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GEOTECHNICAL STUDY OF DRAA SFAR MINE (MARRAKESH, MOROCCO)

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ABSTRACT

Nowadays mining prosperity depends largely on the stability of underground structures. It is then necessary to know the configuration of the deposits. Which means analyze and understand the behavior of enclosing land during Operation Ore.

The Geotechnical study is based on the behavioral aspects of rheological and mechanical response of the rock mass Mine Draa Sfar, the digging of galleries and various infrastructures works necessary for mining. Thus, the comparison between usual failure criteria and geo-mechanical characterization of the rock matrix focused on the peculiarity of the facies of the mine that are attacked by the schistosity and other structural deformations.

Thus, we first conducted a sizing of major operating structures according to Long Holes method. It is, in fact, operating rooms. Then, it was verified the stability of proposed designs for different infrastructure galleries. Then it was important to consider support systems for mining these components.

Therefore, we must return to examine the stability of blocks generated by the joints families found after a statistical statement processing discontinuity plans on ground.

But still, it is necessary to treat the execution schedule sizes by first developing an operating sequence that takes into account the area of influence of mining openings and keep a stable production rate.

Finally, the profitability study has helped to rule this project in terms of financial value. Indeed, economic performance indicators (NPV), (IRR) and (CAF) have clearly shown that the project is highly profitable.

INTRODUCTION

Draâ Sfar is a polymetallic mine classified among the deep mines in Morocco.
One currently reached their depths which exceed the 1100 meters. The exploitation of the layer is done by two methods with knowing; raisin slices embanked (TMR) for the main zones and under levels shot down (SNA) for the thick zones. The digging in the rock solid mass generates important induced constraints, according to dimensions and the depth of the work which can appear on the level of the stability on the grounds of the mine. From where the need for a Geotechnical study thoroughly in order to work out estimates of adequate supporting to ensure the stability of the rock solid masses and to make safe the production activities thereafter.

THE CONTEXT OF THE STUDY

Tally geographical and geological

The sector of Draa Sfar is located at the level of the southern end of the exchange part of the Jebilet solid mass.
The site Draa Sfar appears in the south of the Tensift Wadi. Its detailed cartography made it possible to raise an anticlinal megastructure plunging towards the North and whose sides are especially occupied by volcanoes and volcano-clastic facies. This folded structure was mainly disturbed by the late effects of Hercynian tectonics.

It is plausible to note that the volcanic formations are primarily acid layers with very complex lithological frame. These geological structures are folded, métamorphisées and fractured geological.

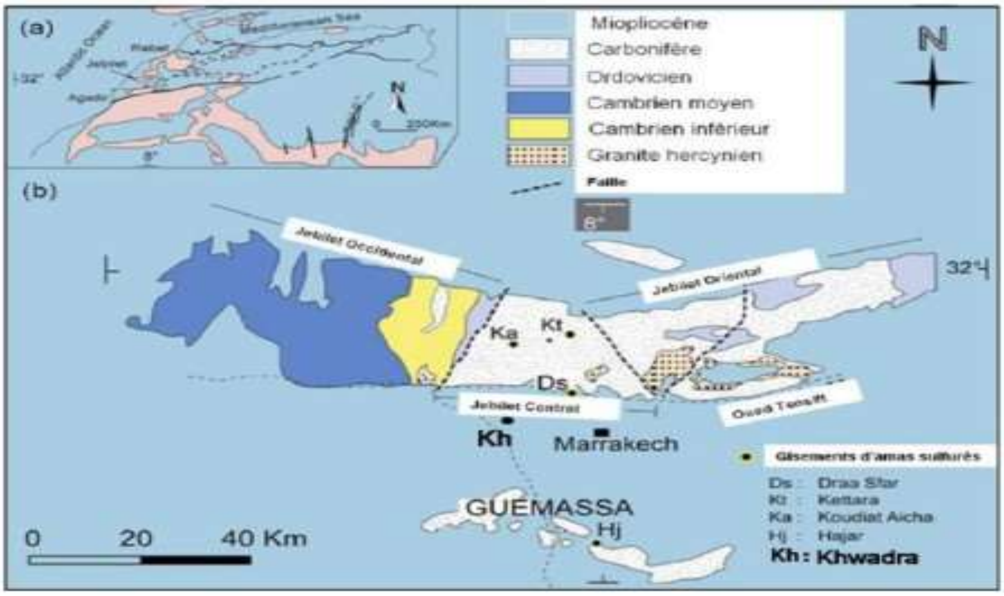

Figure 1: (a): Localization of the solid mass of Jebilet within the framework of the paleozoic outcrops of NorthAfrica. (b) Geological map of Jebilet and the solid mass of Guemassa showing the localization of the layer of Draa Sfa

