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Concept Paper on Shaft Sinking of the Mine "Trepca" in Stanterg New Horizons XIth to XIIIth

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Abstract: The purpose of this paper is to calculate the expenses for shaft sinking below horizon XIth and exploitation fronts in deep horizons of Trepça Stantërg lead and zinc mine and to evaluate on a conceptual basis if a shaft is most suited for underground access requirements from horizon XI to XII which is located on above sea level 15.20m to -45.20m. Even the existing shaft is built until horizon XI there is high water in-flow on the depth, which would prevent the continuation of the shaft construction. This paper was focused on the construction cost and schedule differences of shaft deepening that is currently the most typical access alternative used currently. According to the literature, there are several methods that can be used but no clear answer to state that one method is better because it depend on the ground situation and circumstances. Several different conditions will be assessed in order to find the degree of sensitivity of methods, in particular, comparison of the construction cost and schedule or sinking a shaft. This practice could be experienced in other similar mines as well.

***Keywords**: shaft, mining, construction, horizon*

Introduction

Mine Stanterg currently exploits ore bodies above the XIth horizon. These ore reserves are significantly exploited; therefore next in depth horizons should be prepared for exploitation. Current planning is the development of new horizons XI and XIII which are 60m, 120m respectively below the mine foundation. There are two technical alternatives to deepen the mine:

The traditional method in this mine is subtracted (continued at depth) transport in a shaft in order to use existing equipment, hoisting machine in the lower horizons. The alternative is to develop descending ramps which would allow two functions; transportation of people and current equipment, ore cage and skip. This situation is symptomatic for many deep mines that were operating for many years. This problem was analyzed in each mine in the world separately because of the specific conditions; however, some similar examples could be used. However, even new machinery is used in developed countries to open the shaft by large drilling machinery, as described in a featured article by Burger et al. (2010), in our case we are planning to use an old existing method. The decision was based on the economic benefit of the mine, which option would be most profitable in the long perspective.

Comparison was made using three different components:

- Capital investment in mine equipment
- Capital investment in transport of infertilities materials, and
- Appropriate period to introduce new operating system (normal work).

Stari Trg mine is old mine, but shaft installations, hoisting machine, ventilation facilities etc were outdated models and inadequate compared to modern mining standards. It would be necessary that this equipment could be verified in connection with the development program toward XI and XIII horizons. In this paper detailed assessment is not performed, since the requirements would be similar for both alternatives; the shaft or ramp.

The Technology of the Shaft Construction

On the year 1953, the Management of the mine set to open new shaft from the surface, deepening to the level of the horizon IX. The new shaft was opened to the ceiling of the ore body, and at the same time opened (blind shaft) from horizon Vth to horizon Xth. From blind shaft were developed Works in opening new horizons, developing the main corridor and by opening water accumulation and water

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pumping facilities. In this way, two by two new horizons were opened (VIIIth and IXth in one cycle and the Xth and XIth in the next cycle).
In Figure 1 are given sketches of the opening of the mine "Trepca" in Stanterg.

