DCE 19 3rd DOCTORAL CONGRESS IN ENGINEERING

DOCTORAL CONGRESS in ENGINEERING

Book of Abstracts

1st Symposium on Mining Engineering e Geo-Resources

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

DCE 19 3rd DOCTORAL CONGRESS IN ENGINEERING

Book of Abstracts

of the

1st Symposium on Mining Engineering and Geo-Resources

Editors:
Maria de Lurdes Dinis, Janine Figueiredo, Rui Sousa

Porto
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This volume contains the abstracts presented at the Symposium on Mining Engineering and Geo-Resources, within the 3rd Doctoral Congress in Engineering - DCE19, held in Porto, between June 27th and 28th, 2019.

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WELCOME

The Organizing Committee of the Symposium on Mining Engineering and Geo-Resources welcome you to the 3rd Doctoral Congress in Engineering (DCE19), FEUP, Porto, Portugal. We are pleased to host the 1st Symposium on Mining Engineering and Geo-Resources in the Faculty of Engineering of Porto University organized in collaboration with the Instituto Superior Técnico (IST). This is an excellent opportunity for doctoral and master students to share and discuss on-going research with peers, professors, and industry and develop networking opportunities with other researchers.

The Symposium on Mining Engineering and Geo-Resources focus on a multidisciplinary, advanced and comprehensive approach to scientific or technological issues involved in the life cycle of a mineral resource. Research is preferentially concerned with the fundamental understanding of the basic processes that support the sciences and technologies involved in the application of engineering principles to the Earth Sciences.

Topics for submission for the Symposium on Mining Engineering and Geo-Resources were focused on: Mineral Exploration and Feasibility, Mining Extraction, Mineral Processing, Environmental Mining Impact and, Mining Life Assessment (including: Resources Assessment, Mining Planning, Mine Closure, Recycling, Life Cycle Assessment, Occupational Assessment, etc.).

The responses to the call-for-papers were much higher than expected. We would like to express our gratitude and appreciation for all of the reviewers who helped us maintain the high quality of manuscripts included in this Symposium Book of Abstracts. We would also like to extend our thanks to the members of the organizing team for their hard work, in particular, Janine Figueiredo and Rui Sousa.

Let us wish that all the participants of the Symposium on Mining Engineering and Geo-Resources will have a wonderful and fruitful time at the Symposium. We hope that you will find it useful, exciting, and inspiring.

Symposium Chair

Maria de Lurdes Dinis, CERENA-Polo FEUP, Faculty of Engineering, Porto University.

On behalf of the Co-Chair, Organizing Committees and Scientific Committee

27 - 28 June, 2019

FEUP, Porto, Portugal

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PROGRAMME

Symposium on Mining Engineering and Geo-Resources

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KEYNOTE SPEAKERS

Anabela Magalhães

Executive Director at North Delegation of Assimagra

Topic: Technical Responsibility of Quarries: Challenges and Opportunities

Anabela Magalhães is a Mining Engineer graduated by Porto University, Engineering Faculty (FEUP) in1997. During the academic course of five years (Pre-Bologna System), she spent 6 months in Denmark where she developed research work in the field of environmental biotechnology and water treatment systems for underdeveloped countries. In 2001 she completed the postgraduate course in Health and Safety at Work at Instituto Superior de Línguas e Administração (ISLA).

For more than 20 years, she has provided technical advice to companies in the extractive and natural rock processing sector, contributing to the technological and economic development of the sector, intervening in a consolidated way with the official organizations, in the defense and representation of the sector. Between 1998 and 2017 she held the technical position of Head of the Northern Delegation of CEVALOR - Technological Center for the Valorization of Ornamental and Industrial Stones and since 2017 to the present she is the Executive Director of the Northern Delegation of ASSIMAGRA - the Mineral Resources Association of Portugal.

She has been the External Technical Responsible in dozens of Quarries since 2008, assisting companies in the execution of the approved quarry plan and responding jointly with the exploring company on all issues related to with the technical management and execution of the official quarry plan in its various components.

António Fiúza

Emeritus Professor at Faculty of Engineering of the University of Porto.

Scientific Coordinator of R&D Center Centro de Recursos Naturais e Ambiente – CERENA-Polo FEUP

Topic: Hydrometallurgical Processing of Scheelite

António Fiúza is Emeritus Professor at University of Porto since 2018. He was the director of the Mining Engineering department, and of the Mining Engineering and Environment Engineering Courses (Master and PhD).

He was graduated technician at the "Junta de Energia Nuclear" and head of the planning and project division at the "Empresa Nacional de Urânio, EP", and consultant in several projects for national and multinational organizations. He taught several courses in many Universities in Europe and South America. As a researcher, he was member of the Scientific Commission of several international conferences, he created and coordinated a research center – CIGAR (Centro de Investigação em Geo-Ambiente e Recursos) and was Coordinator and participant of several research projects with national and European funding. He is the author of several scientific publications in peer review journals in different area of interest.

Actually, he is the coordinator of the division Matérias-Primas of the "Centro de Recursos Naturais e Ambiente" (CERENA).

Ernesto Fernandes

Head of Operational Coordination at SOMINCOR - Lundin Mining

Topic: Neves Corvo Mine: A Past with Future!

Ernesto Fernandes is Master's in Mining and Geo-Environment Engineering by Faculty of Engineering and full member nº 39543 of Engineers Order. He started his career at Fundifer, working on tunnels for water caption in the Madeira Island. Between 1985 and 2002, he was Production Engineer at Gré-Granitos and Production Engineer and Services Responsible at Pirites Alentejanas, SA. Since 2002, he was Production Engineer, Department Head and Director for the underground projects at Somincor. In 2017 he was Responsible for the development and production of the Lombador Project (phase 1) and for the starting of the underground works in the Zinc Expansion Project. Since 2018 he is the Head of the Operational Coordination.

Fernando Noronha

Emeritus Professor at Faculty of Sciences of the University of Porto.

Topic: The Santa Helena Breccia: a new tungsten orebody in Portugal

Fernando Noronha is an Emeritus Professor at Faculty of Science of the University of Porto since 2017. He graduated in Geology (1970) and has a PhD in Economic Geology (1984) from the Faculty of Science of University of Porto. He was Full Professor (1991- 2016) of Ore Deposits, scientific coordinator of GIMEF (Metallogeny and Fluids research team 1993), Coordinator of “Centro de Geologia da Universidade do Porto” (2003-2014) and Co-ordinator of "Instituto de Ciências da Terra-Polo Porto" (2015-2018). His most relevant experience was in mining geology (1971-1983), in field study of the geological setting of ore deposits associated with granites and responsible on the elaboration of the geological map (5 sheets) of Portugal (1/50 000) and also in the two Maps of Geological Resources (1/200 000) in collaboration with Geological Survey of Portugal (IGM) and in fluid inclusion studies. In 1976 organized the first microthermometry laboratory in Portugal at “Centro de Geologia da Universidade do Porto” and since 1983 has the responsibility for a team "Fluids and Metallogeny" which works essentially in geology, metallogeny, geochemistry and paleofluids.

Since 1993, he is the scientific leader of the team "Grupo de Investigação em Metalogenia e Fluidos-GIMEF" (Research Group on Metallogeny and Fluids) who works essentially on geology, metallogeny, geochemistry and fluid inclusions.

He has participated in several scientific projects, being the author of more than 100 publications in peer review journals.

Francisco Leite

Technical Service Director at O-ptiblast

Topic: The use of Drone for Mining Topographic Control and Fragmentation

Francisco Leite is Master's in Mining and Geo-Environment Engineering by Faculdade de Engenharia da Universidade do Porto (2013), O-Pitblast co-founder, COO and Technical Services Director. Previously worked with Maxam International S.L. as Project Engineer and Pit Supervisor at Tasiast Kinross Mine – Mauritania. Has experience in International Mining Projects (Spain, Brasil and Mauritania), where was responsible for technical services, project management, control and optimization of rock blasting.

Luís Martins

President of the Board - Portugal Mineral Resources Cluster

Laboratório Nacional de Energia e Geologia/LNEG - Advisor of the Board

Topic: Mineral Resources of Portugal and the global and European raw materials context

Luis Martins is a geologist with more than 30 years of experience in the exploration and mining sector. He graduated from the Faculty of Sciences of Lisbon (1973) and has a MsC in Economic Geology from the same faculty (1995) and also several national and international post-graduation courses. He was a former Director of the Mineral Resources Department at the Geology and Mining Institute (the Geological Survey) and a former Director of the Mines and Quarries Department at the Directorate-General of Energy and Geology (the Mining Authority). He was the Portuguese representative on the "Raw Materials Supply Group" of DG Enterprise and Industry of the European Commission (June 2010-August 2012) and coordinator of the CYTED Ibero-American Network "Land Use Planning and Mineral Resources". He was also Colt Resources Inc. Vice-President Business & Development and CEO of Ozdogu Portugal Mining and Exploration Lda.

Currently is also Vice-President of Assimagra, a Portuguese mining association and President of the Cluster Portugal Mineral Resources.

He has published 110 papers in peer review publications and presenting oral communications in about 400 national and international events.

Mário Machado Leite

Cathedratic Professor at Faculty of Engineering of the University of Porto.

Laboratório Nacional de Energia e Geologia/LNEG - Member of the Administration Board, Head of the Geology and Mines Laboratory and Head of the Science and Mineral Technology Unit.

Topic: Autogenous griding: A mathematical model

Mário Machado Leite got his PhD in Mineral Processing in 1984 at the Mining Department, Faculty of Engineering, University of Porto (Portugal) where he is full Professor of Mineral Processing. In 1996 he started a collaboration with the Institute of Geology and Mining as Director of the Laboratories of Chemistry, Mineralogy and Technology of geological materials, where he launched a system of analytical quality assurance. In 2009 it was created in Portugal the National Laboratory for Energy and Geology (LNEG) that received all the competencies and missions of National Geological Survey and the undersigned was nominated member of Board of Directors of the new LNEG, a position that holds until the present. He has been working in several research projects and contracts with mining companies. In the European H2020 FAME Project, he was WP leader contributing with his knowledge and experience, being also the responsible for the development of a continuous pilot plant, at LNEG facilities, aiming at producing Li-Mica concentrates by froth flotation. He continues teaching mineral processing at the University of Porto in graduation, master and PhD syllabus. His experience and personal interest are modeling of unit operations of mineral processing, mainly comminution, mineral liberation and flowsheet analysis.

