolidated materials such as soil, alluvial gravels, and highly weathered rocks [6]. The majority of small-scale

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miners in all types of mineable mineral deposits, e.g. industrial materials and gemstones use this method due to the lack of capital. In the situations where rocks are relatively hard, the rocks are heated up by fire using either charcoal, ordinary firewood or even old vehicle tires. After heating, the rocks are then allowed to cool down rapidly with the use of water. This method is potentially destructive to the gemstone crystals that may be fractured in the heating and cooling process. The manual extraction methods with the use of pick and chisel are mainly applied in the situations where the use of blasting is not recommended due to the possible inducement of cracks in minerals being mined, i.e. blasting may negatively affect the quality of gemstones. The major advantage of this type of excavation is that it is relatively cheap and affordable. The disadvantages include low productivity and limitations of its application.

In Zambia, emerald mining has mainly been concentrated on the Copperbelt province. The deposits are located near the Kafubu River in the Ndola Rural Restricted Area. Emeralds have been known from this region since 1928 but significant commercial production began only in the 1970s. As of mid-2004, most of the emeralds were being mined from open-pit operations at the Kagem, Grizzly, and Chantete concessions [7]. The emerald deposits are distributed over 200 km^2 within 13°02'–13°11'S latitude and 28°03'–28°11'E longitude on both sides of the Kafubu River. The other relatively new emerald mining area in Zambia is situated in the Musakashi area, in the Chief Munjimanzovu's village. Previously, emerald mining in this area was secluded in secrecy, and was mostly done by the illegal miners. It was not until 2004 that an attempt was made by the Geological Department of Zambia to map and explore the area. The results of the field work conducted by Nguni and Mwamba [8, 9] indicated that there were very little activities being undertaken and most of the locals thought that the deposits were exhausted.

2. Case study–Musakashi emerald mining area

Zwaan etal. [9] have reported that the emeralds have a significantly different color from those found in the Kafubu area. The Musakashi stones are said to show an intense bluish green reminiscent of emeralds from Muzo, Colombia. The similarity did not end there: The most interesting characteristic was the presence in all the stones of three-phase inclusions consisting of a bubble and a cube-shaped crystal in a liquid, almost identical to those commonly seen in the Colombian emeralds [9]. Production reportedly resumed in 2006, starting with hand tools and progressing to the use of an excavator for a few months in 2009[10]. The area produced about 15–20 kg of emeralds from its discovery through late 2010. Pridegems Mines Limited has since been granted a small scale mining licence to mine the emeralds in the Musakashi area (Figure 1).

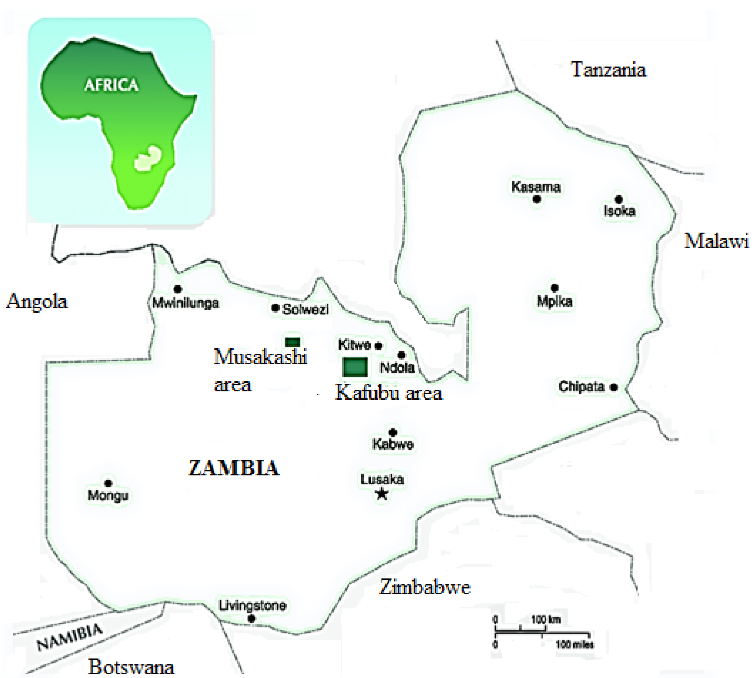

Figure 1: Geographical location of Musakashi emerald deposits.

The future of the mining area lies mainly on the application and effective implementation of the mining methods that should generate a profit. Having been in operation for about 2 years and a half, the operations have a production rate of slightly below 10kg per year of gemstones from approximate depths of 0 to 15 m below the surface. This has made the mining operations uneconomical in terms of costs and returns. Unfortunately, this situation now creates a great threat to the sustenance of the project as well as the livelihood of the locals, consequently bringing in the urgency to increase recovery of production with a bid to salvage the operation over and above the operating costs. The scanty geological information of this area reveals that these precious stones have weathered shales as the major host rock and that they occur in highly randomized pockets. As stated above, the characteristics of this ore body have never been established due to the lack of technical geological information. In addition, the mining area has no record of mechanization. Previously, the conventional methods were used and applied by the existing artisanal miners by use of picks, shovels, and hand-held hammers as well as chisels in the extraction of gemstones. As expected, this led to longer 'dry spells' in regard to gemstone extraction and realization. Therefore, the extraction methods were deemed unsustainable and unprofitable for gemstone mining.

