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Research Article

Safety and exploiting of crown pillars in Trepça stantërg mine

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Abstract:

Most ore bodies of the Trepça deposit, Stantërg are known for a characteristic of these ore bodies with a slope angle and the formation of crown pillars and safety plates in the process of mining at the stopes, especially when the mineral body is of large size. The exploitation of these mineral bodies in existing stopes reaches the existing final levels of exploitation and in those cases when production capacities are in the limited phase, then in order to increase the quality of the ore in production, it is necessary to design the crown pillars and the method of their exploitation using productive mining machinery with a special focus on safety at work. Safety during the use of these plates is established according to the criteria and practices applied which have found proper implementation. The use of productive loading machines can significantly jeopardize this safety; therefore it is necessary to conduct an analysis that will determine the losses of ore in the working sites by implementing safety measures for the use of safety bearing plates. In order to leverage the maximum capacity of exploitation of this mass of mineral located in the bearing plate, the bottom-up ore body exploitation system has been applied. The mining of ore bodies in the lower levels such as the 10th and 11th levels has been carried out using modern machines with large productive capacities.

1. Introduction

From the 9th level and below, the exploitation of ore bodies is designated by numbers 13X (no.X indicates the number of stope). These ore bodies are a continuation of ore bodies from the upper levels and lower levels. In our specific case, we are talking about bodies located on the 9th level. The ore body mining floor is formed as a safety crown of the stope. To clarify, P-140 crown pillar was studied [1-11].

2. Material and Methods

The crown pillar is considered to be almost an unused floor which is considered a safety pillar which secures the stope from one level to another.
Figure 1 explains how to form the crown pillar and prepare it for exploitation. Figure 1 provides a description as follows; The Trepça Stanterg ore bodies have a dip angle of approximately 50º and are in contact (between), the roof part is made of schist rocks while the floor is limestone. This extension of the ore body requires caution in the exploitation of the ore body, therefore the exploitation of the pillar is a task requiring responsibility and increased care.
Ore bodies are exploited using a bottom-up system with filling of the exploited space and from the beginning of exploitation until the end of the work in the level. Upon commencement with the exploitation from the respective level - i.e. below and after the first floor of 5-6 m is exploited, before the filling system (hydrofilling) of the exploited space begins, a steel mesh must be laid and a 20 cm layer of concrete placed on top and then the process of hydrofilling the workshop begins to continue with the ore body exploitation system.
These two layers (steel mesh and concrete) will be needed as a crown pillar for the exploitation of the crown pillar of the same mineral body but located at the lower level.

3. Results and Discussions

From the level where the 10-th level opens, the extent of the ore bodies is obvious, but the ore body has an irregular shape and an extent with a location approximately similar to the levels of the other mine levels. The extent and beginning of the exploitation of the 10th level for the P-140 mineral body, which in this level is named as 14X (no. X indicates the number of stope) 10th level (figure 2).

The exploitation system of these ore bodies, the P-140 and P-130 stopes, is a "bottom-up exploitation system with filling of the exploited mining space" figure 1. The filling of exploited mining areas is done by hydro filling from the flotation process, in which the non-flotated waste as residual material is returned to the mine to fill the mining areas. The condition of the ore body exploited at the level of the 9th level of the P-130 stope differs from the final level of the 10th level.

Figure 3 brings to the conclusion that the floor support crown pillar at the 9th level, the condition of the support pillars and the P-130 ore body is ready for exploitation. Below, we will present the ore body of P-140 and the last floor with the crown pillar and the condition of the pillars. Figure 4 explains how the pillars were constructed and the preparation for exploitation of the crown pillar. Figure 4 also shows a pillar that appears in yellow, which means that twinning of the ore body has occurred, thus increasing the exploitation area. What is important to know as information is that the area that has covered the surface with the yellow pillar does not appear to be profitable or safe, therefore the ore body of this level in the crown pillar section was observed to have deviations, but the ore was of very low quality with a high pyrite content