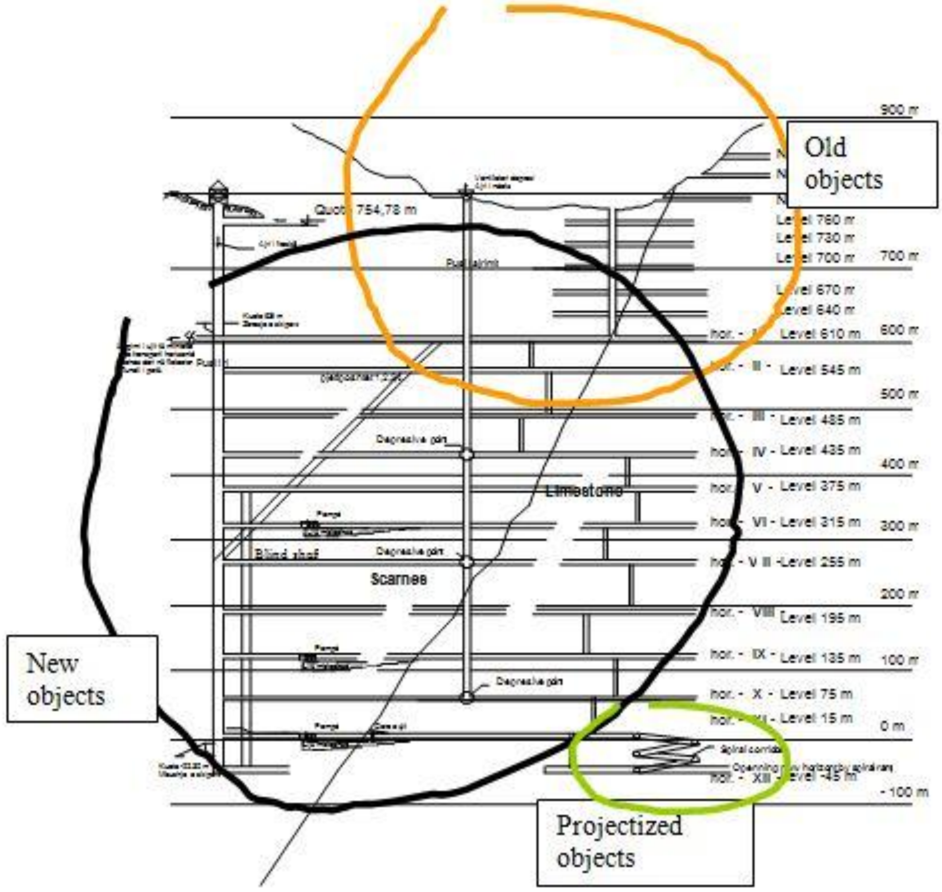

Figure 1. Scheme of the mine openings in Stan Tërg mine

Current situation

The current situation in the mine is as follows:
The main shaft extends to the XIth horizon depth, which is the ultimate level of infertile and ore transportation. Not far from the main shaft, the blind service/shaft, this serves to transport men and material from the horizon IXth to horizon XIth. The blind-servicing shaft can be adapted in depth, but in this case, the main shaft could be modified to transport men and material. The ventilation shaft is located some 300 meters from the main shaft but extends only to the horizon Xth and should achieve horizon XIth to air the space and mechanized mining part. Service shaft in the north is located away from the mine in a distance of 1,500 m from the main shaft. The ability to move materials from digging works and objects deepening of XIth to XIIIth horizons and ventilation facilities should ensure the development of downstream unobstructed horizons (Walters, 2009).

For the following review is considered that the establishment of barren material through the main shaft will be done by skip from level XI. Fresh air is estimated to be flowing to the rest of shaft, or alternatively through the ramp and head towards horizons XI and XIII (Walters, 2009).

A shaft is a vertical object which is opened from the surface and has a cross-section of 5,5m and contains the entire basic infrastructure including two cages for people, two skips to transfer the ore, passing for emergency exit and space for placement of water pipes and compressed air and for filling material for mining spaces. It is important to note that there is still free space for additional pipelines and other infrastructure (Feasibility study, 2006).
The shaft volume that can be taken is as follows:
Cage for men has two floors with 12 + 1 and 12 people can occupy i.e. 25 people.
Skip has the volume around 2 m3 or 5.5 t.

They move depending on each other as one is downloading by the surface the other is loading in depth. The speed of movement of the cage for people is limited to 4m/sec. Skip speed is 13 m/sec. The new shaft should be opened by the blind shaft and has very small size and lacks all the elements that have the main shaft, has a cage and a counterweight and very little space for water and compressed air. Figure 2, shows schematic view of the main shaft in mine:

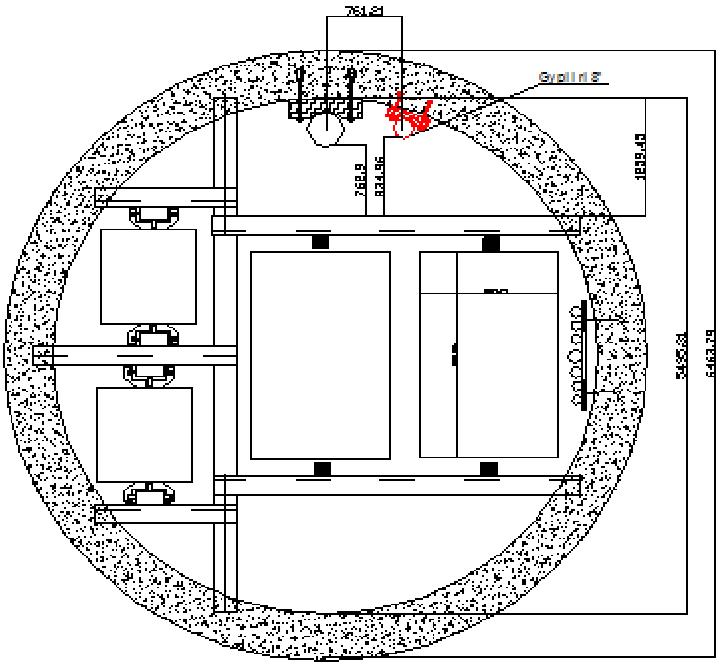

Figure2. Cross section of the main shaft

Stages of opening or deepening A horizon

Stages of deepening the shaft are presented as follows:

The first stage involves the deepening of the shaft and then work is beginning on opening new horizons i.e. horizontal work on opening new horizons as explained by Brock & Wooton (2000). The second stage involves work on continuing to open new horizons separately. Despite those opening new horizons opened shaft –is sinking from the top - down, the deepening of the blind shaft to the extent of opening new horizons.

The third stage- once the blind shaft is continued by horizontal corridor toward the center of the main shaft, which will be used in opening the main shaft. The fourth Stage is opened by a small scale stack, down - up with advancement to the upper horizon. Then by boreholes around stack and blasting, it would be expanded. As mined material falls down through the blind shaft, and mined material removed, and simultaneously continuing support with concrete from the top-down.

Capital investments for opening by classic method deep horizons through shaft

From the archive of the mine, we found that the opening of the main shaft from IXth horizon to horizon XIth was cost around $ 5,333,300, which was realized in the year 1980-1983. Given those parameters, our calculations show that capital investments for opening the shaft by classical method between horizons XI-XII are presented in the following Table 1:

Table 1. Expenditure for the opening of the blind shaft

Expenses for the opening of the corridor embracing	23,724
Workforce	160,200
Wage per night	16,020
Total	199,944 €

Time for deepening blind shaft:

The shaft should be deepened from the horizon XII - quotes "-45 m" to the horizon XIV - quotes "-170 m", *i.e.* 125 m).

The global schedule for carrying works includes 6 shifts and progress of works is 1.6m for a cycle. Number of cycles to deepen the shaft:

$$N_{CTHP} = \frac{H_p}{P_C} + 2 \bullet P_{sh} = \frac{125}{1.6} + 2 \bullet \frac{20}{1.6} = 78.125 + 25 = 102{,}125\,\text{cycle}$$

$$N_{shift} = N_{CTHP} \cdot Nd / cycle = 102.125 \cdot 6 = 612.75 \text{ shifts}$$

$$\text{Working days} = \frac{N_{shift}}{3} = \frac{612.75}{3} = 204.25\,\text{days}$$

Main corridors facilities for links with opening and main objects such as blind shaft and main shaft

From blind shaft to the pump station and to the main shaft and corridors that will be used for communication around the shaft, and water basins until the completion of the main corridor that has a length of 640 m with 3x3,2m cross section. The expenses for opening main korridore are shown in Table 2

Table 2. Opening of the corridor

Explosives expenses	68,680
Expenses for machines and consumables	46,990
Corridor Anchoring	202,000
Work force	948,000
Wage per night	94,800
Total	1,360,470€

The duration of the opening of this corridor is:
The global works schedule includes 4 shifts and progress of works in a cycle is 1.6m.
The number of cycles in the opening corridor is:

$$N_{CTHP} = \frac{H_p}{P_C} + 2 \bullet P_{sh} = \frac{640}{1.6} + 2 \bullet \frac{20}{1.6} = 78.125 + 25 = 425\,\text{cycle}$$

$$N_{shift} = N_{CTHP} \cdot Nd / cycle = 425 \cdot 4 = 1700 \text{ shifts}$$

$$\text{working days} = \frac{N_{shift}}{3} = \frac{1700}{3} = 566\,\text{days}$$