3. Problem statement

Due to the absence of geological information for this region in relation to gemstones, the generation of ore body characteristics (such as thickness of mineralization and dip) has not been undertaken explaining the lack of technical information. Additionally, there is no record of mechanization prevalent in the area because the artisanal miners in the past used the conventional methods (picks, shovels, chisels, and hand-held hammers) for searching and extraction of gemstones. With a bid to implore mechanization as a way to increase and improve productivity as well as recovery, Pridegems Mines Limited has since acquired the mining rights for bulk extraction and eventual recovery. However, the mechanized mining currently implored has faced an economic viability challenge because the cost of the operation at present is more than the recovery of emeralds. In this work, therefore, we seek to come up with better extraction methods in line with the challenges encountered and highlighted above so as to profitably sustain the mining operations. This work will also show the importance of linkage between the pit design and extraction methods in emerald mining based on the geological information.

3. Geology of area

3.1. Local geological setting

Locally, medium to fine grained grayish black shales underlie the tenement area. Near the surface, the shale formation exhibits reddish brown coloration due to weathering of the rocks. A light green shale is noted in places. The shales are overlain by a gravelly laterite and soil capped with quartz fragments that range from poorly sorted to well-sorted rounded pebbles in places. The rocks have a northeast-southwest strike with bedding dips ranging from 15 to 20 degrees southeast. Two types of fractures are noted. The main one runs ENE-WSW, while the minor one runs WNW-ESE. The fractures are very steep and sub-vertical. The emplacement of the quartz-feldspar-limonite-magnetite-tourmaline veins/veinlets into the country rocks seem to have been controlled by the fracture patterns noted in the area. Hydrothermal fluids rich in Beryllium (Be) silicate melts have since crystallized as quartz-feldspar-limonite-tourmaline assemblages. Preliminary observations show that these are the feeders of emerald mineralization in the area.

The quartz-feldspar-magnetite/limonitic veins and veinlets that are the source of hydrothermal fluids rich in Be have been targeted in the study. These veins/veinlets cross cut with the Cr/V bearing shale rock and alter the shale in order to form a cream alteration band of varying types of mica and clay. Emeralds have been noted to grow in these alteration zones within the mica foliations. The micas range from being muscovite rich to green type, fuchsite. Emeralds have also been reported to grow within the quartz bodies.

The reported stones reveal good quality in terms of color and clarity. During the current prospecting stage, illegal trenching in the Kabangu area that is about 15km northeast of Musakashi area recovered some small emerald pieces from the contact rock material of quartz veins and the surrounding host rocks. The host rocks are believed to be metagabbros, while the contact rock is generally altered into different forms of micas. The information gathered at Kabangu does indicate that the source of Cr and V necessary for emerald formation could possibly be linked to the metagabbroic host rocks found in the area (see Figure 2). This type of occurrence has been observed in the emerald occurrence of Panjsher in Pakistan. The Be source is by and large related to the hydrothermal quartz vein lenses, dykes, and sills. This could have happened in the Musakashi area, where the intermediate and acid igneous intrusive rocks have left an effect of hydrothermal activity.

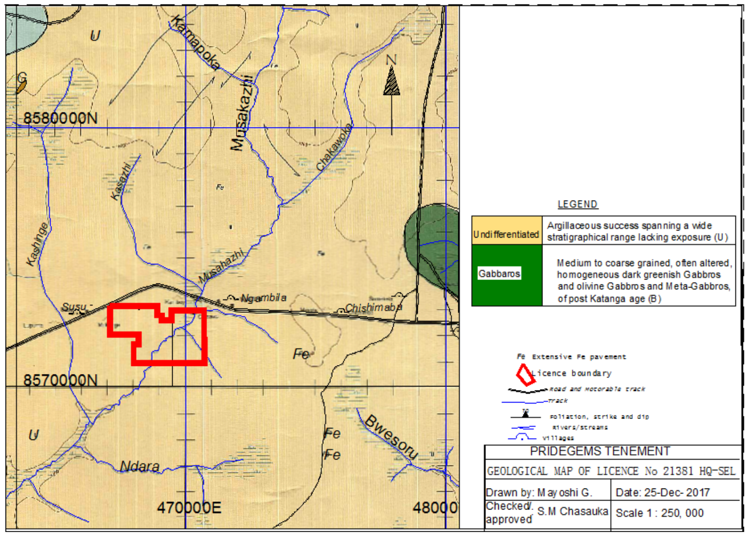

Figure 2. Geology of studied area.

3.2. Nature of deposit(s)

The emeralds generally occur in random pockets. The profitability of such a deposit is highly dependent on the concentration of gemstones (per tonne of rock) and the weathering stage of the host-rock [11]. At the Musakashi Mine (see Figure 3), the contact zones mostly range from 1 to 5cm. Therefore, any form of exploration without exposure has a very low probability of telling the true story. Vincent Pardieu etal. [12] have also noted that the geological origin of the emeralds in the area is not clearly understood and that it is difficult to evaluate the potential of the deposit. He recommended that a serious geological survey was necessary to confirm whether this deposit was of economic interest, and to assess if the Musakashi area could, one day, become an important source of emeralds for the trade. Jose A Puppim de Oliveira [13] has also highlighted that the emerald occurrences in Brazil are very concentrated in small pockets, like in the case of Bahia. Since the mine design is mainly based on the geological data, it becomes very difficult and almost impossible to implore any form of design techniques as required by the engineering principles of mining.