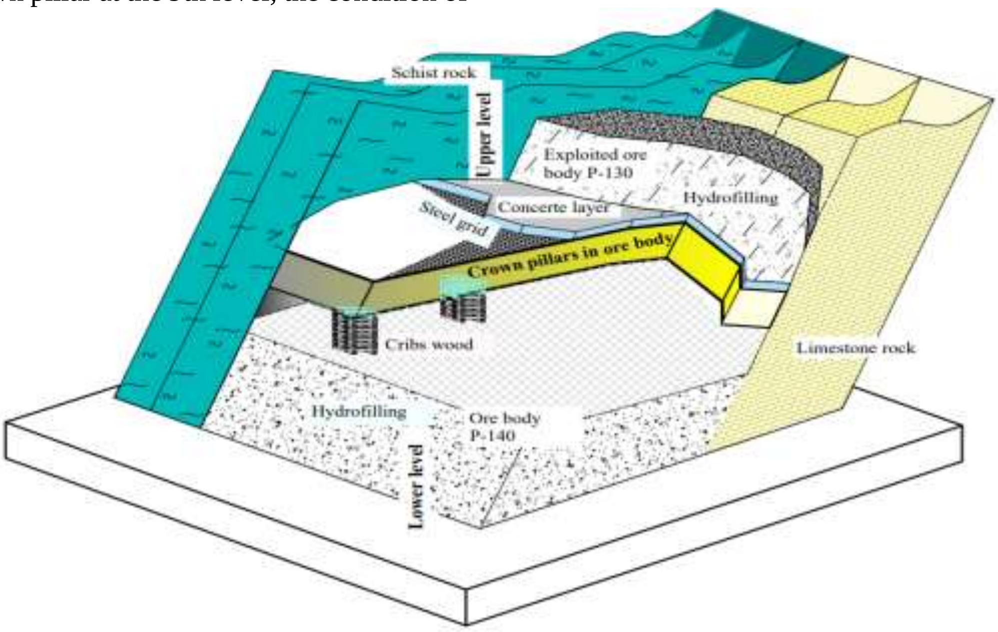

Figure 1. *Description of the ore body and the crown pillar*

Table 1. *The state of the overall ore reserves in the P-140 stope's crown pillar*

Name	Area (m²)	Volumetric weight (t/m³)	Description
Crown pillar	2980	3.7	Safety crown pillar without the pillars
Pillars	438	3.7	Total surface area of the pillars
Safety crown pillar for exploitation	2542	3.7	The surface area on which the safety crown pillar can be exploited

Table 2. *Status of exploitable ore reserves*

Name	Area (m²)	Thickness of crown pillar	Productive ore tons	Description
Total crown pillar	2542	(m)	28.217	Crown pillar comprised as a total
Timber support	4.4	3	---	It is expected that 25% of the stope will remain without support.
Total support	745	3	8.270	The area that may remain unexploited by the crown pillars
Safety crown pillar for exploitation	---	3	20.000	-----

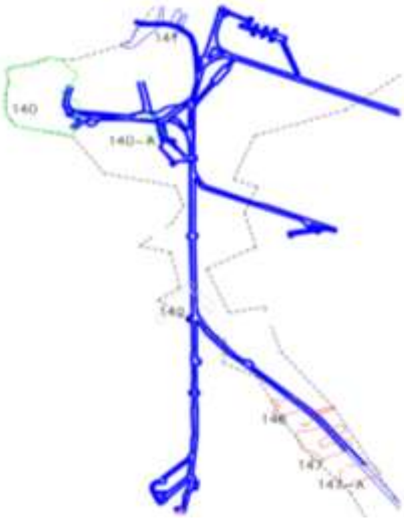

Figure 2. *10th level, ore body P-140 and the condition of the first exploitation bench*

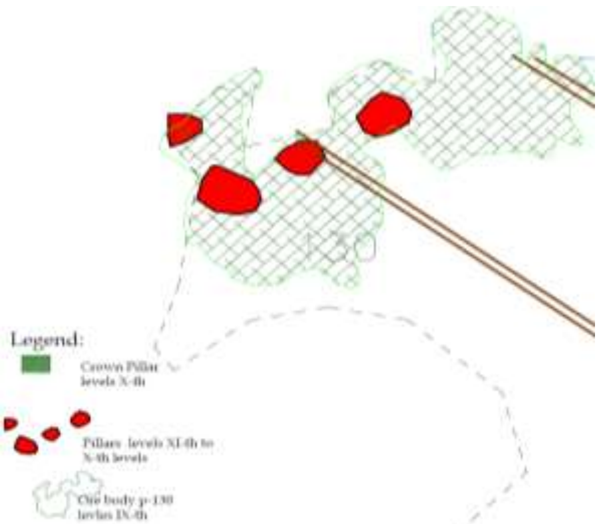

Figure 3. *9th level, P-130 ore body, crown pillar and safety pillars of 10th level*