ORAL PRESENTATIONS

Design of a Lepidolite flotation pilot plant based on lab scale tests

Rui Sousa[1,2], Aurora Futuro[2], António Fiúza[2] Mário Machado Leite[1]

[1]Laboratório Nacional de Energia e Geologia, Rua da Amieira, São Mamede Infesta, Portugal
[2]CERENA - Polo FEUP - Centre for Natural Resources and the Environment, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 PORTO, (ruijcsousa@fe.up.pt)

Abstract
Lithium is a strategic element with a key role for storage in the energy transition systems. The extraction of Li from hard-rocks deposits is fundamental to answer to the market requirements adequately. Froth flotation is the most promising technology for the beneficiation of lithium minerals, being able to produce high-grade concentrates suitable for the metallurgical extraction. Several studies have been conducted to demonstrate the potential of froth flotation for the beneficiation of different lithium ores. In this study, laboratory-scale flotation tests were carried out, together with other preliminary tests to assess the production of lithium concentrates using a lepidolite ore from Alvarrões deposit, Center Portugal. This preliminary work was the basis for the design of a processing flowsheet, demonstrated then in a pilot scale plant, allowing for the assessment of the process feasibility, but also to produce concentrates for metallurgical tests.

Author Keywords. Mineral Processing, Pilot Plant tests, Froth Flotation, Lithium-Mica Minerals.

Type: Oral Communication

1. Introduction

Lithium (Li) is a key material for modern life due to its distinctive properties, having an important role in the global energy demand (Forster and Rutherford 2011), essentially for energy storage, electrical mobility, and wireless devices. The beneficiation of hard-rock Li minerals is fundamental for the Li supply chain. Froth Flotation is the most applied technique for Li concentrates production, being able to produce high-grade concentrates (Sousa et al. 2018a, Sousa et al. 2019b, Vieceli et al. 2016). Under the scope of FAME (Flexible and Mobile Economic Processing Technologies) H2020 project, a flotation pilot plant was designed to produce Li concentrates. This work aims at demonstrating the importance of preliminary laboratory tests to design the flowsheet for pilot plant demonstration adequately.

2. Materials and Methods

A Lepidolite (Li-Mica Mineral) from the Alvarrões deposit, located in Gonçalo, south of Guarda (Central Portugal) was used in this study. Sample mineralogical characterization, size and grade analysis, froth flotation laboratory-scale tests and non-metallic by-products recovery and gravity separation for other metallic by-products recovery were carried out to evaluate the overall market potential of the ore. Finally, based on preliminary lab tests, a flotation pilot plant was designed and adjusted to run several trials of ores mined in the Alvarrões deposit.

3. Discussion

Laboratory scale tests allowed for the following remarks: i) in situ lepidolite grain size in the texture pointed out for the ore to be ground to below 0.300 mm; ii) in a roughing stage is possible to obtain concentrate grades in the range of 4% Li_2O under recoveries of 65% Li; iii) final upgrading should be performed in a separated stage, but it seems that concentrates above 4.5% Li_2O would be difficult to obtain due to very fine inclusions of silicate minerals inside lepidolite aggregates; iv) Li recovery is optimized in scavenging stages by incrementing collector dosage; v) fines removal by desliming is crucial for flotation performance and leads to the enrichment of the flotation feed; vi) heavy minerals in the paragenesis can be recovered by gravity separation. Based on these previous findings the flowsheet of a flotation pilot plant aiming the production of lepidolite concentrates was designed. A brief summary of the content of the flowsheet may be indicated as follows: material crushed below 8 mm is ground in a rod mill in closed circuit with a spiral hydroclassifier located in the mill feed to avoid overgrinding. The rod mill discharge goes to a Wilfley shaking table to recover heavy minerals, which tailings go to the spiral hydroclassifier, closing the mill circuit. The hydroclassifier overflow is deslimed in a 2-inch hydrocyclone. Then, a double conditioning stage is used for pH adjustment and collector addition. The flotation stage is composed by 6 flotation cells (35 L each), that produce a lepidolite rough concentrate and final tailings.

4. Conclusions

Mineral Processing Laboratory scale tests are crucial to assess the feasibility of concentration methods for Li hard-rock minerals upgrading. On the other hand, pilot-scale tests are important to demonstrate the applicability of these methods. This work pretends to claim the importance of laboratory scale tests for the pilot plant flowsheet design, giving valuable information for the equipment selection and future setup.

References

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Acknowledgments

Author R. Sousa also acknowledges the “Fundação para a Ciência e Tecnologia” for financing the scholarship programme with the reference SFRH/BD/114764/2016.

An assessment of Cabeço do Pião tailings aiming its recovery of metals as a sustainable alternative

Janine Figueiredo[1,2], M. Cristina Vila[1,2], Joaquim Góis[1,2], Bárbara Biju[1,2], Diogo Martins[2], Aurora Futuro[1,2], M. Lurdes Dinis[1,2], Alexandre Leite[1,2] António Fiúza[1,2]

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[2]Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 PORTO, Portugal

Abstract
The present work is under development within the scope of ERA-MIN/0007/2015 REMinE project, aiming to assess the recovery of metals present in an abandoned mine tailings deposit, located in central Portugal, named as Cabeço do Pião. These materials have been exposed to atmospheric conditions through the last 90 years posing a risk to the environment in general. Nevertheless, they may contain significant content of valuable metals, such as tungsten. The multivariate analysis was applied to the elemental chemical data of the tailings, and it allowed to establish mineralogical associations, proving to be a useful planning tool in a future re-mining of the tailings deposit. Re-mining these tailings can be considered as a solution that minimizes environmental impacts recovering some essential metals at the same time.

Author Keywords. Tailings disposal, re-mining, tungsten, multivariate data analysis, geostatistics.

Type: Oral Communication
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1. Introduction

Many mining abandoned sites, in Europe and worldwide, have an old dam which has been generated high impacts and several potential risks to the environment and the local community. Tailings from metallic mining when are indiscriminately deposited, due to their sulfide content, could result in the spread of heavy metal contamination material through air or water streams to the surrounding regions. These deposits also may contain significant valuable metals, considering the current market prices for some metals and the availability of those commodities.

This paper aims to be useful in the assessment of re-mining tailings as a secondary raw ore source. The geostatistics and multivariate data analysis treatment were adopted to understand the spatial distribution of each element analyzed and to infer the zonation of metal grades present in the tailings.

2. Site Description

Cabeço do Pião is an abandoned mine site, located in Castelo Branco district and belongs to the Municipality of Fundão. The site is composed of mine waste and tailings originated by a former tungsten processing plant (“Rio”), which belonged to the Panasqueira Mine Complex. The large volume of the dam configures an altered landscape with an average height of 90 m and a steep slope gradient up to 35 °, constituted by a total volume of waste rock and tailings of roughly 1.900.000 m^3. A fine tailings product of the wolframite

concentration was discharged into the top of Cabeço do Pião dam, until 1996. The volume of tailings is around 731.034 m^3 with high heavy metal(loid) content, like As, Cu, Zn, and W.

3. Materials and Methods

A sample campaign was conducted in the surface of Cabeço do Pião area, submitted to a designed as a regular rectangular mesh, at two different levels (depths and superficial). A total of 66 samples were analyzed and studied for physical-chemical characterization. Based on the chemical analysis characterization (Energy Dispersive X-ray Fluorescence) results, 23 locations were selected, totalizing 46 samples considering both depth levels. These data were submitted to geostatistical and multivariate data analysis comprehensive study using appropriate software tools, as Surfer® 15 and Andad® 7.10.

4. Results

The XRF analysis detected, in all the samples, the presence of some toxic elements as well as valuable metals. The analysis of grades shows that the tailings have economic potential in tungsten; however, the dam represents an environmental threat due to the high arsenic concentrations. The best-fit variogram model, based on cross-validation, was selected to assess the spatial distribution of the grades for the main elements. The spatial distribution of tungsten on deep samples is shown in (Figure 1a) (Figueiredo et al. 2018).

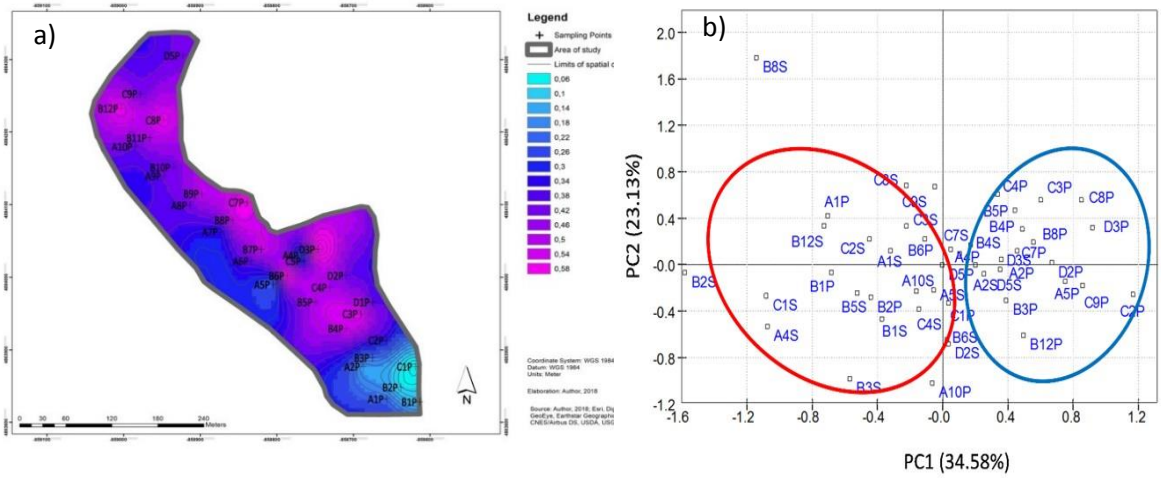

Figure 1: a) Contour map of tungsten of deep samples. b) Projection of the samples in the factorial planes

The projection of the samples on the principal components analysis (PCA) PC1 and PC2 (Figure 1b) allows the distinction between surface and deep samples. This evidence leads to separate the analysis of the samples for each depth level studied. The elements variables were (Mn, Fe, Cu, Zn, As, W), which are interesting for a future re-mining project.