Figure 3. Production contact point, Musakashi (Photo by: Joseph Manyepa-2019).

Therefore, if any designs of extraction methods as well as mining sequences are to be derived at the Musakashi mine, it has to be with the progression of the mining activities and analysis of the previous exposure methods implemented within the area. Consequently, documentation of the mining progression as well as the geological data gathered were used to design and propose the extraction methods as well as mining sequence in this work.

3.4. Host rock type

The host shale rock is a dark grey black rock; the altered equivalent is altered by bleaching it to a cream yellow-red band with different types of mica at the contact of the quartz vein and the shale. The shale with pre-requisite chromium/vanadium is necessary for the green pigmentation of the emeralds. The protolith of the shale is sedimentary. These intrusive bodies could be of Pan African Orogenic event with an age of 600-500 Ma, and are part of the Lufilian Arc activity. Gemologically, these emeralds have been likened to the stones from Chivor in Colombia and Panjsher in Pakistan.

Broadly speaking, the sediments have undergone a degree of metamorphic recrystallization, although in the case of the quartzite rocks, this has not been sufficient to destroy the sedimentary micro– and macro-textures. The most common metamorphic minerals are biotite, chlorite, tremolite, talc, sericite, and albite. This assemblage indicates a metamorphic grade in the Greenschist Facies. There is some variation in grade from the quartz-albite-epidote-biotite sub-facies in the more highly deformed areas to the quartz-albite-muscovite-chlorite sub-facies in the less deformed rocks.

4. Methods and materials

4.1. Approaches for selecting and designing extraction methods for emeralds

Scientific literature on gemstone mining and mine reports were reviewed in order to appreciate different extraction methods and the previous mining methods used in the Musakashi mining area.

4.2. Exploration program

The exploration program by drilling was conducted over the tight grid using the niton analyzer in order to generate a tentative picture of the lithological status for the area.

4.3. Diamond drilling program

A total of 51 diamond drilling boreholes were drilled in the central part of the tenement. The target depth was approximately 50m.The drill hole spacing was sited at 30-35m apart so that the ore could be delineated clearly. The 150m strike extent was covered and eventually investigated for any potential emerald occurrence. The preliminary mineral resource quantification (estimation) for an economical assessment on the potential for mining was reviewed using the collected data.

4.4. Geological core logging

The Wire line method was used in order to retrieve the core from the hole. Aluminum trays with marked borehole numbers were utilized on site for every core recovery. Plastic core blocks were marked using an indelible ink indicating the drilled depth, core drilled, and core loss.

4.5. Design of extraction method

This was done in the following order: generating the geological model, designing the proposed pit, and conducting an economic analysis of the proposed extraction method.

5. Results

5.1. Surface mapping, geochemical sampling, and trenching

The targeted area of concentration for surface mapping, geochemical sampling,and trenching activities are indicated in the yellow circle in Figure 4 on a 50m by 50m tight grid, consisting of 1,156 sample points. The remaining area was further split into two grids: the first target area was 0.625km X 1.20km with 650 sampling points, while the second target area was 0.55km X 1.35km with 504 sampling points. The samples were analyzed using the XRF niton machine. The following distribution of mineralization was observed: faults and fractures; quartz limonite; quartz veins, and stock works.

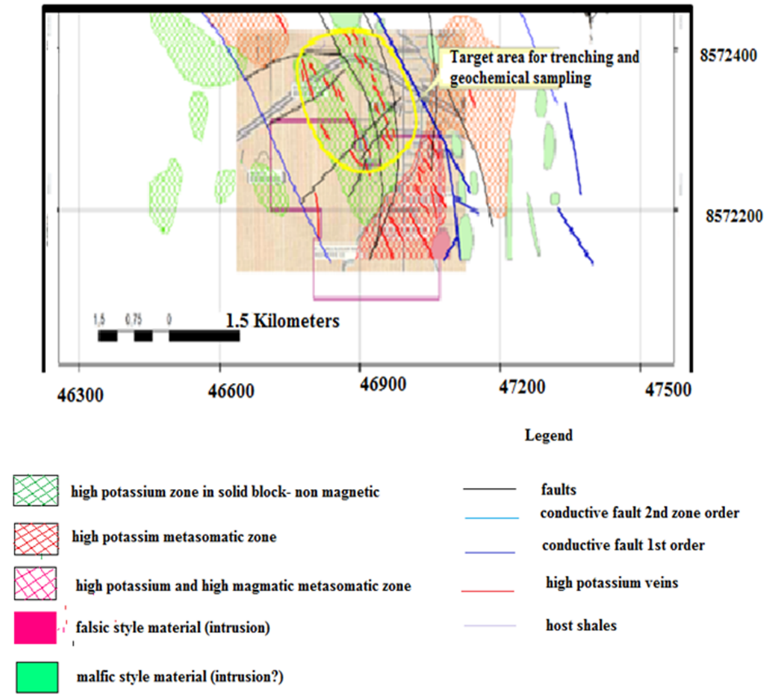

Figure 4. Airborne survey results on Musakashi mine area (September 2019).