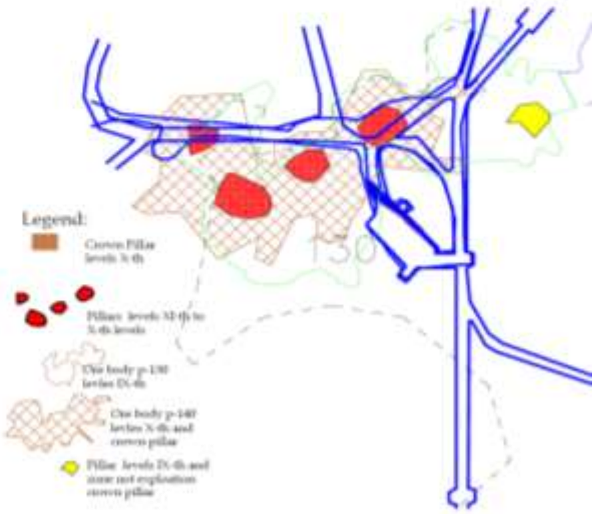

Figure 4. *9th level, P-130 ore body, crown pillar and safety pillars of 10th level*

and the ore quality of Pb - Zn and is with a low percentage of Pb-Zn. The crown pillars are of dimensions for 1/2 of the exploitable floor, but based on practical work, this pillar can vary from a thickness of 2.5m to 3m.

The surface area of the entire pillar is presented in the following table 1. The table 2, based on the parameters of the exploitation system, presents the reserves that can be determined as productive.

Tables 1 and 2 present data that can be considered as rationally exploited ores, but taking into account the modern heavy-productive machinery is used. Loading machines do not possess good operative advantages for exploiting ore during loading compared to methods of using other machines such as autoloader or similar. Therefore, this study will explain the exploitation system according to the type of working machinery. Figure 5 explains the maximum length of the wood cribs installation and their arrangement in columns that must be installed before the beginning of the exploitation of the ceiling section up to these securing objects - wood cribs. Their ordering is done in dimensions as in Figure 6.

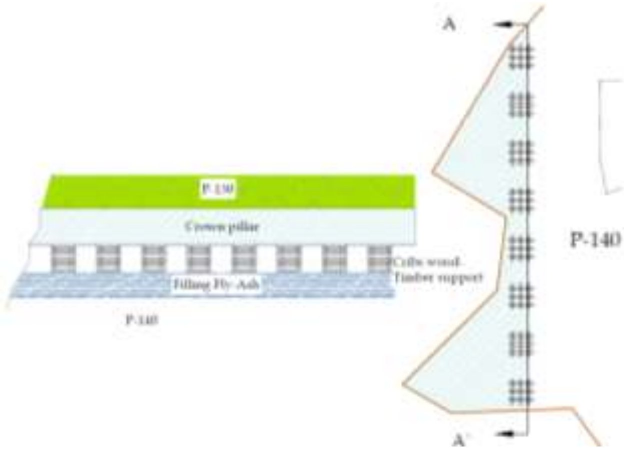

Figure 5. *Scheme for the commencement of exploitation works of the crown pillar.*

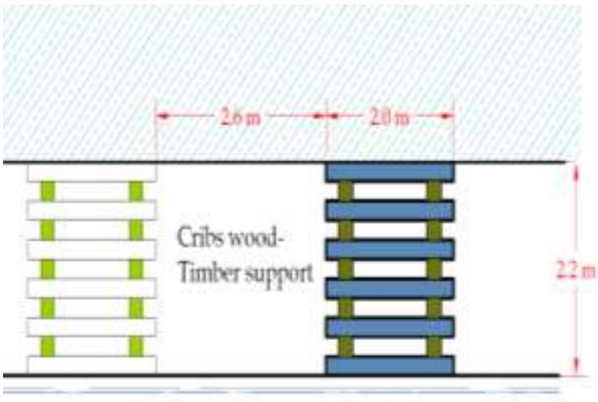

Figure 6. *Wood cribs distance scheme and loading space with productive mining machines*

Analyzing the mining machinery specified according to the mining mechanization and the distances between the wood cribs with which the crushed ore must be loaded, presented as the mined mass and which mass is ready for loading, (see Figure 6). The machine that will work to load the mined ore is a modern, productive machine that has the following characteristics (figure 7). The basic characteristics of this machine will mainly be explained only in terms of maneuverability and loading parameters.