5. Conclusions

Multivariate data analysis and the geostatistical study showed potential as an approach to identifying regions of high element content present in the dam, and in the planning of re-mining, according to the metal of interest. Further, the PCA may be considered a useful

tool to understand the behavior of the tailings compared with original geology, industrial processing ore from Panasqueira Mine, and adverse weather conditions.

References

Figueiredo, Janine, M. Cristina Vila, Joaquim Góis, Bárbara Pavani Biju, Aurora Futuro, Diogo Martins, M. Lurdes Dinis, and António Fiúza. 2018. "Bi-Level Depth Assessment of an Abandoned Tailings Dam Aiming Its Reprocessing for Recovery of Valuable Metals." *Minerals Engineering* 133 (December 2018): 1–9. https://doi.org/10.1016/j.mineng.2018.12.016.

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Separation of PS and ABS using froth flotation combined with a heating treatment

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Abstract
This study proposes the study of the separation of PS and ABS plastics from the waste of electrical and electronic equipment using froth flotation combined with a heating treatment (HT). Froth flotation, commonly used in mineral processing, is a promising technique to separate plastics with similar density. In the present study, the separation of PS and ABS, with size ranging from 2 to 4 mm, was addressed. Due to the hydrophobic nature of both plastics, a boiling treatment was used prior to flotation to physically modify the surface of ABS and render this polymer hydrophilic. It was developed an L16 Orthogonal Array of Experiments using the Taguchi experimental with seven manipulated variables: HT time, HT temperature, elapsed time between the end of the HT and the start of the flotation test, frother concentration, air flow rate, impeller speed and pH. The results obtained show the ability of the proposed treatment to separate PS from ABS while obtaining products with high purity. Furthermore, the experimentation methodology allows the correct evaluation of the effect of several operating variables and some interactions on the flotation results.

Author Keywords. Plastics separation, ABS, PS, WEEE plastics, froth flotation, Taguchi design of experiments

Type: Oral Communication
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1. Introduction

The use of froth flotation for the separation of plastic mixtures is referred by several authors as a simple and effective method (Wang et al., 2015). However, it is necessary to manipulate the natural wettability of the plastics in order to provide a selective separation. Wang et al. (2014) developed a physical conditioning method by boiling in water a mixture of acrylonitrile-butadiene-styrene (ABS) and polystyrene (PS), produced a hydrophilic surface ABS. Salerno et al. (2018), proposed the use of factorial experimental designs to evaluate the separation of plastics by froth flotation. This study proposes using a Taguchi Experimental Design to study the impact of the froth flotation combined with a heating treatment on the separation of PS and ABS plastics.

2. Materials and Methods

The PS and ABS samples were from WEEE, and it was used the size range of 2 to 4 mm. The samples were heated in tap water using a heating plate with magnetic stirring. The treatment followed (Wang et al. 2014) boiling treatment procedure. After the treatment, the samples were cooled by water directly and left (or not) to rest for a certain period before flotation tests. The flotation tests were carried out in a single separation stage in a

Leeds Flotation Cell using tap water. The reagents used were Methyl Isobutyl Carbinol as frother agent and for the pH modification solutions of 25% of sodium hydroxide and 20% of sulfuric acid. The variables chosen for manipulation were related to the heating treatment (HT) applied to the plastics, namely the treatment time, temperature and time between the end of the HT and the flotation test and flotation operational variables, such as frother concentration, air flow rate, impeller speed, and pH. According to the Taguchi design, two levels for each parameter were chosen. To study the main effects of the factors as well as some expected interactions, an L16 (2^7) orthogonal array (OA) of experiments was chosen, with 16 tests plus three tests on a centre point. All tests were randomly performed to ensure the independence of observations and errors.

3. Results and Discussion

In (Figure 1) it is shown an overview of the experimental results. The ultimate recovery in the floated product is higher in the ABS samples, particularly in the treated samples tests (Figure 1b), indicating that under the treatment conditions PS was depressed while the overall floatability of ABS was slightly altered, unlike (Wang et al. 2014) results.

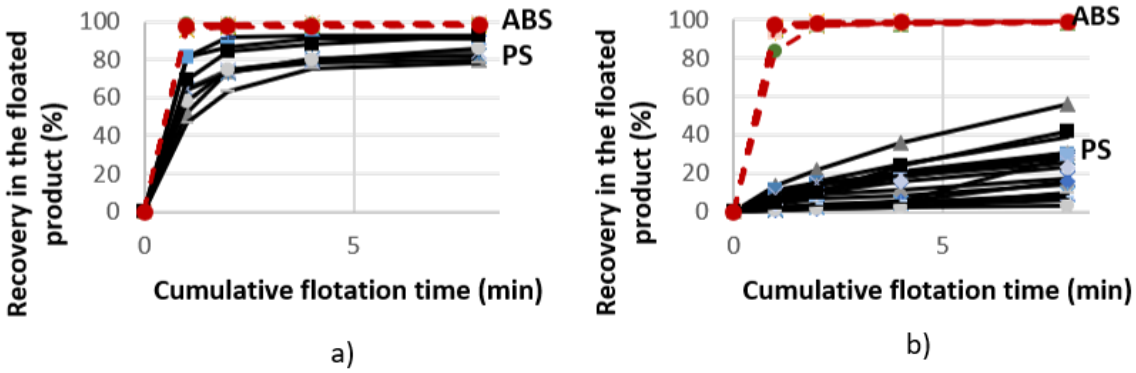

Figure 1: ABS and PS recovery in the floated product over time, without heating treatment (**a**) and with the heating treatment (**b**)

It was possible to achieve both floated and sunken products with high purity in ABS and PS, respectively. After two minutes of flotation, it was possible to achieve 91% ABS in the floated product and 97% PS in the sunken product. The statistical significance of the variables main effects and interactions were confirmed by analysis of variance effects (ANOVA). The models with statistical significance that better fit the responses to the factors were linear models, both presenting an adequate signal-to-noise ratio. For the PS response model, the most significant factors were frother concentration, air flow rate, treatment temperature, impeller speed, time occurred between HT and flotation test, and treatment time. The ABS response model shows that the most significant terms were air flow rate, pH, time occurred between HT and flotation test. The predicted interactions presented high significance, namely frother concentration, and air flow rate, frother concentration and pH, frother concentration and impeller speed, as well as some confounded interactions yet to be disclosed.

4. Conclusions

This work shows the efficiency of the froth flotation combined with the heating treatment to the separate the PS and ABS plastics. The Taguchi method presents as an adequate experimentation methodology to correctly identify and evaluate the effect of several operating variables and their predicted interactions on the flotation results.

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Strategies to integrate geological consistent information into geostatistical seismic inversion methods

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Abstract

During the last years, numerical models have been the preferable tool to characterize the Earth subsurface geology. These are often inferred using seismic inversion as a common geo-modelling technique. While these methods allow reliable inferences of the spatial distribution of the subsurface rock properties, there are always discrepancies between the simulated models and the reality. The main goal of this work is the development of methodologies to integrate uncertainty and auxiliary geological information in a geostatistical framework of seismic inversion. The several strategies developed under this scope were successfully applied to synthetic and real case studies allowing for the improvement of subsurface models while reducing the uncertainty associated with the spatial distribution of elastic properties.

Author Keywords. Geostatistical inversion, reservoir modelling, stochastic simulation

Type: Oral Communication

1. Introduction

Seismic inversion techniques play an important role for a quantitative evaluation of hydrocarbon reservoir characterization and monitoring studies. The existing seismic inversion techniques may be divided into deterministic and stochastic (Bosch et al. 2010). Iterative geostatistical seismic inversion (Azevedo and Soares 2017) is a stochastic inversion technique that allows the integration of both direct (i.e., well-log data) and indirect (i.e., seismic reflection data) measurements, the inference of small-scale variability and the modelling of uncertainty related to the spatial continuity patterns of rock properties. The inverted models are always approximations of reality due to several factors such as the complexity of subsurface geology, the non-uniqueness of seismic data (inverse problem) or measurement errors in data acquisition (Tarantola 2005). In this work, different strategies are presented to incorporate uncertainty (Pereira et al. 2019) and prior geological knowledge in seismic inversion procedure. These methods aim at increasing the geological reliability of the inverted models while quantifying the spatial uncertainty in the final elastic models.

2. Methods

Traditional iterative geostatistical seismic inversion uses stochastic sequential simulation and co-simulation technique (Soares 2001) as model perturbation and where the spatial patterns of rock properties are described by a single global variogram model. However,

these methods struggle to reproduce the subsurface properties when challenged to highly non-stationary geological environments (e.g., curvilinear geological structures as channels). This work presents the inference of elastic properties incorporating local anisotropies, which acts as steering volumes when the model parameter space is perturbed to generate the models. These local anisotropies, directly computed from seismic reflection data using seismic attribute analysis, account for both local structural (azimuth and dip) and spatial (variogram ranges) information.

3. Discussion

The results of inverted models for a synthetic application example are shown in (Figure 1). The integration of a data-driven but geological consistent approach (Figure 1b) allows handling better non-stationary patterns when compared with conventional approaches (Figure 1a) that rely on a global variogram model to express the spatial continuity pattern of the true geology.

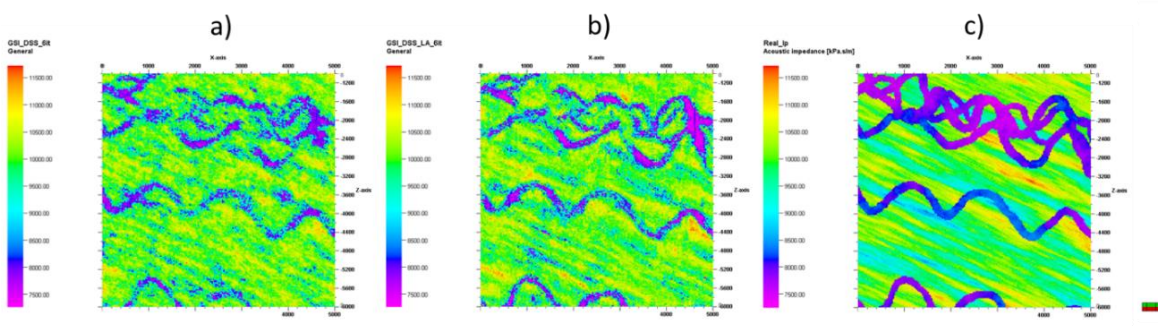

Figure 1: Comparison of vertical time sections of inverted Ip using stochastic simulation with a global variogram (Figure 1a) and with local anisotropies corrections (Figure 1b); and the reference acoustic impedance section (Figure 1c)

4. Conclusions

This work proposes consistent methods to improve the reproduction of relevant and non-stationary geological features in inverted models resulting from geostatistical seismic inversion. The development and application of proposed methods under a geostatistical framework allowed the uncertainty assessment of spatial continuity patterns of inverted elastic properties.