Out of the 1139 samples analyzed, the following observations were made and recorded:

- 18 samples analyzed were below 4000 ppm (1.6% of 1139 total samples)
- 385 samples analyzed were between 4000.1 and8000 ppm (33.8% of 1139 total samples)
- 334 samples analyzed were between 8000.1 and12000 ppm (57.9% of 1139 total samples)
- 18 samples analyzed were between 12000.1 and18283.96 ppm (6.8% of 1139 total samples)

5.2. Diamond drilling program

Figures 5, 6, and 7 show the plan views of the drilled borehole collars, trenching, and in-situ veins and gravel outline against pit outline, respectively. In total, 51 boreholes were drilled in the central part of the tenement. The target depth was approximately 50 m, while the strike length was 150 m.

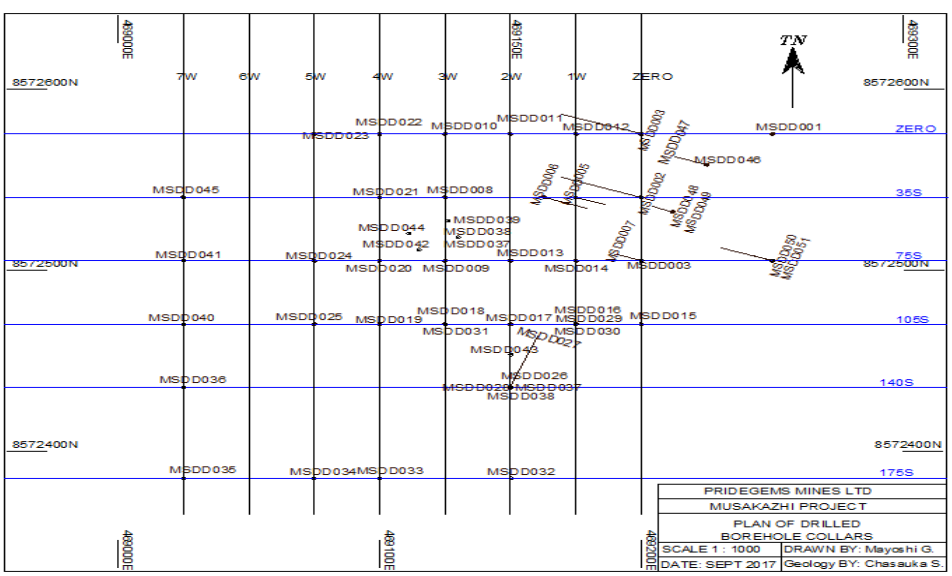

Figure 5. Diamond drill boreholes at Musakashi area.

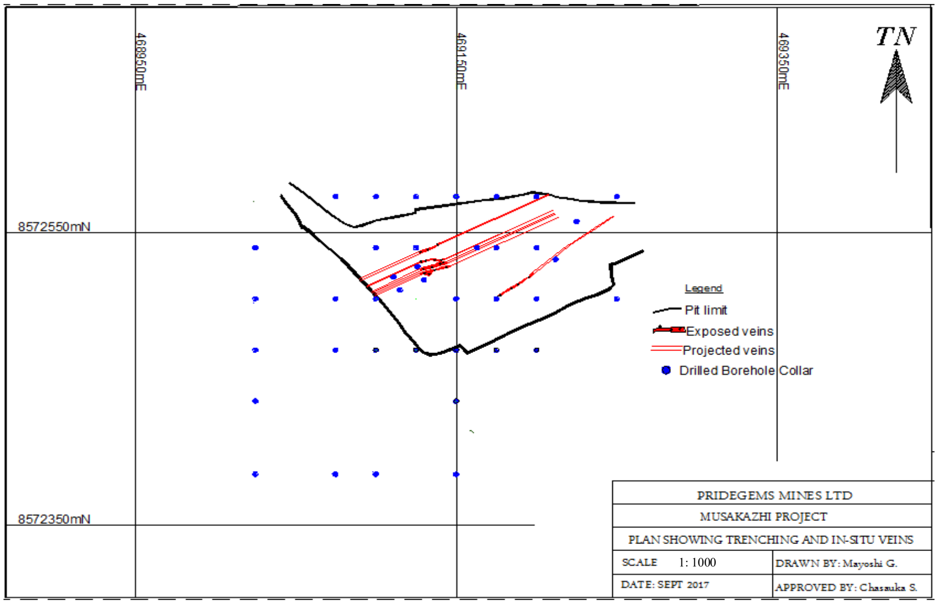

Figure 6. Plan showing projected in-situ quartz veins.

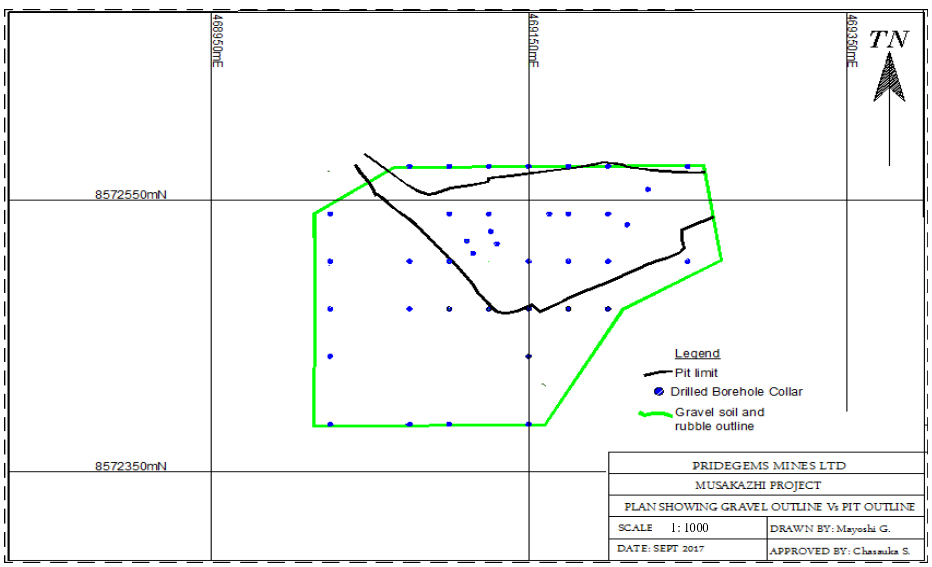

Figure 7. Plan showing rubble ore distribution.