- The height is sufficient and is less than 2.0[m].
- The loading bucket is 1.0 [m^3]
- Inner curve 2.64 [m] and outer curve 4.73 [m]
- The maximum turning operation distance is 3.61[m], as well as
- The loading distance needs to be at least 6.28 [m].

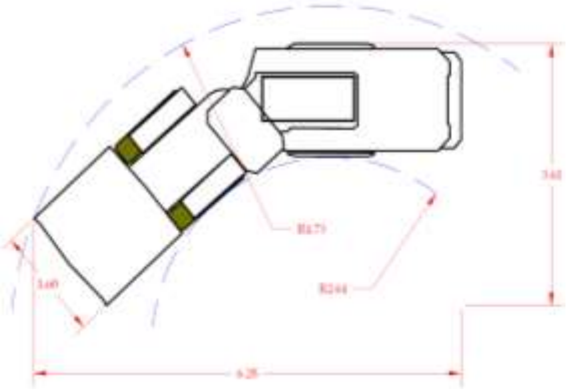

Figure 7. *Productive mining machines and maneuverability properties*

The effective work of loading the mined ore is explained as the ratio of the amount of ore remaining unloaded as a result of the handling properties in curves. During the analysis carried out, Figure 8 shows the areas in the two positions where the machine has the largest operative curve. Area 1 is taken as the most suitable analysis surface and area 2 is based on the calculation of the unladen surface remaining as mined ore lost due to manipulation effects and the construction of the loading machine, our specific case is with machine characteristics as in Figure 7. From the loading machine as in Figure 8, it can be seen that the remaining ore as a result of the loading mining activity is shown in yellow, while the operation positions of the machine are explained in the figure. From Figure 8, the amount of remaining ore in percentage is extracted according to Table 3. From area 1 and comparison with area 2, the result is that 10.2% of the total mass is unexploited as waste due to inability to load. Furthermore, by analyzing these factors, we obtain the value of the rational exploitation of ore exploited from the crown pillar in the P-140 stope using Table 4. According to Table 4, the value that is considered as reserves that can be considered to be exploitable has been obtained and that value is18,980 tons where the percentage of Pb 4.5%- Zn 5% is approximately the remaining part of the total reserves of the stope of 28,217 tons, not considered as exploitable reserves according to Table 5.

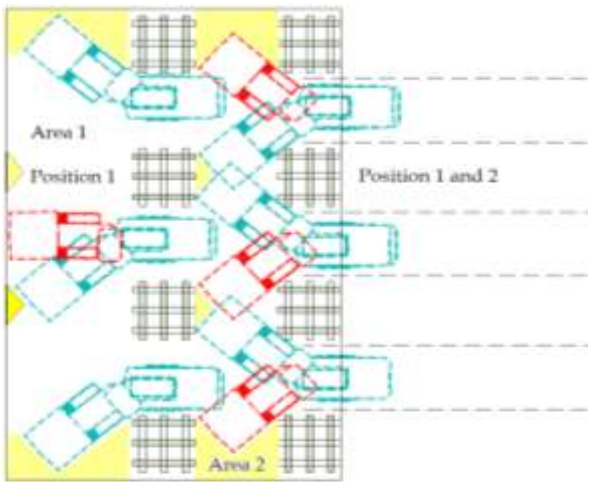

Figure 8. *Remaining positions of ore mined by the loader*

Table 3. *Percentage of ore remaining in the loading process*

Name	Area (m^2)	Description
Area 1	170	The surface area that was taken for examination
Area 2	17.5	The yellow-colored surface which is considered to be a remnant from area 1.