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Pore Pressure prediction and modeling using seismic velocities

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Abstract

A quantitative predrill prediction of pore pressure is critical when drilling in overpressured formations and for an effective reservoir simulation and management. Accurate pore pressure prediction can be obtained from elastic wave velocities using a velocity-to-pore-pressure transformation model, calibrated with laboratory measurements or offset well data. This work presents a methodology for three-dimensional pore pressure prediction using a refined velocity field built from seismic velocities measured at the laboratory. Pore pressure models are then inferred based on Eaton's and Bowers' pore pressure estimation methods. Because seismic velocities correlate with formation's effective stress, these were inferred from triaxial compression tests performed on rock samples from the Codaçal limestones, the Portuguese geological unit analogues of the reservoir formations of Brazilian pre-salt, and was assessed the variation between vertical effective stress and porosity at depth.

Author Keywords. Pore Pressure, effective stress, elastic wave velocities, triaxial compression test, Eaton's method, Bowers method.

Type: Oral Communication

1. Introduction

Abnormal pore pressures are encountered worldwide, often resulting in drilling problems such as borehole instability, stuck pipe, lost circulation, kicks, and even blowouts. Predict the spatial extent of overpressured formations is required to drill wells safely and with reduced costs. Typically, the pore pressure predictions use models based on porosity and stress values available from existing well-log data. A pre-drill estimate of pore pressure can be obtained from seismic velocities using a velocity-to-pore-pressure model calibrated from offset well data. In this work, we propose the use of laboratory measurements acquired using rock samples to calibrate the velocity-to-pore-pressure transform model.

2. Methodology

Laboratory tests were developed to measure simultaneously porosity, seismic waves propagation velocities, and deformability parameters, E and ν, respectively. These experiments used rock samples from Codaçal limestone's geological unit through triaxial compression tests. Twenty-five core samples were tested at IST's GeoLab (Laboratory of Geosciences and Geotechnologies). These measurements allowed relating the porosity and seismic wave velocities with the effective stress and pore pressure, to further develop a compaction trend model. The pore pressure (P_p) can be calculated from the relation between elastic wave velocity and vertical effective stress. The models proposed by (Eaton

1975) and (Bowers 1995) are the most used methods in the oil and gas industry to predict P_p using vertical effective stress. The models proposed herein using the laboratory measurements have been developed to use the Eaton and Bowers methods in an efficient pore pressure prediction.

3. Results

Laboratory measurements allowed to build P-wave (Vp) and S-wave (Vs) velocities models in depth. These are important to define the normal compaction trends needed to predict pore pressure using Eaton's method. The calibrated Vp versus depth model (Formula 1) from the laboratory experiments is:

$$V_{Normal} = 2081.2 + 0.9711z \quad (1)$$

The calibrated V_p versus effective stress trend model (Formula 2) from Bowers equation was also defined:

$$V_{Normal} = 1976 + 326.3\sigma_v'^{0.3646} \quad (2)$$

These experimental models were applied to a synthetic P-wave velocity cube (Pinto 2014) developed for a carbonated sedimentary basin to assess the reliability of the proposed approach to estimate pore pressure. Using the seismic velocities, the physical and mechanical parameters and the vertical effective stresses, 3D models were generated for normal compaction, overburden stress, hydrostatic pressure, porosity, vertical effective stress, density and V_p in normal compaction conditions. Finally, pore pressure models (Figure 1) were developed using Eaton's and Bowers' methods, the synthetic P-wave velocity cube, and the analysis from the lab results.

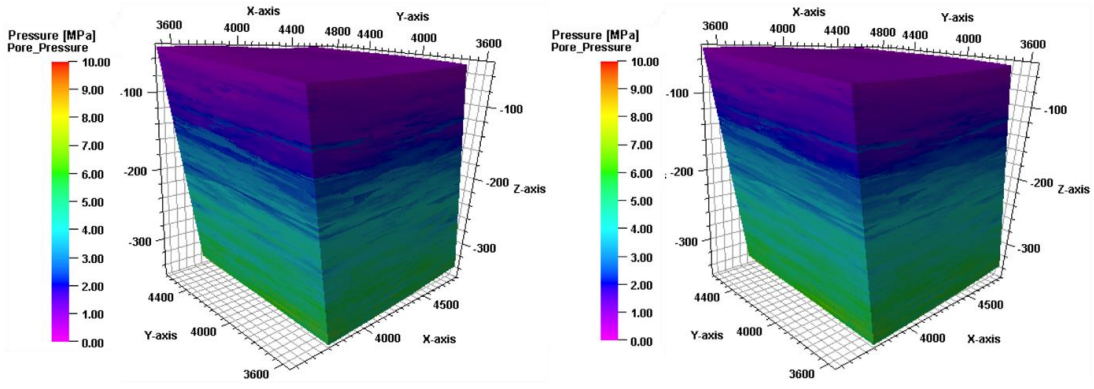

Figure 1: a. Pore pressure prediction cube using the Eaton method; b. Pore pressure prediction cube using the Bowers method

4. Conclusion

A qualitative and quantitative analysis of the proposed methodology was performed by comparing the laboratory results with empirical relationships from other authors, and distinct trends between lower and higher confining pressures were found. Using the Eaton method and the Bowers method, it was concluded that in the Eaton method, the

compaction trend model dependence is huge and can induce underestimated P_p estimations. The Bowers method has a higher sensitivity in P_p estimation from seismic velocities. Finally, it is concluded that this methodology, using triaxial tests, enables a more robust approach to P_p prediction.

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Inferring subsurface acoustic properties through different seismic inversion methodologies for reservoir characterization

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Abstract
Reservoir characterization relies on the understanding of the spatial distribution of subsurface rock properties. However, the inference of those properties from seismic data is not a direct process requiring the use of inversion algorithms to transform the observed seismic data into subsurface elastic and/or rock properties. This work focuses on the application of deterministic and stochastic inversion methodologies to a real case application. Results are compared and contrasted aiming for the best characterization possible of an oil reservoir.

Author Keywords. Stochastic seismic inversion, deterministic seismic inversion, reservoir characterization, rock properties

Type: Oral Communication
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1. Introduction

The prediction of the spatial distribution of the subsurface elastic properties can be made using seismic reflection data, which allows having a better knowledge of the reservoir. The understanding of the spatial distribution of the reservoir's petrophysical properties reveals to be a key aspect for reliable characterization. This study can be done by the generation of subsurface models with properties of interest conditioned spatially to the seismic reflection and locally to well-log data. Solutions for seismic inverse problems can be achieved through different methodologies, namely, deterministic and stochastic approaches. While in deterministic approaches it is obtained a single solution that best fits the data by the minimization of an objective function, stochastic methodologies provide multiple solutions and allow uncertainty assessment and quantification by the use of probability density functions on the model parameter space (Bosch et al. 2010).

2. Materials and Methods

This work compares a deterministic model-based seismic inversion method against an iterative global geostatistical acoustic seismic inversion one (Azevedo and Soares 2017). Both methods are used to infer the spatial distribution of acoustic impedance and facies with different parameterizations. The best-fit inverted models are compared in terms of spatial continuity, geological reliability and against a blind well not used to constrain the inversions.

3. Discussion

Five seismic inversions were run over the dataset with different *a priori* conditions (Figure 1). Variograms with one, two, and three structures, low-frequency models from the deterministic inversion and a regionalization model with two different zones were considered to compare the results of the two seismic inversion methods.

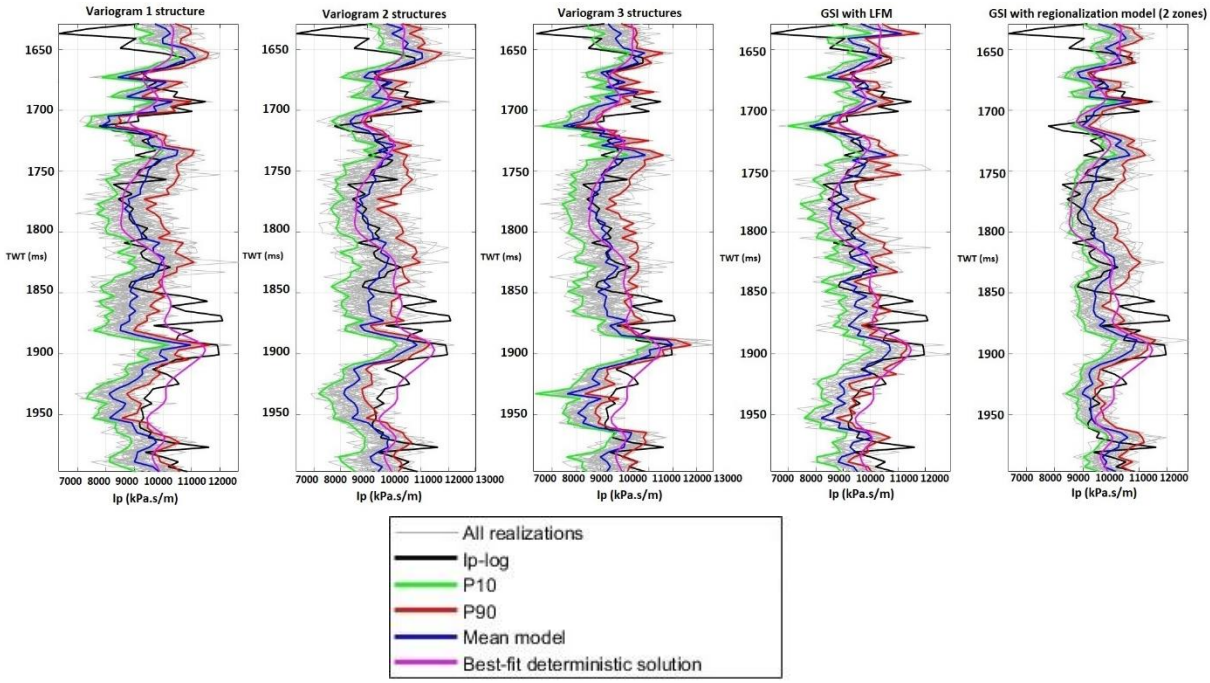

Figure 1: Different scenarios were considered in order to explore the uncertainty in spatial continuity model

Generally, the results from the different scenarios encapsulate the P-impedance upscaled logs and are constrained within the P10-P90 interval. When the low-frequency model is considered, the results are closer to the mean value while in the regionalization model, more geological information is added, which can provide a result closer to the real geology.