The diamond drilling works highlighted the following:

- The rubble emerald zone was confined in the quartz-gravelly laterite capping.
- Minor fragments of emeralds randomly occur in the gravel.
- Trenching and washing of this material has resulted in the recovery of some stones.
- Drilling has intersected thin quartz-feldspar-limonite veins/veinlets intruding the in-situ weathered and fresh shale units.
- The veins are very steep with a dip of about 80 degrees towards the south. The contact of the vein and the host shale has been altered into a cream colored zone.
- The emeralds have been noted in this alteration zone.

The Musakashi deposit has revealed a series of thin veins and veinlets running E-W and minor trends of N-S.

The host rock has a NNE-SSW strike with shallow dips towards the SSE direction.

5.3. Mineral resource estimation

The Mineral resource estimates for the rubble ore and the in-situ ore zones were computed using the SURPAC GEOVIA software following the establishment of emerald distribution and mineralization. Anisometric view of the *insitu* veins is shown in Figure 7.The sections containing the in-situ ore zone were digitized, and the ore body solid generated. A modest concentration factor of 10g/m^3 was assumed in the in-situ ore zone, while in the rubble, it was estimated at 5g/m^3, as shown in Table 1.The sections for the rubble horizon were also digitized, and a total volume of 69,058m^3 was generated.

Table 1. Estimated mineral resources.

Material	Volume (m^3)	Concentration factor (g/m^3)	Contained emeralds (g)
Rubble ore	69,058	5	345,290
Discordant veins	12,387	10	123,870
Total	81,445		469,160

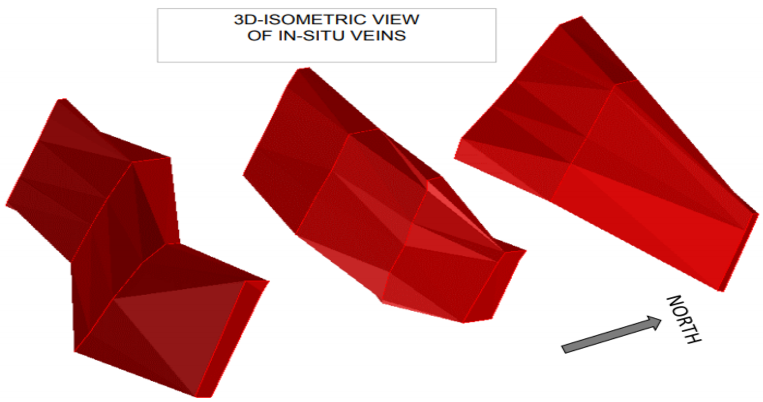

Figure 8. An isometric view of in-situ veins looking west.

Table 2 presents a report from the Surpac software in order to confirm and validate the solid created for the isometric view of the in-situ veins as well as the consequent data generated and represented in Table 4. Figures 9 and 10 show the dip section zero and dip section 70S, respectively.

Table 2. Solid modeling object report (Layer name: insitu-veins.dtm).

Trisolation	Status	Location	Extent		Surface area (m^2)	Volume (m^3)
			Minimum	Maximum		
		X	469100.100	469175.270		
1	Solid	Y	8572497.634	8572509.616	3,750	3,979
		Z	1183.116	1208.164		
		X	469099.916	469175.270		
2	Solid	Y	8572528.983	8572545.999	3,786	3,219
		Z	1182.458	1208.958		
		X	469100.106	469175.284		
3	Solid	Y	8572457.856	8572480.982	4,023	5,189
		Z	1181.432	1206.068		
Total					11,559	12,387