The lithological composition of the sector of Draa Sfar:
A cartography of detail on the outcrops of Draa Sfar and the petrographic studies on various scales (at the level of the solid mass, the sample and minerals) carried out starting from the samples taken on the surface and in the mine or on cored surveys made it possible to note four types of geological facies:

- méta-deceits and méta-rhyodacites of Tazakourt;
- pyroclastic méta-tuffs;
- sandy métapélites of the wall;
- sulphuretted mineralization;
- Black métapélites of the roof.

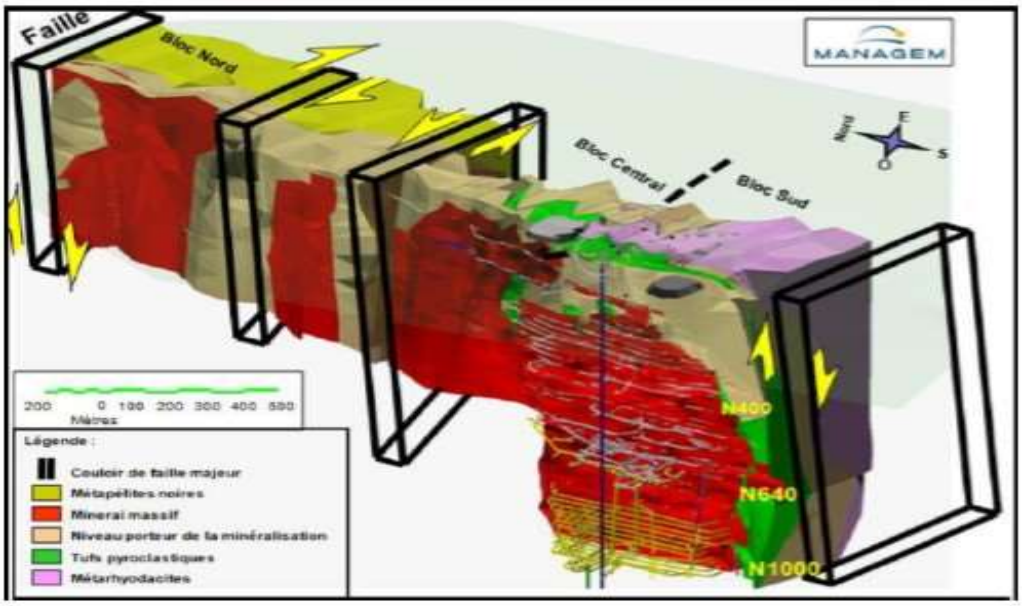

Figure 2: Three-dimensional geological model ofthe layer of Draa Sfar

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Discontinuities of the rock solid mass of the mine Draa Sfar:

The geological facies of Draa Sfar recorded the print several types of deformations sign to post Hercynian in the form of discontinuities and of fractures of the rocks. The print of each phase of deformation is expressed differently in the rhyodacitic lava, the tuffs, the métapélites and associated mineralisation.

The tectonic faults existing on the level of the wall-rocks, the spectacular phenomenon of the mine of Draa Sfar is the extent of schistosity and the foliation which mark its facies. This mineral and mechanical transformation, to see even rheological, involved a transformation of the behavioral mode of the solid mass to their proximity.

PROBLEMS

Indeed, in terms of this study, one has been already to 1100 m of depth in the mine of DRAA SFAR. One kilometer under the ground made it possible this mine to hold the record of the Moroccan mining network.

However the wealth of this layer pushed group MANAGEM to study the possibility of an exploitation beyond the level 1100m.

Admittedly, this promising project must be initially validated by a Geotechnical preliminary study, which makes it possible to justify that the deep layers could be dug without resorting to modes of expensive supportings.

Consequently, our problems were: Is the layer a mineral wealth, but is exploitable from the Geotechnical point of view?

The answer to this question requires to evaluate balance Forced/Resistance. With this intention, one carried out a calculation in extreme cases of balance (model digital) and thereafter one examined the behavior of the layers of rocks in the vicinity of a gallery by measuring the values of the Safety factor.