4. Conclusions

Comparing the two different seismic inversion methodologies, deterministic inversion results are smoother and closer to the mean value while in stochastic inversion the results not only can incorporate more geological information but also ensure the reproduction of the extreme values which allow a better reservoir characterization.

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Grade uncertainty integration into STPS

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Abstract
Short-term production scheduling (STPS) characterizes the time sequencing of reserves mining for a short horizon. These reserves are inherently uncertain, both due to high spatial grade variability and data scarcity. Most underground mines use Krige estimation to model reserves, however, while this provides good grade estimates it does not characterize spatial uncertainty. Hence, production sequencing is often scheduled without uncertainty characterization, resulting in unpredicted deviations from scheduled production. This work proposes a method enabling reserves model uncertainty characterization and its integration onto STPS. The method leverages on the usage of Direct Sequential Simulation (DSS) combined with Gaussian Mixture Models (GMM) to retain reserves model uncertainty into the STPS, enabling uncertainty to be used as an STPS optimization criterion.

Author Keywords. Short-term production scheduling, underground mine planning, Uncertainty Integration

Type: Oral Communication

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1. Introduction

Stochastic simulation has already been applied in surface mines for long-term production scheduling (Ramazan and Dimitrakopoulos 2013), and to solve the underground equivalent (Carpentier et al., 2016). The short-term approach consists of optimizing mining sequence to each simulated realization, followed by unitary period uncertainty characterization. This practice has two drawbacks: (i) the need to retains all simulated models and calculate an optimal mining sequence for each one, highly impractical for large block models; (ii) the period uncertainty is only known after the optimum mining sequence is applied to all simulated models, so cannot be used for STPS optimization. The proposed method converts static into dynamic uncertainty of reserves via GMM. For each simulated block, only local mean and variance are retained. Then, a GMM is applied to characterize the uncertainty of the scheduled production. Once grade uncertainty for a candidate period is evaluated, it can be used as an STPS optimization parameter.

2. Methodology

2.1. Reserves Model generation

Reserves Model is generated using DSS with point distributions (Horta and Soares 2010). This algorithm allows the integration of uncertain data into the model, and due to the enabled higher data density, produces a model with overall reduced uncertainty (Neves et al. 2018).

2.2. Grade uncertainty aggregation into STPS

Grade uncertainty is aggregated into STPS' period via a GMM as is illustrated in (Figure 1). The $m \times N \times b$ values characterizing the period's blocks uncertainty are turned into a GMM parametrization with $2 \times b$ parameters. From there, values can be easily drawn to serve as optimization criteria in an STPS optimization algorithm.

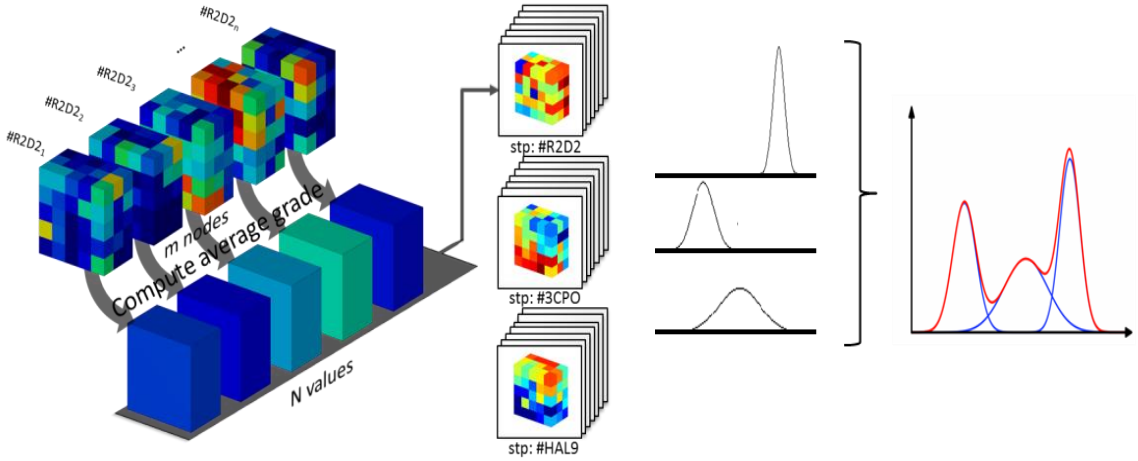

Figure 1: Grade uncertainty aggregation from model to STPS period

3. Results

The method enables the preservation of uncertainty characterization in STPS and its usage in the optimization routine. (Figure 2) shows the resulting STPS integrating uncertainty.

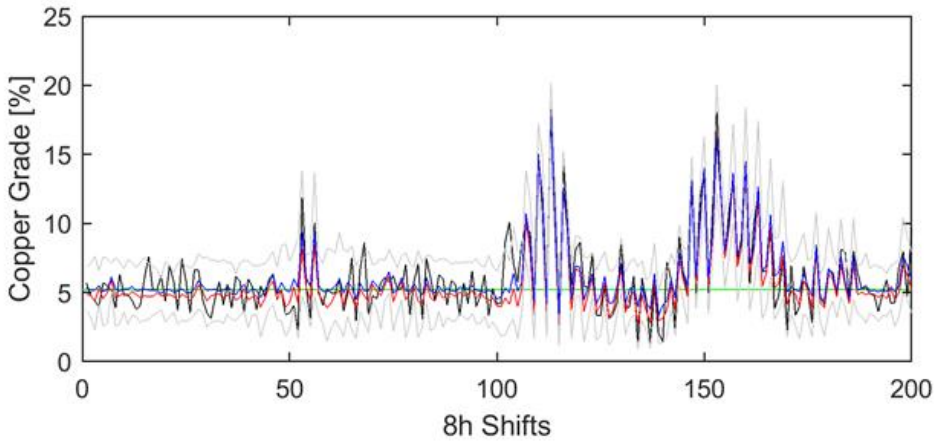

Figure 2: STPS integrating grade uncertainty, grey lines show upper and lower uncertainty bounds, blue line is expected production, red line P50, black line actual production, green line target production

4. Conclusions

The method allows grade model uncertainty integration into STPS optimization. The resulting STPS retains grade uncertainty characterization. In addition, STPS with uncertainty integration has tighter uncertainty bounds than traditional schedules would,

as uncertainty is minimized during optimization, yielding smaller deviations to scheduled production.

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Acknowledgments

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Exploration Data Analysis and Mineral Grade Estimation of Calcium fluoride of the Okorusu Ore Deposit, Namibia: A Case Study

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Abstract

A reliable mapping and understanding of the spatial distribution of the ore grade in a mineral deposit is a critical issue in ore reserve estimation, previously and during its exploitation, as it assists geologists and mining engineers in delineating an optimized exploitation project. In this paper, the objective is to illustrate and compare the application of a geostatistical method (ordinary kriging estimation) and a common geometrical estimation method (inverse square distance) as mineral resource estimation methods, using the georeferenced data obtained from an exploration and geochemical prospecting process at Okorusu Mine fluorite ore deposit in Namibia. Surfer software was used as a 2D mapping tool to evaluate the spatial distribution and compare the estimation error of two interpolation methods applied to calcium fluoride (CaF_2) borehole sampled data. Estimates from both methods have descriptive statistics closed to the measured sample set, although different spatially distributed estimation models.

Author Keywords. Geostatistics, variogram, resource estimation, ordinary kriging, inverse square distance.

Type: Oral Communication
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1. Introduction

The accuracy of mineral resource and ore reserve estimation is necessary for the process of mining deposit evaluation; planning and mine design (Shahbeik et al. 2014). The complexity of the geological processes and the limitation of financial resources are some of the difficulties that geologists and mining engineers face in the process of mineral resource estimation. This results in many failure projects around the world. Currently, there are two common methods developed and used for the estimation of spatial data: geostatistics, specifically kriging and simulation (probabilistic interpolator) recommend by several researchers (Shahbeik et al. 2014) and inverse square distance (deterministic interpolator) favored in some research work (Arfaoui and Inoubli 2013). This paper aims to evaluate calcium fluoride (CaF_2) spatial distribution and compare the estimation error of the two referred interpolation methods based on an analysis of subsurface geochemical data.

2. Materials and Methods

This study relates to the geochemical exploration data from Okorusu Mine, which has an open pit mine of CaF_2 located approximately 60 km northwest of Otjiwarongo in Otjozondjupa region, Namibia. The data set used in this study comprises 749 sample points from 43 boreholes. The samples have the following attributes: HoleID, x, y, from, to and CaF_2 concentration measurement, where x, y, and z are the longitude, latitude and

elevation coordinates of the sampled drill-holes. Before the interpolation methods were applied to the dataset, the data were subject to exploratory statistical analysis (ESA) and spatial structural analysis (SSA) to the possible detection of mistakes and anomalies. In addition, to determine the data probability distribution, and to make hypotheses and identify possible spatial patterns in the data. Prior to using kriging estimation methods, the studied regionalized variables shall be mathematically characterized by, for instance, a continuous variogram model based on a structural analysis in which experimental directional variograms are obtained using the following (Formula 1).

$$\gamma(h) = \frac{1}{2N(h)} \times \sum_{n=1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2 \quad (1)$$

Where: γ (h) = experimental semivariogram, N (h) = the number of pairs of values Z' (x_i), Z (x_i +h), h = lag distance.

Microsoft Excel was used for the descriptive statistics while Surfer 11 for the estimation via kriging and IDW.

3. Results and Discussion

A summary of the ESA results is presented in Table 1.