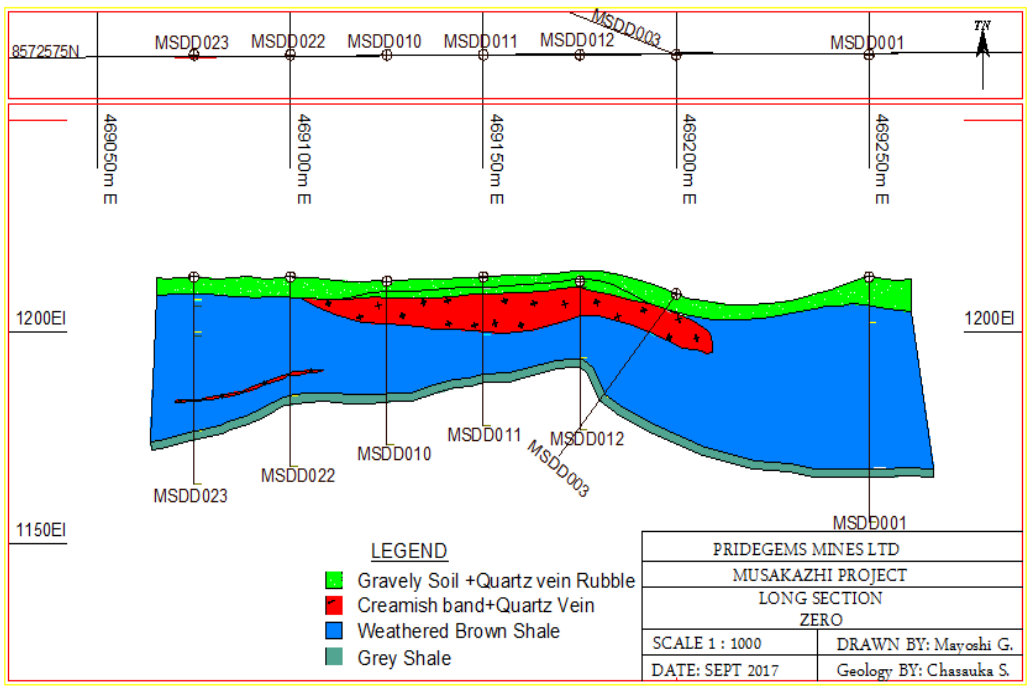

Figure 9. Dip section zero.

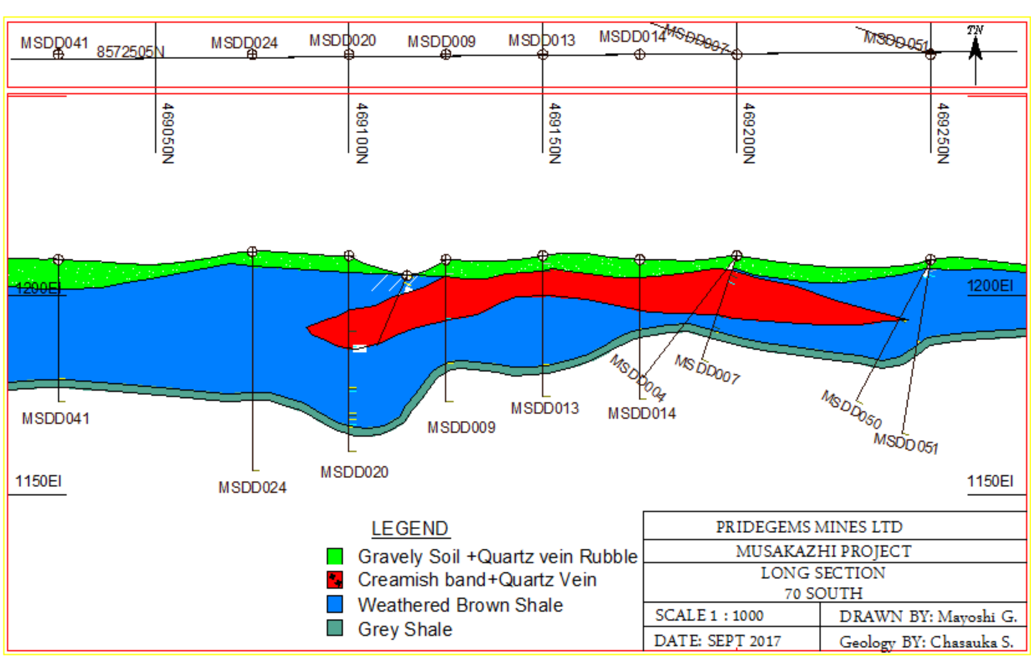

Figure 10. Dip section 70S.

Based on the geologic information obtained above, a near surface trial open pit design (Figures 11 and 12) was proposed with the parameters as set in Table 3.

5.4. Economic analysis of proposed extraction methods

Two aspects were conducted in order to ascertain the viability of this work:

a) Increasing production from 10Kg to 100Kg of emerald recovery per year

This aspect was established based on the analysis of the designed pit and the geological model. The approximated average concentration factor of 7.5g/m^3 is expected to yield 469,160 g of emeralds within the designed pit. With the blended extraction method of pit works as well as washing plant recovery having been proposed, it means that at the mining rate of 50,000 tonnes per month, the designed pit would be exhausted within a period of 22 months or 1 year and 10 months. This further implies that an average recovery of 21,325.45 g (equivalent of 21Kg) per month will be expected to be recovered. This translates into an average recovery of 255, 905.45 g (equivalent of 256 Kg) per year which is twice the desired emerald recovery as per project study.

b) Reducing cost of operation

In order to establish this aspect, the average cost of production incurred over the past year (Table 4) was used, and then compared with the projected cost of production for the first year of executing the designed extraction methods, as proposed in this work. The tonnage output for 2019/2020 is shown in Table 5.