Duration of shaft sinking is 1.6 years

Main shaft

The main shaft begins to open from the central construction site and the advance from the up-down. Originally there is opened a narrow space in the size of the stack dimension 2.5 x 2.5 m to the exit of the existing shaft, then begins the expansion of the existing shaft with bore holes drilled and mined around this space and by gravity the mined material goes down through ore pass and is loaded. The shaft will be deepened from the horizon XII (after it is opened) to the horizon XIV, means 5m below the horizon in the distance 120m.

Opening the ore pass stack 2.5 x 2.5 m

Table 3 shows the expenses for opening the stack:

Table 3. The expenses of stack opening

Stack opening expenses	33,562
Workforce	33,120
Wage per night	3,312
Total	69,994 €

The duration of the stack opening is:

The global schedule includes work performed in three shifts and 1 cycle progression is 1.6 m.
The number of cycles in the opening corridor:

$$N_{CTHP} = \frac{H_p}{P_C} + 2 \bullet P_{sh} = \frac{125}{1.6} + 2 \bullet \frac{20}{1.6} = 78.125 + 25 = 102{,}125\,\text{cycle}$$

$$N_{shift} = N_{CTHP} \cdot Nd\,/\,cycle = 102.125 \cdot 3 = 306.375\,\text{shifts}$$

$$\text{Working days} = \frac{N_{shift}}{3} = \frac{306.375}{3} = 102.125\,\text{days}$$

Expansion of the main shaft
Timetable of the corridor sanation:
Total schedule includes works that need to be done in 7 shifts and the advance is 1.6m per cycle.

$$N_{CTHP} = \frac{H_p}{P_C} + 2 \bullet P_{sh} = \frac{125}{1.6} + 2 \bullet \frac{20}{1.6} = 78.125 + 25 = 103.25\,\text{cycles}$$

$$N_{shift} = N_{CTHP} \cdot Nd\,/\,cycle = 103.25 \cdot 7 = 721.85\,\text{shifts}$$

$$\text{Working days} = \frac{N_{shift}}{3} = \frac{721.85}{3} = 240\,\text{days}$$

Table 4 shows the expenses for opening the corridor:

Table 4. Corridor opening expenses

Costs of explosives	**23,562**
Workforce	**99,360**
Wage per night shift	9,936€
Total	132,858 €

Pump station

It has crossed section surface of 60m2 comparing to 10 m2 of corridors, and the length of pump station is 25m, and to conclude expenses per length/meter 1m\` of pump station has the value of 6m\` of a corridor, increased for 20% of other works, in total the object has value of 7,2m\` of corridor calculated previously.
Since the expenses for corridor length of 640m were SH= 1,360,470 €, i.e. per length/meter 1m\` would be 2,125 €.
1m\` of pump station = 7,2m\` of corridor then:
1m\` of pump station =15,300 €
The total expenses for pump station are SH= 15,300*25=382,500 €

Water basins
These are calculated as to the pumping station and refer to the value 1m\` of water basin, but length of one water basin is 130m, as 2.5m of corridor. In this case, we have two water basins. Global Schedule includes works in shifts and progress to 1 cycle, which is 1.6m.
Number of cycles in opening water basin/ pumps is:

$$N_{CTHP} = \frac{H_p}{P_C} + 2 \bullet P_{sh} = \frac{120}{1.6} + 2 \bullet \frac{20}{1.6} = 75 + 25 = 100\,\text{cycles}$$

$$N_{shift} = N_{CTHP} \cdot Nd\,/\,cycle = 100 \cdot 6 = 600\,\text{shifts}$$

$$\text{Working days} = \frac{N_{shift}}{3} = \frac{600}{3} = 200\,\text{days}$$

1m\` of pump station = 2.5 m\` of corridor then we have value of 1m\` pump station =5,300 €
The expenses of opening two water basins are SH= 5,300*130*2=1,378,000 €