Parameter	Mean (%)	Median (%)	SD	SD. Error	C.V	Maximum (%)	Kurtosis	Skewness
Measured	40.89	42.35	13.68	2.09	0.36	71.88	1.32	-0.54
OK	39.47	40.14	6.09	0.22	0.15	62.21	2.57	-0.05
IDW	39.34	40.36	6.93	0.25	0.18	68.92	2.94	-0.08

Table 1: Descriptive statistics of sampled and estimated geochemical data

The SSA results led to the conclusion that the studied geosystem should be considered stationary and anisotropic, and consequently, ordinary kriging was chosen for estimation. The fitted spherical continuous variogram model with longer range along 30° direction model (Nugget effect =115, Range = 230, Sill = 235) was chosen based on the root-mean-square error (RMSE) value and the Akaike's Information Criterion value. To map the estimated spatial distribution of CaF_2%, a 10 m x 10 m grid was used. The significantly different spatial distribution maps generated from the two methods are presented in (Figure 1). The patterns of distribution do not show any global trend in the data but show the >42 % of estimated CaF_2 located in the center of the study area. Both methods show a tendency to smoothing as the small values are inflated towards the mean and the large values are deflated likewise.

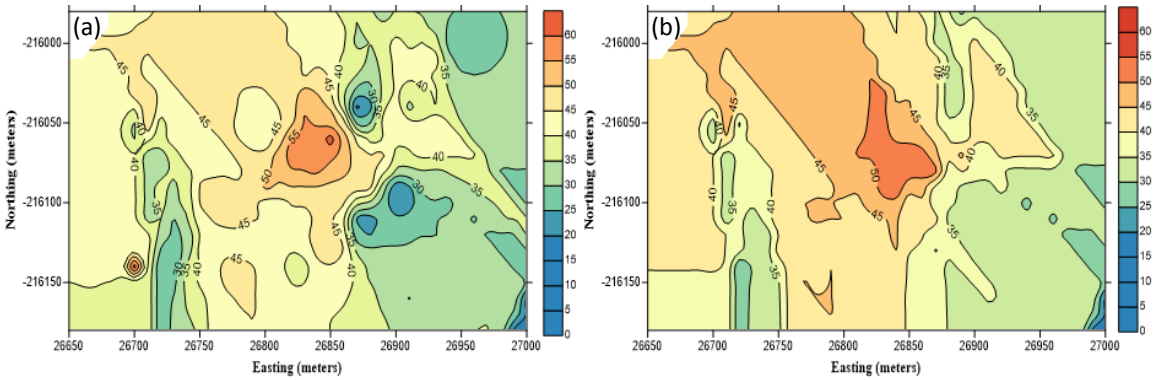

Figure 1: Spatial interpolation of CF_2 using IDW (a) vs OK with a spherical model (b)

4. Conclusions

This study shows that although having very close descriptive statistics, there are differences on the mapping results obtained using two common estimation methods in analyzing the CaF_2 spatial distribution in the process of mineral deposit exploration, evaluation, and exploitation. Moreover, based on the cross-validation analysis between the measured value and estimated value the OK method has shown to be better as it has correct this RMSE of 15.00 % while the OK have 17.40 %.

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Simultaneous mine exploitation with environmental recovery-circular economy concept

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Abstract
A conceptual approach was developed to test the technical feasibility of carrying out simultaneously open pit extraction and environmental recovery of a phosphate deposit. The proposed feasible depth for exploitation was determined considering the land surface level after recovery, to avoid any drainage problems in the future. During the extraction, the ore is transported by conveyor belt, and a tunnel is built over the conveyor belt under the waste dump, continuously, until the Ultimate Pit Limit. This infrastructure allows the transition from an open pit into underground mining with no need of creating a new one, as its dimensions allow the movements of underground mining vehicles. The developed work is based on geological and topographical data from a phosphate deposit which enabled the design of this proposal. The greatest challenge was to manage the masses of the removed material with the tailing of the phosphate processing plant to fill the pit. The closed cycle created from the production to the waste management is based on the circular economy concept leading mining industry into sustainable development.

Author Keywords: Open pit, Environmental recovery, Circular economy, Sustainable development

Type: Oral Communication
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1. Introduction

Phosphate rock can be extracted by surface or underground mining or the combination of both, although being extracted mainly by open pit mining (Daafi et al. 2014) or stripping mining using drill/blast and draglines (Asri and Daafi 2016). The appropriate mining method can be chosen according to the deposit's characteristics. Surface mining method involves the removal of the overburden. The management of these volumes is an essential task in mine environmental recovery. It is necessary to consider the site topography and morphology, as well as the geological and geotechnical properties of the removed materials (Oggeri et al. 2018; Karan, Kumar, and Samadder 2017). In the case of combined exploitation, the optimal transition point from open pit to underground mining should be determined (King, Goycoole and Newman 2017).

The main goal was to design the open pit mine with simultaneous environmental land recovery and to create at the same time conditions for underground mining.

2. Materials and Methods

In this manuscript, an open pit mine planning is presented where the ultimate pit limit (UPL) and the mine block sequencing were determined with a simultaneous recovery using the generated wastes/tailing to create a closed mine cycle. The volumes removed from each layer were calculated as well, as the total volume of the pit based on the mine design. The volume of the dump has been calculated, considering the swelling factor of each material (waste/tailing) (Eastman et al. 2011). The closed cycle from the production of primary materials to the management of the wastes is a new concept of a circular economy that can lead mining industry into sustainable development (Ghisellini, Cialani, and Ulgiati 2016).

3. Results and Discussion

The results of the performed calculations were compared with the total amount of material removed from the pit to verify the circumstances in which the generated waste materials are enough to fill the space open by the mining operation. The comparison has shown a significant difference and validated that, although phosphate exploitation generates many wastes, they are not enough to make the environmental recovery. To fill the rest of the pit, it was necessary to calculate the tailing volumes produced by the processing plant, considering the practical performance of each treatment phase and the phosphate-swelling factor as well.

After these considerations, the difference became smaller, which demonstrated that the quality of landscape recover could be improved by transporting the tailings to the waste dump. The dry tailings can be transported into the dump by dumpers, while the wet tailings can be pumped through pipelines to play the role of cement which gives more compaction to the landfill.

4. Conclusions

From the obtained results, it can be concluded that the work's goal was achieved and the technical feasibility of carrying out the open pit mining with the environmental recovery and also to create conditions for the transition into underground mining, was proved.

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Bioburden and Radon in Indoor Spas Air Project - BRISA

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Abstract
Hydrogeological and geothermal resources are a significant part of the Portuguese natural resources. Portugal is one of the world's richest countries in mineral and spring waters where the tradition of hydrotherapy dates back at least to the Romans, who had the habit of taking hot medicinal waters. Mineral and spring water exploration either for thermal baths or for bottled water are highly related to the hydrogeology. Some thermal waters have often shown to be enriched in dissolved radon, which can also accumulate in the air during therapy treatments. In these situations, radon can enter into the human body through the exposure to these media, drinking-cure, thermal spa-cure or dry spa, and inhalation therapy. Additionally, there is a gap of information regarding microbial contamination in these indoor environments, although it can influence the health of users and staff who attend them.
The project aims to study the exposure of bathers and workers to bioburden (comprising fungi and bacteria) and radiation burden in different thermal spas in Portugal.

Author Keywords. Radon, bioburden, thermal spas.

Type: Oral Communication
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1. Introduction

Hydrogeological and geothermal resources are a significant part of the Portuguese natural resources. Mineral and spring water exploration either for thermal baths or for bottled water are highly related to the hydrogeology. Portugal is very rich in mineral and spring waters, and the composition of these waters has raised the interest of scholars and investors over the years.

The tradition of hydrotherapy dates back at least to the Romans, who had the habit of taking hot medicinal waters. Still, nowadays, thermal bathing pools in spa centers containing geothermal water are very popular and, therefore, the thermalism in Portugal is experiencing a phase of growth, evolution, and innovation (Silva et al. 2017). Thermal spas aim not only to improve some techniques of classic use but also to attract new audiences, for a more playful aspect, the "wellness", although most of the times this water remains without any kind of disinfection or treatment (Silva et al. 2017).

At the same time, with the increasing tourism in Portugal, the number of bath users is also expected to increase, which can in turn increases the bioburden in the pools environment and, therefore, compromise not only bathers but also workers' health safety (Klánova & Hollerová 2003; Leung & Chan 2006). In addition, thermal waters have often shown to be enriched in dissolved radon, which can also accumulate in the air during therapy treatments (Park et al. 2013).

In these situations, radon can enter into the human body through the exposure to these media, drinking-cure, thermal spa-cure or dry spa, and inhalation therapy. Moreover, radon present in spa facilities has been identified as an agent of additional radiation burden for bathers. The relation between radon in air and the risk of lung cancer is well documented but what has not been studied yet is the variety of microbiota that may be present in thermal water and how they are affected, among others things, by the presence of radioactive elements such as radon. These natural environments are characterized by different conditions which are constantly changed by many factors (ventilation, temperature, humidity, etc.) that also may affect the indoor radon concentration (Mentese and Tasdibi 2014).

2. Materials and Methods

Bioburden (fungi and bacteria) is being assessed covering indoor air samples and passive methods, such as surfaces swabs. Radon concentration as bioburden is being measured in the indoor air of all rooms of the spa facility: pools, thermal inhalation therapy rooms (ORL), showers, technical areas, buvete halls, bathtubs, etc. Water samples are being collected from water points to measure radon concentration: springs, boreholes, buvete, emanatorium, ORL, showers, bathtubs, pools, etc. Gamma dose rates are also being assessed in addition to total gamma measurements. The effective dose will be estimated with the collected data and for a realistic exposure scenario. Part of the microorganism's data is being collected and managed by Lisbon School of Health Technology from Politécnico de Lisboa. At a later stage, these data will be combined with the results from the radiological assessment, both for environmental and occupational environments.

3. Discussion

A major outcome of this work will be the protocols and guidelines specifically designed to assess and reduce bioburden and radon levels. A better understanding how external factors influence indoor radon levels will be outlined too, and therefore all thermal SPA participants will receive instructions, through technical-scientific reports, based on the aforementioned deliverables informing how they can contribute to avoiding bioburden and radon exposure. In addition, a checklist standardized for the workplaces characterization will be available to facilitate comparisons between different studies. This approach will permit efficient dissemination of the results through scientific society.

4. Conclusions

The proposed works link the exploration and use of hydrogeological resources with both environmental and occupational exposure to different risk factors such as radiological and biological.