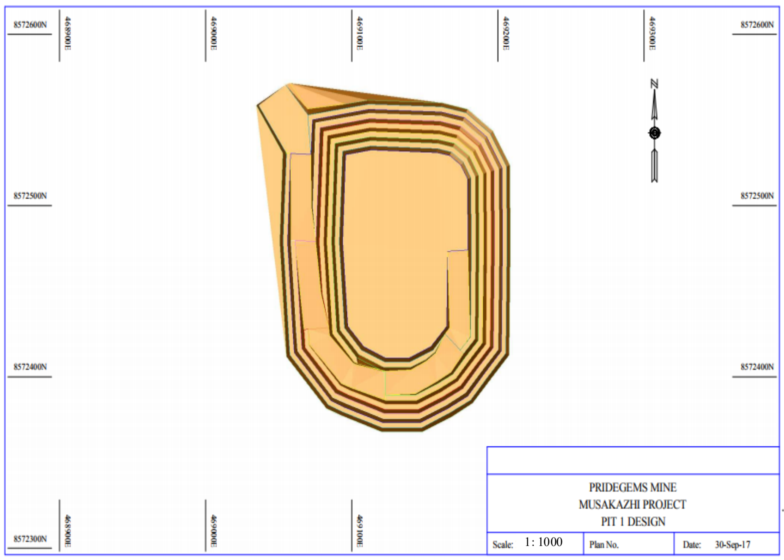

Figure 11. Idealized proposed pit design.

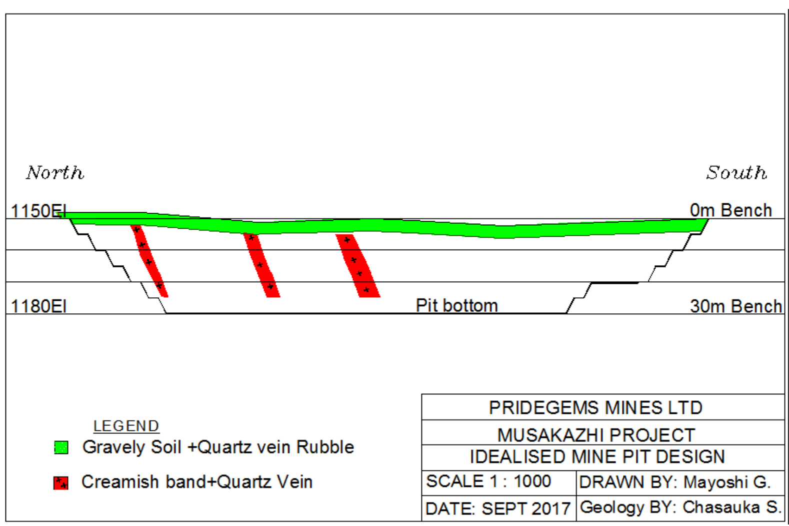

Figure 12. Idealized section for the proposed pit design.

Table 3: Pit design parameters.

Pit depth (metres)	Volume (Cubic metres)	Tonnage (tonnes)	Bench			Ramp gradient
			Height	Width	Angle	
30m	450,000m^3	1, 100, 000	5m	3.5m	60 degrees	10%

Table 4. Previous year cost and consumption.

	Cost of production from July 2019 to July 2020	Fuel consumption from July 2019 to July 2020
Total cost	$ 2,761,488.07	538,985
Average cost	$ 230,124.01	44,915.42

Table 5. Previous year tonnage output.

	Tonnage Output from July 2019 to July 2020
Total Tonnage	865,117
Average Tonnage	72,093.08

5.5. Projected cost of production for proposed extraction methods based on previous cost profile

Based on the analysis of the cost profile for the previous year, the major parameter of assessment becomes the tonnages to be moved per month. From Table 6, the average cost per tonne moved was pegged at US$ 4.05. Since the planned tonnage to be moved per month for the proposed extraction methods is 50,000 tonnes, It follows that the projected monthly cost for the proposed extraction methods is 4.05 x 50000= US$ $202, 500. Comparing this figure with the average monthly cost for the previous year of US $230,124.01, the proposed extraction methods is projected to have a cost reduction of US$27,624.01 per month implying a total cost reduction of US $607,728.22 over the 22 months. Reduction in the production cost is also attributed to the reduced number of equipment to be used (see Table 7). The reduction of mining equipment by half is likely to translate into a corresponding reduction of fuel consumption by half as well.

Table 6. Cost comparison of dollar and fuel per tonne.

	Cost Comparison from July 2019 to July 2020
Average Kwacha per tonne (ZMW/t)	$ 4.05
Average fuel per tonne (L/t)	0.67

Table 7. Comparison of equipment in use and proposed to be used.

Existing equipment in use		Proposed equipment to be used	
Description	**Quantity**	**Description**	**Quantity**
Excavators	4	Excavators	2
Dump trucks	6	Dump trucks	3
Front end loader and drilling machine	1 each	Drilling machine	1
Grader and bull dozer and water bowser	2 each	Bull dozer	1
Diamond drilling machine andTLB	1 each	Diamond drilling machine	1
Light vehicles	16	Light vehicles	8

6. Discussions

In the Musakashi emerald area, the shales offer a favorable host for emeralds due to the rich melt that has scavenged chromium from the shale into the resultant beryl. Where the beryl is green and transparent, this has resulted in the deposition of high grade emeralds. The thickness of the zone ranges from the centimetre to the meter size. Pockets, stringers, and pods of emeralds occur in the altered zones in a pinch and swell nature. Furthermore, the Musakashi deposit has revealed a series of thin veins and veinlets running E-W and minor trends of N-S. The host rock has a NNE-SSW strike with shallow dips towards the SSE direction.

Based on the emerald distribution and mineralization, the mineral resource estimates for the rubble ore and the in-situ ore zones were computed using the Surpac Geovia software. The establishment of resource estimates formed the basis of mine design. It should be noted that prior to undertaking this work, extraction of gemstone in the area was not guided by the resource estimation. As a result, emerald extraction was done through trial-and-error mining. The geological survey (airborne, field mapping, and geochemical soil sampling) conducted was, therefore, necessary to confirm the economic viability of the Musakashi area.