DESIGN ASSUMPTIONS

Modeling by a continuous medium

One seeks to replace the real solid mass, crossed discontinuities, by a continuous medium are equivalent to his mechanical properties. Two questions arise: is this sells by auction? How to estimate the properties of the equivalent medium?

Sometimes the digging of a gallery modifies the constraints with its vicinity and makes leave the rock the field of elastic behavior. The stability of a deep gallery and the dimensioning of a supporting can be studied by regarding the solid mass as a continuous medium like first approximation; however, that does not exempt to analyze except for the stability of rock blocks in the vault, under the effect of gravity.

The finite element method makes it possible to subject the virgin solid mass to initial constraints given, to simulate the digging of a gallery. With this intention, one used the modeling and computation software Phase2 6.0.

Materials

The materials are supposed to be continuous, homogeneous, isotropic, elastic and heavy. West with the East, one will adopt this order:

Métapélites black – Ore – Méta-Tuffs – Métapélties sandy – Métarhyodacites.

Boundary conditions

Normal constraints (or variety of constraint) depend on there and the mechanical characteristics on the faces only. The deformations will be thus planed in the plan (X, there).

One will consider a 'secure' zone if its safety factor is at least of 1.5. For the continuation, we always will highlight the points belonging to this ISO-FS curve.

Geographical location of the works

The mining works of the downstream will be built in the same rock prolongation of the upstream of the level 1000m. I.e. the slope, the crosscuts, the galleries of attack and the galleries of access will be created in the facies of the black métapélites and the rooms of exploitations will be elaborated in mineralisation. Thus, thereafter one will only be interested in these two facies. The geographical location of these works is represented in the following figure:

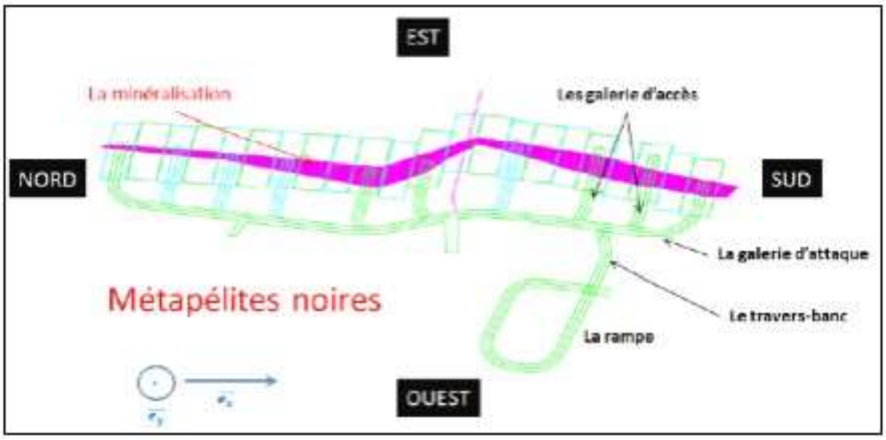

Figure 3: Plan of level showing the geographical location of the works

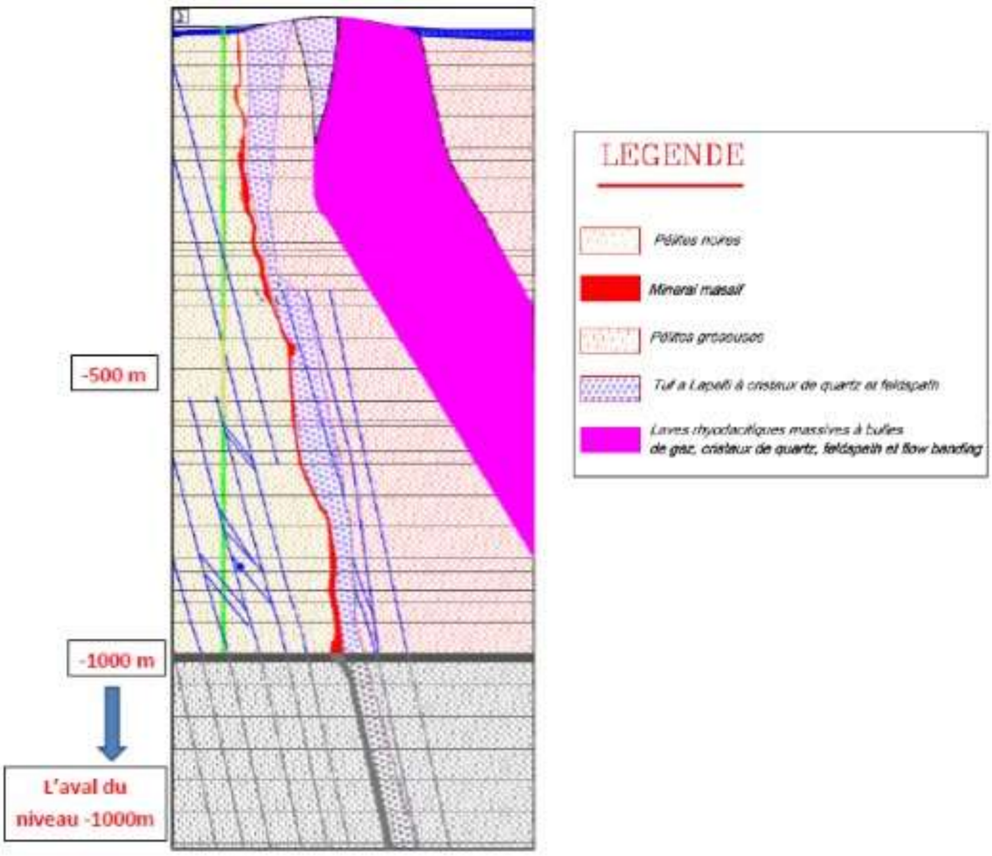

Figure 4: Transverse section E-W showing thefield of the new study

MECHANICAL AND GEOTECHNICALCHARACTERIZATION

An approach based on the systems ofclassification of the fractured rock masses

The systems of classification of the rock solid masses are generally used in order to assign adigital value given (sometimes a beach ofdigital values) todefine the characteristics andproperties of the rock solid mass to estimatethe behavior of the excavation and to allow adesign of support of the adequate andsedentary ground.

- **the Rock'n'roll Mass Rating - RMR(Bieniawski, 1989):**

The classification of Bieniawski envisages theevaluation of various parameters for each onewhose a digital coefficient is allotted according to a scale and while being based on thefollowing parameters:

- Compressive strength uniaxial of therock;
- The value of index RQD* for the rock mass;
- The spacing of discontinuities;
- The state of discontinuities;
- Hydraulic conditions;
- Orientation of discontinuities.

- **the Rock'n'roll Farmhouse Quality- Q-system(Barton, 1974):**

Q is an index making it possible to describe thequality of the rock solid mass for theexcavation of tunnels. The system ofclassification names Rock'n'roll Mass Quality(system Q) or quitesimply system of the NGIin homage of the Norwegian GeotechnicalInstitution. The six p rticular characteristics of the rocksolid mass, is:

- Index RQD;
- Many families of joints (JN);
- Index of roughness of the joints (JR);
- Index of the deterioration of the joints(JA);
- Factor of reduction for the presence ofwater (JW);
- Factor of reduction for in situ constraints (SRF).

Classifications of the ore

Paramètre de la classification	**Description**	**Valeur moyenne**	
		Q-system	**RMR**
RQD	Mesurée dans les sondages de CMG	62	13
Nombre des familles de joints Jn	3 familles de joints à directions différentes (1-Schistosité. 2-Famille horizontale. 3-Famille sub-verticale orientée NNW)	9	
Espacement des joints	Espacement moyen 0.3-1m		12
Rugosité des joints Jr	Discontinuité plane lisse à lisse et ondulée (1-1.5)	1	12
Altération des joints Ja	Epontes largement altérées	2	
La résistance à la compression uni-axiale de la roche intacte	Une plage très large (10 à 200 MPa)		8
Conditions hydrogéologiques JW	Excavation considérée hors d'eau*	1	15
Orientation de l'excavation	Non considérée*		0
Facteur de réduction des contraintes SRF	Non considérée*	1	
Valeur moyenne		**3,4**	**60**
GSI moyenne= RMR -5			**55**