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Radioactivity and risk assessment in the Nisa area applying basic geostatistical methods

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Abstract
The Nisa uranium deposit, located in Central Portugal, was discovered during the 1950s when evidence of uranium minerals were detected in apatite deposits in the region (Limpo de Faria and Pinto de Mesquita 1962). Even though an experimental open pit was developed in the Nisa deposit, the occurrences identified have not been exploited until this day. In the experimental pit area, a few open pits and dumps remain in place, and there is a concern to local and national authorities. A geophysical survey was carried out in a selected area comprising the old rock blasting and surrounding areas (Ramalho, et al. 2012). Concentrations of ^{40}K (%), ^{232}Th (ppm) and ^{238}U (ppm) were measured using a gamma-ray spectrometer Exploranium GR-256 in georeferenced locations. Using the acquired data, geostatistical methods were applied to assess and map the locations where the soil is associated with higher values of radiation hazard (Hex) and excess lifetime cancer risk (ELCR).

Author Keywords. Geostatistics, radiation, uranium, radiation hazard, Nisa, Portugal

Type: Oral Communication
Open Access Peer Reviewed

1. Introduction

The Nisa deposit is located in the northern border of the granitic batholith of Nisa-Castelo de Vide, also covering part of the schists of the *Complexo Xisto-Grauváquico das Beiras* (Beiras Schist Greywacke Complex). Experimental rock blasting operations were carried out in the past, but the area was abandoned and remains unrecovered until the present (Ramalho, et al. 2012), with open pits and dumps. The studied area is located SE of the *Monte Branco* water dam, where there is still an open pit from the experimental rock blasting period, known as Maria Dias deposit.

The concentrations of ^{40}K (%), ^{232}Th (ppm) and ^{238}U (ppm) were measured in 213 points distributed in a regular grid, and the *Hex* and *ELCR* were calculated (Taskin, et al. 2008). The *Hex* index indicates the risk of exposure to radiation sources external to the human body and must be less than 1 unit (dimensionless) to be negligible, and the *ELCR* measures the additional risk of developing cancer due to exposure to a toxic substance incurred over the lifetime of an individual (Ramasamy, et al. 2013). Both parameters are usually employed to assess radiation in construction materials or in soil samples. In this study, these parameters were calculated to assess radioactivity in the surface soil and sediments at the sampled points.

2. Geostatistical Methodology

As the collected data was georeferenced, it was possible to apply geostatistical methods in order to assess and map the spatial distribution of the soil samples, associated with *Hex* and *ELCR* values. After an initial exploratory statistical study and spatial description of the data, the spatial data continuity was studied through the variogram surface and experimental omnidirectional and directional variograms, along directions 0 º, 45 º, 90 º and 135 º. These variograms were fitted by different theoretical models and continuous variogram models were obtained. These ones were submitted to cross-validation to select the best fit model. Finally, using ordinary kriging as the estimation method, maps of the spatial variability of the studied *Hex* and *ELCR* in the soil were obtained.

3. Discussion

In (Figure 1a) displays the satellite view of the studied area, including the measured points, and (Figure 1b) depicts the map obtained through ordinary kriging using the chosen variogram model. The map label shows Hex and *ELCR* values for the soil. The region with the higher values for the *Hex* corresponds to the open pit and surrounding areas, and it is possible to observe that some of these values are much higher than the recommended threshold limit of 1 unit. However, there are no dwellings in this area and no potential material extraction for construction purposes as the studied area is preserved.

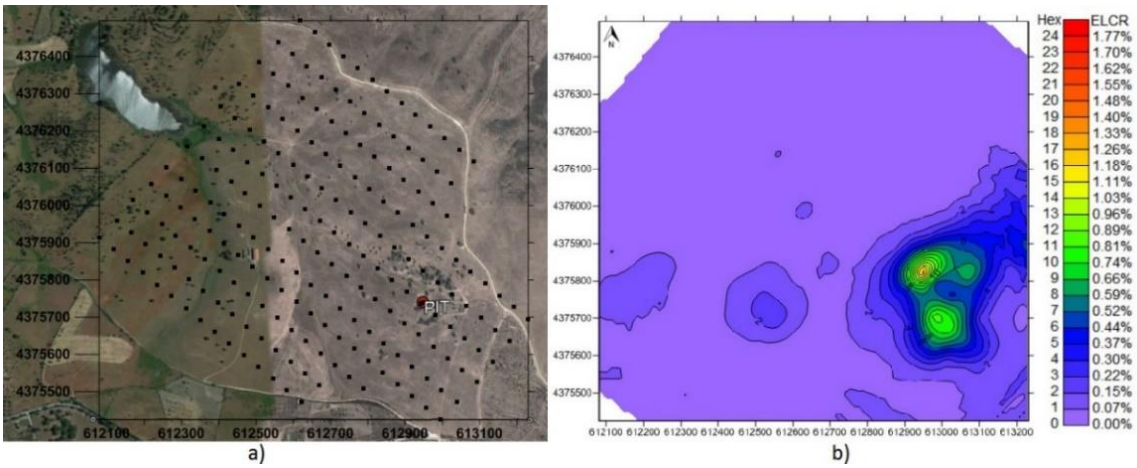

Figure *1*: a) Satellite image (GoogleEarth@) and measured points of the studied area; b) *Hex* (dimensionless) and *ELCR* (%) map of the area

4. Conclusions

The geostatistical approach, which provides consistent estimates and reliable maps, is an appropriate solution for spatially distributed data analysis. Its additional benefit is its ability to quantify estimation uncertainty and provide risk analysis tools for decision making (Desnoyers 2016). The map shows regions where the soil is associated with *ELCR above* 1.7 % and *Hex* superior to 24.

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Borehole Deviation Control Using Electronics: An Euler's Approach

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Abstract

The consequences of rock blasting with explosives are related to the accuracy of drilling and, because they have an effect on fragmentation, they should be controlled to ensure a problem free production. The authors evaluated the possibility of measuring holes deviation by creating a prototype using an accelerometer and a microcontroller. This paper aims to validate it by Euler method, given the stepping limitations of the sensor and microcontroller in order to reproduce of the hole shape. A case study was carried out, comparing the measurements of borehole deviations made by traditional equipment and the prototype. A residue analysis was used to validate the data obtained. After confirming the equipment effectiveness, the normality tests prove a symmetric distribution with null expected residual mean and minimum variance. Thus, the authors aspire to emphasize the potential of using these sensors allied to a traditional numerical method for analysis of hole deviation.

Author Keywords: Blasting, accuracy, drilling, fragmentation, inclinometer, deviation, boreholes, Euler
Type: Oral Communication

1. Introduction

Rock blasting aims to divide a certain amount of rock mass into smaller pieces (at the lowest cost possible). This procedure is applied in the majority of mining operations, quarries, civil engineering applications and even in some cases of ornamental rock operations. Therefore, the conditions that the rock blasting process is carried out affects directly the operation´s results (Bhandari 1997). For this, the precision in the steps of rock blasting to achieve the planned objectives and the knowledge of the rock conditions are essential in order to obtain the desired fragmentation (López Jimeno 2017).

Drilling is one of the most important steps in this process. Consequently, the control and the prior knowledge of drilling results is essential to proceed with the planned blast, maintaining the necessary economy throughout the cycle of mining operations (Leite, Miranda, & Palangio 2018). It is called a drilling deviation when a hole is subjected to an unintended abnormality of a planned trajectory. The deviation of the path of the planned hole can lead to problems such as high cost of drilling, fragmentation issues, fly rocks, irregularities in the floor or ramps, damages to the instrument, among others (Harris 1999). In addition, the analysis of the profile of the borehole with the use of deviation measurement equipment allows the control and minimization of the generation, over excavation, slope stability and monitoring of drilling operations (Miranda & Leite 2018).

2. Methodology

2.1 Field Procedure

The field test was carried out in Quinta do Moinho quarry (Vila Nova de Gaia - Portugal) explored by Solusel, Lda. The field tests included: scan of the free face with Drone; Registration of holes position; Measurement of hole's profile with a Cabled Boretrak; Measurement of hole's profile with the developed methodology (Figure 1).

Figure 1: Field Procedure: a) probe assembling; b) probe deployment; c) offset measurement; d) measurement time record

2.2 Measurement Results

After the field procedure, the operator gets the information of the real inclination, heading, and depth of the borehole. With that information and with a blast design software, it is possible to analyze different situations and problems.

2.3 Data Analysis

Multiple measures were recorded, inside of the borehole, at different positions. Before lowering the equipment into the borehole is define the measure interval – 1 measure at each meter (3.2 ft). In case of the hole having a size that is not multiple of the interval, the difference between the position of the first measurement and the remaining will be different. This difference is usually called off-set, while the other measures will have a difference that is equal to the interval adopted (Miranda e Leite 2018).

3. Results

Some restrictions were observed (at least with this first approach) using the Euler's methodology due to the limitations of the sample rate (Figure 2a). It was possible to get around 300 samples/second, which is a low number when trying to obtain displacement from acceleration (applying the Euler method two times). Visually the results are quite similar as shown in (Figure 2b) (using the inclination and heading at each meter).

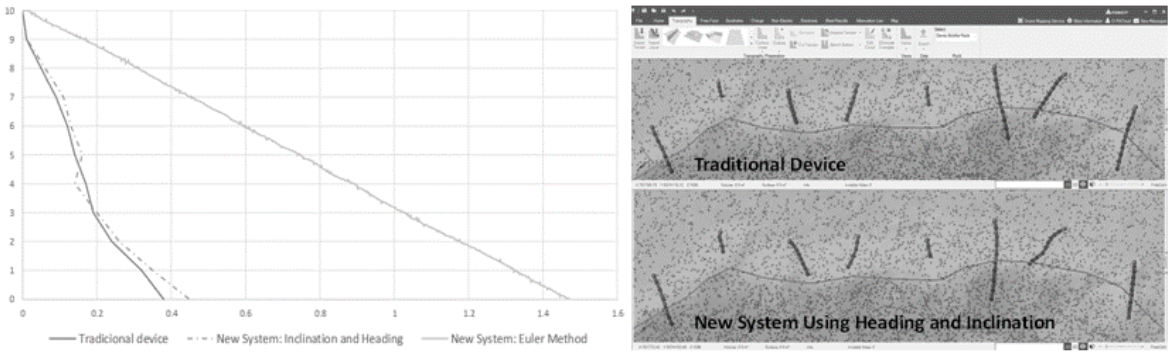

Figure 2: Comparison between a) Euler's methodology b) heading and inclination

4. Conclusions

The results obtained using Euler's methodology showed some restrictions. One way to overcome some of these restrictions is to increase the sample rate allowing to obtain better results. Due to the limitation of the sensors used, it was not possible to obtain a better solution. However, the results obtained using heading and inclination on the new product are extremely interesting. The possibility of reproducing the obtained values with a lower cost product will definitely open new doors to small operations in order to control drill accuracy, improving safety and production. This product allows a fast and immediate action due to the easy access to the information. The data analyzed shows a direct relation between the conventional method and the new one, showing the quality of the methodology presented. The equipment is very practical to use, the required training is low, and the integration with smartphones potentializes the use of technology with the blast operation, saving time to the blast operations activities.