A blended approach of extracting emeralds in the Musakashi emerald area was, therefore, proposed based on adequate geological information. The extraction method will include the use of mining equipment such as excavators for excavating and loading, dump trucks, and tippers for hauling the material to processing plant(s) or waste dumps as well as hand-held tools like picks and shovels at the production points. The use of hand-held tools will be limited to the already exposed targets, while application of mining equipment will be concentrated in areas meant for exposure. Two excavators and three trucks will be used for loading and hauling, respectively. The mine plan design has an estimated mining rate of 50,000 tonnes of material per month. The use of equipment will solely be for the stripping of top waste material for the purpose of exposing the contact points of interest. Once these points are exposed, the chisel men will move in with the hand-held chisels picks shovels and hammers for close inspection and hand-picking once the production is seen. The material from these production points will then be loaded and hauled to the stockpiles for processing through washing. In order to speed up the recovery for spread of revenue, massive washing will be required and implored through the washing plant. It is expected that more material will go to the washing plant stockpiles as compared to the wasted dumps. The extraction process at the washing plant will be done by water only. The material will be cleaned via a tumbler (trammel), primary screen, and secondary screen. Thereafter, the material will be sorted by hand on two separate belts by the sorters.

7. Conclusions

The extraction methods previously used in the studied area for mining randomly occurring pockets of emeralds were reviewed. It was discovered that since 2002, the emerald mining area was associated with illegal mining activities and legalized artisanal mining as well as semi-mechanization in which seasonal mining was practiced with works being abandoned in most rainy periods. Whereas the previous methods only implored hand-held picks and shovels, the current method implores sizable excavators and hauling equipment in the form of dump trucks and tipper trucks to expose the areas of interest. However, the existing extraction methods have faced viability challenges resulting from low production and production cost escalation. In order to address the above challenges, the design of the proposed extraction methods has been done based on the following approach:

The geology of the area has been re-defined by conducting an airborne survey of the area and drilling holes using diamond drill CS10. The diamond drilling has unraveled the existence of an alteration zone enveloping the shales in an area of 150m by 100m. The alteration zone is due to the reaction of the near vertical thin feeder quartz veins cutting through the rock units in the east-west direction, and is steeply dipping towards the south. Emerald mineralization has been localized within these reaction zones, and is estimated to extend to a depth of about 20-30m below the surface. Definition of the area has resulted in the establishment of the geological model. The geological model established has an expected approximate recovery of 469,000 g of emeralds.

Based on the analysis of information from the unconventional extraction methods implored previously as well as the technical knowledge derived from the drilling activities undertaken at the mine, a blended approach has been proposed, and a trial pit has been designed, in which mechanization will be implored to a degree that fits into the economic model, while the traditional methods of using hand-held tools will only be applied at a point of production for purposes of maximizing recovery of the product desired, thereby confirming the existence of an economic emerald body.

The economic viability exercise conducted indicates that the proposed extraction methods, once implemented, will increase the production recovery from the current 10kg per year to a minimum of 100 kg per year, and this should be within a depth of 0 to 35 m.

8. Recommendation

This work recommends that further works should be directed on the formation and quantification of emeralds so as to increase the confidence levels for any future mining project.

Acknowledgments

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رویکردهای برای طراحی روشهای استخراج تصادفی سنگهای قیمتی: مطالعه موردی از منطقه زمرد موساکاشی، سولوزی، زامبیا

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چکیده:

طراحی روشهای استخراج مناسب برای استخراج تصادفی سنگهای قیمتی در معدن زمرد موساکاشی به دلیل اطلاعات محدود زمین‌شناسی هرگز آسان نبوده است. به منظور بهبود بهره‌وری و همچنین بازیابی گوهرها، در این کار، یک بررسی زمین‌شناسی دقیق انجام شده است (هوابرد، نقشه برداری سطحی، نمونه برداری ژئوشیمیایی و فعالیت‌های ترانشه‌ای) و به بررسی، تجزیه و تحلیل و ایجاد روشهای استخراج مناسب و اجرای اقتصادی معدنکاری زمردها در منطقه موساکاشی پرداخته شد. در مجموع ۵۱ گمانه اکتشافی به منظور شناخت کانی سازی و برآورد منابع معدنی و مناطق معدنی در محل با استفاده از نرم افزار Surpac Geovia حفر شد. با استفاده از حفاری با مته‌هایی با سرمته الماسی یک زون آلتراسیون شیل به ابعاد ۱۵۰ در ۱۰۰ متر پیدا شد. زمرد در این مناطق آلتراسیون قرار دارد و تخمین زده می‌شود که تا عمق ۲۰ تا ۳۰ متری زیر سطح امتداد یافته است. مجموع ذخایر معدنی عبارت است از۳۴۵۲۹۰ گرم برای سنگ معدن و ۱۲۳۸۷۰ گرم برای رگه‌های پراکنده است. بر اساس داده‌های زمین شناسی به دست آمده، طرح گودال آزمایشی با هدف افزایش بازیابی زمرد از ۱۰ کیلوگرم فعلی به ۱۰۰ کیلوگرم در سال ایجاد شده است.

کلمات کلیدی: روش‌های استخراج، معدن مکانیزه، مدل زمین‌شناسی، تشکیل توده سنگ‌های قیمتی، بازیابی زمرد.