Table 1: Classification of mineralisation

Classifications of the black métapélites

Paramètre de la classification	Description	Valeur moyenne	
		Q-system	RMR
RQD	Mesurée dans les sondages de CMG	54	10
Nombre des familles de joints Jn	3 familles de joints à directions différentes (1-Schistosité. 2-Famille horizontale. 3-Famille sub-verticale orientée NNW)	9	
Espacement des joints	Espacement moyen 0.3-1m		12
Rugosité des joints Jr	Discontinuité plane lisse à lisse et ondulée (1-1.5)	1	12
Altération des joints Ja	Epontes largement altérées	2	
La résistance à la compression uni-axiale de la roche intacte	Une plage très large (10 à 200 MPa)		7
Conditions hydrogéologiques Jw	Excavation considérée hors d'eau*	1	15
Orientation de l'excavation	Non considérée*		0
Facteur de réduction des contraintes SRF	Non considérée*	1	
Valeur moyenne		**3,0**	**56**
GSI moyenne= RMR -5			**51**

Table 2 : Classifications of the black métapélites

The properties géomechanics of the blackmétapélites and the ore:

Paramètre géo-mécanique	Métapélite noires	Tufs	Minerai
Densité (Kg/m3)	0,027	0,0272	0,04
RC (MPa)	31	34	106
E (Mpa)	16874	15174	27534
ν	0,15	0,2	0,25
Paramètre M-C			
C(Mpa)	1,4	1,74	7,2
φ (°)	25	31	38
Paramètre H-B (roche intacte)			
GSI	51	54	55
m_i	8	12	12
D	0	0	0
Paramètre H-B (roche sur terrain)			

m_b	1,38	2,02	2,41
s	0,0043	0,0057	0,0067
a	0,5	0,5	0,5

Table 3 :The properties géomechanics

The recourse to seek parameters M-C (MohrCoulomb) equivalent starting from parameters H-B(Hoek Brown) was to bring the pace closer to thefunctions of rupture of these two criteria. Indeed, the limiting function of surface of criterion M-C in the plan deviatoric, found starting from equivalentparameters M-C is contiguous with the function ofH-B in this same plan:

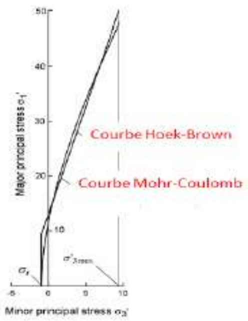

Figure 5: Curves of the rupture limits for thecriterion Mohr-Coulomb and Hoek-Brown

CHARACTERIZATION OF THE MINERAL RESOURCES

Mining method

The method of the Long Holes consists in cutting down the rock between two distant levels several meters. In general all the ore is cut down between these two levels. After exploitation, the room is thus entirely empty. It is however necessary to embank this vacuum by a cemented fill or a file into sterile. This fill will take the shape of pillars distributed in an almost regular way.

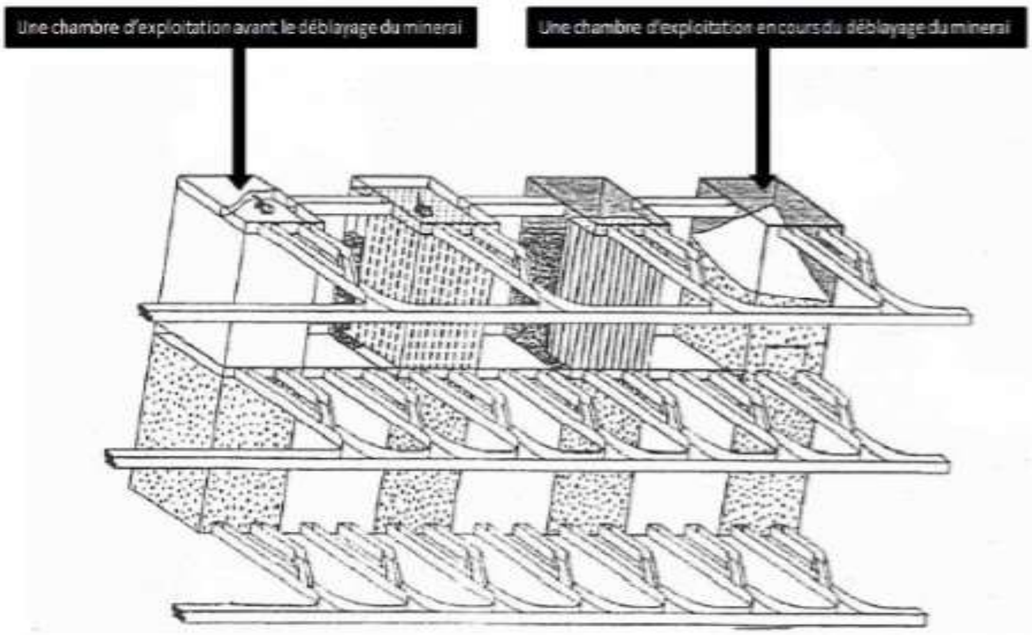

Figure 6: Three-dimensional diagram of theprocess of the method of the Long Holes

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This method of the long holes is very flexible gets more security for the workers. This method requires low costs of mining in comparison with the TMR, which requires to make cut down the steps each time rise of the mobile arm.