The global schedule includes works completed in six shifts, while the progress per 1 cycle is 1.6 m.
Number of cycles for water basins/pumps is:

$$N_{CTHP} = \frac{H_p}{P_C} + 2 \bullet P_{sh} = \frac{120}{1.6} + 2 \bullet \frac{20}{1.6} = 75 + 25 = 100 \text{cycles}$$

$$N_{shift} = N_{CTHP} \cdot Nd / cycle = 100 \cdot 6 = 600 \text{shifts}$$

$$\text{Working days} = \frac{N_{shift}}{3} = \frac{600}{3} = 200 \text{days}$$

The expenses of opening water basins are equal to expenses per making loess. That loess is identical and there are two of them, but their length is small 60m each.
The expenses for opening two loess are SH= 5,300*60*2=636,000 €

Main corridors
There are in total two levels of horizons in length of 1000 m each.
The global schedule includes works in four shifts and progress per cycle is 1.6m.
Number of cycles in corridor opening is:

$$N_{CTHP} = \frac{H_p}{P_C} + 2 \bullet P_{sh} = \frac{2000}{1.6} + 2 \bullet \frac{20}{1.6} = 1250 + 25 = 1275 \text{cycles}$$

$$N_{shift} = N_{CTHP} \cdot Nd / cycle = 1275 \cdot 4 = 5000 \text{ shifts}$$

$$\text{Working days} = \frac{N_{shifts}}{3} = \frac{5000}{3} = 1667 \text{days}$$

Water gate
The expenses for opening water gate are as follows:
Water dam 28,800$ = 22,153€
Doors 9,500$ = 7,300€
Total 38,300$ = 29,453€ or 30,000€
For two water dams on the horizon XII and XIII we should have expenses around 60,000€.
Total expenses for opening capital objects are 4,219,766 € or assumed 4,3 million € without calculation of pump infrastructure.

The duration of shaft deepening
The progress of work on deepening the horizon XII XIII is now complete (finished). Continued progress will be made for digging ore bodies, with ramps, crossings (ore passes), as described by Lategan (2009). Production time can start from the first workshop in the XII horizon. Assessment will be made after 12 months. The total time period of shaft deepening since decision to start the production, estimated at about 46 months for horizon XII and 60 months for XIII horizon (Hetemi, 2013).

The total opening is 1,914 days or approximately 5:47 years not including the opening of all corridors in horizons (1,667 days), and excluding the establishment of pumps and pipes. In these calculations are not included the costs for the replacement of existing hoisting machines since existing machine can not afford deeper depth then horizon XI on the basis of the Law on Mining Operations. For this reason, buying a new machine would cost as follows:
For skip (hoist) would cost about $ 3,500,000 (€ 2,700,000);
Transport would cost about $ 3,200,000 (€ 2,500,000).

In total, therefore, must be calculated the additional costs about € 5,200,000 for a hoisting machine.
Total expenses for the opening of horizons XII and XIII will be about:
4,219,766 + 5,200,000 = 9,419,766 €

On the table 5 there are detailed durations of the completion of sinking for the main shaft:

Table 5. Activities and duration of works in the shaft

Activity	Duration
Valuation of alternatives in details and technology assessment.	3 months
Planning and preparation, modification of blind service shaft for deepening main shaft. Installation of equipment for deepening.	6 months
Shaft sinking of length 120m and cross section $18m^2$ ore basins on the horizons XII e XIII.	5 months
Preparation of the shaft ending, workshop facilities, main shaft location direction.	1 month
Water basin and pump station on horizon XIIIth, permanent installations of pumps.	3 months
Stack construction under main shaft by Alimak in length of 150m.	2 months
Installation of working platform for shaft sinking.	1 month
Main shaft sinking by cross section $20m^2$	8 months
Continuation of installations on horizon XIII, skip loading station below horizon XIII.	1 month
Ore passes from horizont XIII to XII and XI.	2 months
Main corridor on horizon XIII should be connected with ventilation shaft in length of 350m.	3 months
Ventilation shaft for connection to horizon XII.	1 months
Total	**36** months

NOTES: Provisional regulation of ventilation in the XII horizon. The development of mining work can start on this horizon.

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