Table 4. *Potential exploitable reserves of crown pillars at the P-140 stope*

Name	Area (m^2)	Volumetric weight (t/m^3)	Description
Crown pillar	2980	3.7	Safety crown pillar without the pillars
Pillars	438	3.7	Total surface area of the pillars
Remaining quantity during loading	475	3.7	
Safety crown pillar for exploitation	1710	3.7	The surface area on which the safety crown pillar can be exploited is **18,980 tons** of ore

***Table 5.** Exploitable reserves and their comparison for the exploitation of the crown pillar in the P-140 stope*

Name	Area (m^2)	Volumetric weight (t/m^3)	Total (ton)
Crown pillar	2980	3.7	33078
Pillars	438	3.7	4862
Timber support	475	3.7	5273
Remains from loading process	357	3.7	3962
Profitable quantity to be exploited			**18980**

Safety measures are essential in this study because the impacts that may be caused to wood cribs by the operator driving the loading vehicle can be very dangerous for the safety of the crown pillar. To avoid this, proximity sensors may be used. These sensors ensure avoiding the vehicle collision with wood cribs. Sensors installed in machinery create and detect electromagnetic fields. To create a magnetic field very close to wood cribs, metal rods (metal struts) must be installed. These metal struts will perform two functions. The first is a physical visual identifier for wood cribs and the second will create a magnetic field which will detect with an audible alarm the presence of the machine in relation to wood cribs. This proximity identification system with wood cribs includes the unit that is impossible to see or carelessly miss during loading and transportation. Warning alarms will be activated and the interlock or alarm will enable the operator to move the machine safely and to automatically slow or stop the machine when necessary. Figure 9. Proximity identification sensors. This proximity identification system with wood cribs includes the ability in those cases when visual observation is impossible or due to carelessness of the operator during loading and transportation. Proximity warning alarms will be activated and equipment interlocks will enable the system to safely control movement and automatically slow or stop the machine when necessary. The metal strut assembly system is simple, fast, and easy to use (figure10).

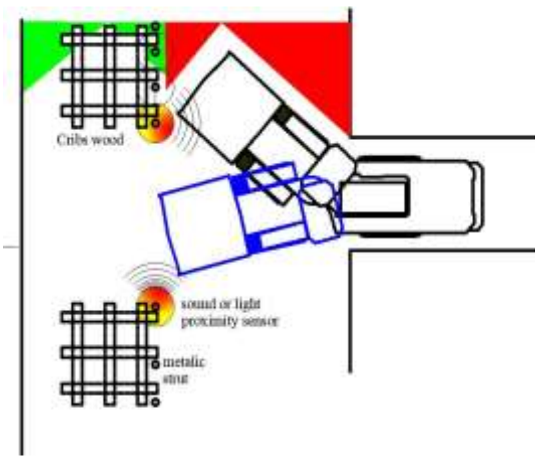

***Figure 9**. Proximity identification sensors*

***Figure 10.** Strut system*

The metal strut mounting system, in addition to having the effect of identifying the proximity of the object - the loader, is also a ceiling reinforcement system and at the same time a good visual identifier for the machine operator during loading between or near the wood cribs.

4. Conclusions

The system of exploitation of the ore bodies and their angle of dip provide good geo-mechanical conditions for the exploitation of the ore bodies. Since a large part of the ore bodies is contained in the crown pillars, nevertheless, the thickness of the crown pillars is not stable enough to be exploited. The crown pillar is secured by the support of "wood cribs". This again poses a risk and a metal strut should be placed as a reinforcement and identification tool. The safety factor will be increased by applying wood cribs support, metal struts, and from the roof of the loading machine itself to the machine operator. The installation of sensors on the far side of the wood cribs, on which acoustic and optical sensors are mounted, will identify the vehicle that has approached the wood cribs. The greatest safety is only in those cases where the order of the wooden support is more congested and when the above-mentioned sensors are installed for additional safety. The loading machine has its own cabin secured against minor collapses. The loading machine has its negative sides, namely the ore losses are present at 10.2% as an additional loss from all other known losses, but since it is a productive exploitation system, this has helped the best, both in terms of rational use of loading and safety of the crown pillars and ceiling avoiding the damaging of the wood cribs.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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