Nevertheless, this method remains less selective because of its operational concept based on caving of the layer. Of another with dimensions this method sometimes the dilution amplifies which becomes difficult to quantify because of the quantity of sterile, coming from the immediate strata, which will be added during the collapse of the ore.

Calculation of the reserves

- dilution and the salissage: Demolition is envisaged with the explosive, this kind of demolition, in spite of the will of the operators, are generating of dilution on the level as of immediate strata of the rooms of exploitation, because of the irregularity of the interface between the ore and the sterile one and in particular in the zones where the rock presents less mechanical competences. This dilution is inevitable; nevertheless it is controllable thanks to an adequate supporting.
- Ø industrial tonnage: This data is of a major importance for the cost-benefit analysis of a mining project. Industrial tonnage corresponds to the effective quantity of the Hoi-polloi sent to the treatment plant by taking account of the losses of the recovery of the layer and the two phenomena: Dilution and Salissage. It is calculated starting from geological tonnage by the following formula

$$Tonnage\ industriel = (1 + Coef_{dilution} + Coef_{salissage}) \times Tonnage\ géologique\ récupérable$$

THE DIMENSIONING OF THE UNDERGROUND WORKS

Considering the morphology of the layer which is characterized by a dip between 70°et 80°, it will be necessary to consider that each room of exploitation undergoes the weight of the nonabove mineral-bearing rock facies. In addition, the twinge of the ore in the North-South direction is far from being rectilinear. Indeed, it tends to besimilar to a Gaussian bell-shaped curve towards the direction South-North.

The analysis of the computation results shows that the difference between the limit of the zone in transition without support and the hydraulic ray becomes almost worthless starting from a width of 10m.

One presents a model in 2D which models the general pace of the distribution of the constraints around the room of exploitation, calculated starting from the analytical method.

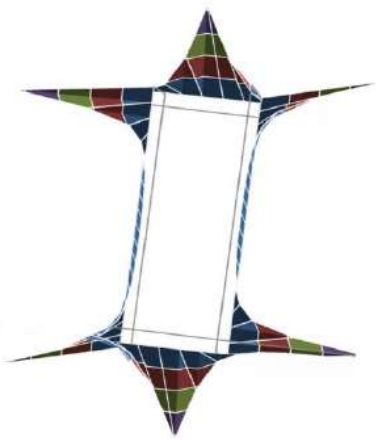

Figure 7: Model 2D of the state of the constraintsaround a room of exploitation

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SYSTEMS DESIGN OF SUPPORTING

The objective of the stabilization of the rock solid mass by a system of supporting is to maintain theintegrity of the excavation. The reinforcementconsists in increasing the internal resistance of therock solid mass with respect to the mechanicalrequests; one inserts the bolts or the cables in therock solid mass, so that the solid mass is rigidifiedand reinforced.

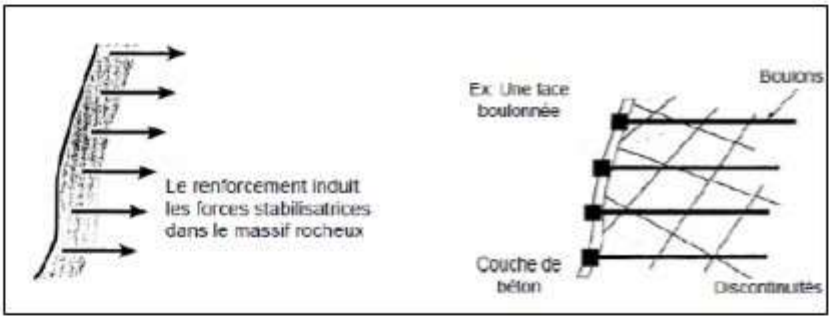

Figure 8: The concept of the reinforcement

The zone of Métapélites contact/Ore is the most critical zone, indeed the distance between the gallery and the line is-FS=1, 5 varies between 5m with 8m, which requires a heavy supporting. The provisions of supportings will be applied almost according to the standards already proposed for the higher levels, indeed the general Geotechnical behavior of these levels remains almost linear. In short, the answer to the question of exploitability to the Geotechnicaldirection of 1100m with 1500m is relatively positive.

CALCUL OF THE PROFITABILITY OF THE PROJECT

Computationresults of profitability thus the curveof evolution of annual tonnage, the receipts andthe requireme t in investment. It is important to note that this distribution is proposed to answer the evolution of work of the exploitation ofthe downstream of the level -1100m

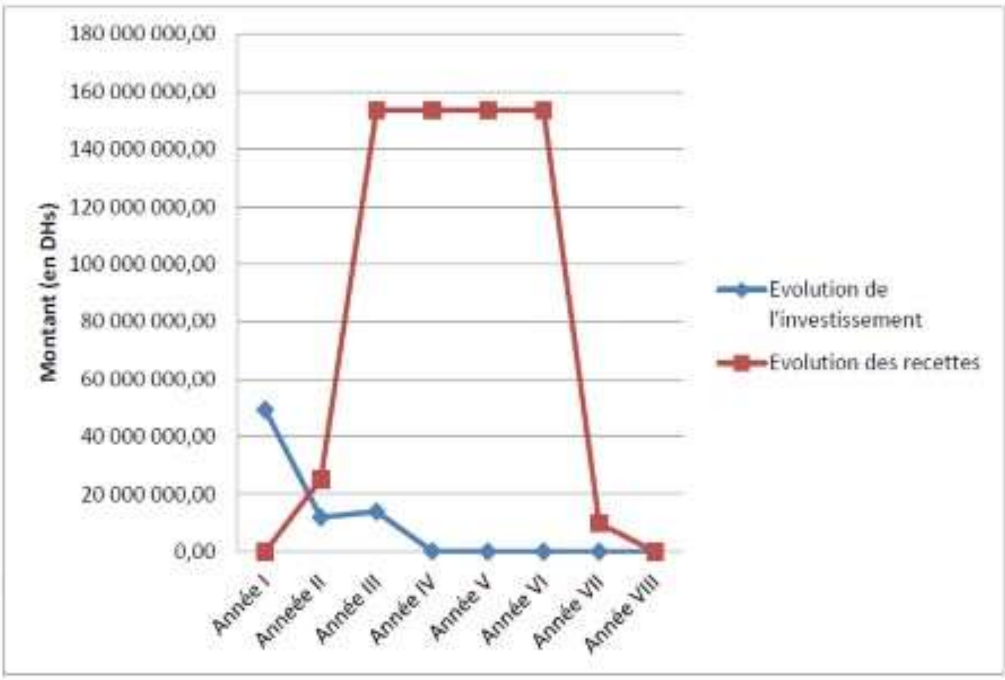

Figure 9: Evolution of the investment to be mobilized and the receipts through the years ofexploitation

The summary table of the indicators of performances of profitability:

Table 4: Cost-benefit analysis

Flux monétaire résiduel (CAF)	Valeur ajoutée Nette (VAN)	Taux de rentabilité interne (TRI)
154.418.981,45	62.321.066,82	40,99%

Taking into account the values of the indicators of performances quoted above, one can conclude that the project of exploitation of the downstream is a true economic opportunity which reveals an important benefit as from the third year exactly. Thus, one will be able to really recommend to launch out in this promising project.

GENERAL CONCLUSION
Arrived at the end of this work, one will be ableto conclude that the project of the exploitationof the downstream of the level -1100 m of themine of Draa Sfar is profitable and possible.

The development of the infrastructurenecessary for the exploitation as well as theother essential mining works for the productionproves to be possible from the geotechnicalpoint of view.

Finally, it is advisable to highlight thecharacteristic of the facies of the mine of DraaSfar which shows an abundant schistositywhich is generally the source of the unhappyaccidents underground in the mine. In thisdirection, considering a good mining design is based, primarily, on retro-analyzes and theexperience feedback, one launched in theprocess of the instrumentation to equip themine with average the techniques able to followthe rheological evolution of the point-keys of themine in order to work out a geotechnical map,brought up to date without delay, mine but alsoto gauge the methods and the models of calculation adopted in the phases of dimensioning.

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