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Modelling two-dimensional steady non-ideal detonations

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Abstract

Industrial ammonium nitrate-based explosives, such as those used in mining and quarries, usually tend to react with a low velocity of detonation, significantly below of its ideal speed. In these cases, the explosive's dimensional size-effects become important to proper model the detonation phenomenon. In order to use the explosive as an energy source-information for more realist blasting performance simulations, a simple and effective modelling strategy is desirable. In this line, a new approach to two-dimensional steady non-ideal detonation for cylindrical stick explosives is proposed. Based on an ellipsoidal shock shape approach, the proposed model combines the quasi-one-dimensional theory for the axial solution with boundary limiting conditions for the explosives' edge determination. For a given velocity of detonation and reaction rate parameters, a vital relationship between the axial shock curvature with the shock shape parameters is stablished, which reduces the problem in finding the shock shape parameters subject to the sonic edge condition. The model offers a full mapping of the diameter-effect curve of the explosive, relating relevant detonation properties with the explosive size-effect. Finally, because of its low computation cost, the proposed engineering approach can also be used for characterizing the rate law parameters by fitting to data from unconfined detonation experiments.

Author Keywords. Detonics, non-ideal detonations, explosives, blasting.

Type: Oral Communication

1. Introduction

Rock blasting processes are composed of complex mechanisms. Those phenomena have been the subject of intense investigations in the past decades, including the non-ideal detonation process. In blasting and mining fields, interactions between explosives and inert confiners are still a matter of research and discussion (Sharpe & Braithwaite 2005). The interest of studying non-ideal detonations is mainly motivated by the need of providing a reliable source energy-term information for rock blasting simulations.

2. Ellipsoidal Shock Shape Approach

Most of the non-ideal detonation approaches are based on the reactive Euler equations for conservation of mass, momentum, and energy. Direct numerical simulations DNS indicates that shock shapes can be well fitted by an arc of ellipse (Sharpe & Braithwaite 2005). Thus, in this work, a simple engineering approach to two-dimensional steady non-ideal unconfined detonation is proposed based on the combination of axial reactive flow solution with an ellipsoidal shock shape. The axial solution for a steady-state non-ideal detonation is determined by a quasi-one-dimensional analysis (Sharpe & Braithwaite 2005). For a pseudo-polytropic equation of state, the Q1D set of ordinary differential equations are:

$$\frac{du_n}{dn} = \frac{Q(\gamma - 1)W + \kappa(1 + n\kappa)^{-1}c^2(u_n + D_n)}{c^2 - u_n^2} \tag{1}$$

$$\frac{d\rho}{dn} = \frac{-Q(\gamma - 1)\rho\frac{W}{u_n} + \kappa(1 + n\kappa)^{-1}\rho u_n(u_n + D_n)}{c^2 - u_n^2} \tag{2}$$

$$\frac{d\lambda}{dn} = \frac{W}{u_n} \tag{3}$$

where u_n is the normal particle velocity; ρ is the density; D_n is the normal velocity of detonation; c is the sound speed; Q is the head of reaction; γ is the adiabatic gamma; $\kappa^* = \kappa(1 + n\kappa)^{-1}$; and W is the reaction rate. This set of ordinary differential equations form an eigenvalue problem in κ or D_n (Sharpe & Braithwaite 2005; Stewart & Jin 1998).

3. Results

The results of the experimental and modelled shock fronts are shown in (Figure 1). As can be seen, the comparison between the shape of the unconfined shock fronts obtained with the Q1D EA model agrees very well with the experimental curvatures. Surprisingly, the results obtained with the Q1D EA model agree very well with the numerical curvatures published by (Schoch et al. 2013). This result reveals the interesting predictive capacity of the model.

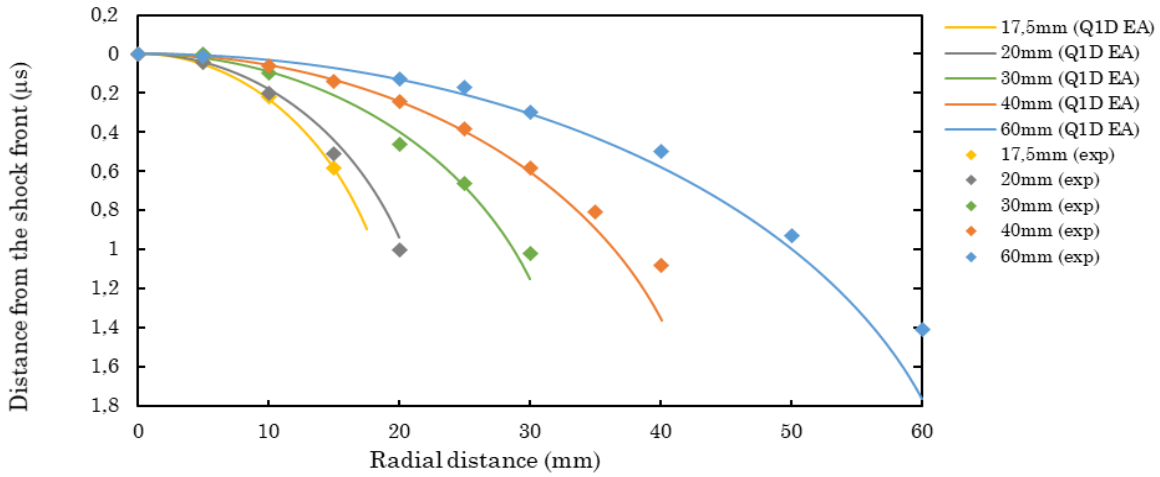

Figure 1: Comparison between the experimental and modelled shock front shapes for unconfined detonations

4. Conclusions

An engineering approach to two-dimensional steady non-ideal unconfined detonation, based on the elliptical construction of the detonation shock front, was presented. It was found that the proposed multidimensional extension, coupled with the Q1D axial solutions, provides exceptionally good predictions about both velocities of detonation and diameter effect curves, including good failure diameter predictions.

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Diamond exploration and mining in Angola: technical and economic issues

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Abstract
This paper analyses information regarding several past and current Angolan diamond mining projects – both alluvial and kimberlite, comparing their technical and economic parameters (between the group and with international diamond mining projects), aiming to identify negative competitive factors.
In earlier work production costs in the Catoca mine are shown to be much higher than comparable international kimberlite mines. This could be explained by a difficult logistical process, (with an impact in the costs of diesel fuel and parts), bureaucratic and administrative inefficiencies, low productivity and hidden costs.
In certain deposits, geology also plays an important role – higher unit production costs may also be due to a high stripping ratio (when the production is sourced from Calonda Fm. basal conglomerates, as is the case of the SOMILUANA project) - or to low grades (as is the case of the Lulo project).

Author Keywords. Angola, Diamond, Exploration, Mining, Benchmarking, Challenges, Economy.

Type: Oral Communication

1. Introduction

For some years now, world class diamond deposits discovery rate has abated. The novelty of the Canadian diamond fields as long disappeared, Argyle (Australia) is close to the end of its life, Catoca (Angola) is a mature mine, as others all over the world. Some new sources appeared in the last two decades, as Lucara's Karowe kimberlite in Botswana, may definitely emerge as Lucapa's Lulo in Angola or become more than a hint, an expectation, as the Luaxe kimberlite in Angola. These new sources won't replace the (already or soon to be) lost capacity; to maintain a significant natural diamond production in the long-term, new sources need to be found and developed.

Angola is one of the diamond fertile territories with high potential for new discoveries, despite being in production for over a century. It is therefore no surprise that De Beers returned to the country following a thawing in relations due to the new Angolan Government policies. There is potential for diamond production from both alluvial sources (either modern deposits – river bottom, river plains, terraces and abandoned channels, or the Upper Cretaceous Calonda Fm. Basal conglomerate) and kimberlite deposits.

Angola produced 8,2 Mct valued at 1.200 M USD in 2018, the Catoca kimberlite mine representing 75 % and 60 % of the production volume and value, respectively. Other relevant diamond production sources in Angola include, e.g., the Somiluana (TRANSHEX)

alluvial mine, the Camútuè kimberlite mine and the Lulo alluvial mine (and kimberlite prospect) producing the highest value per carat diamonds in the world.

Despite its high known resources (yet with a decreasing reserve base) and potential for new discoveries, the Angolan diamond industry faces several challenges. One of the issues is the lack of economic and technical information regarding the operation of exploration and mining projects in Angola, a key information in investment decision and project benchmarking.

2. Materials and Methods

This paper compiles and analyses information regarding several past and current Angolan diamond mining projects – both alluvial and kimberlite, comparing their technical and economic parameters (between the group and with international diamond mining projects). The projects analyzed are:

- DIAMANG (1917-1975).
- SML – Sociedade Mineira do Lucapa: Projects Mufuto, Lucapa e Calonda.
- SMC – Sociedade Mineira do Catoca.
- Project Chimbongo – ESCOM Mining.
- SOMILUANA – TRANSHEX.
- Project Lulo – Lucapa Diamond Company.
- SMCC – Sociedade Mineira Camatchia Camagico.

3. Discussion and conclusions

Earlier work by (Chambel, Caetano & Reis 2013; Xavier 2017; Bravo 2017) identified several factors needing improvement as, e.g. the Catoca mine production costs are much higher than comparable international kimberlite mines. The higher Catoca costs can be explained by a difficult logistical process, (with an impact in the costs of diesel fuel and parts), by bureaucratic and administrative inefficiencies, low productivity and hidden costs.

In certain deposits, geology also plays an important role – higher unit production costs may also be due to a high stripping ratio (when the production is sourced from Calonda Fm. basal conglomerates, as is the case of the SOMILUANA project) - or to low grades (as is the case of the Lulo project).

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The Future of the Angolan Diamond Industry: a Clash Between External Disruptive Forces, a New Government Policy and Heritage Problems

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Abstract
This work discusses the policies for the Angolan diamond industry in the next decade. Angola has grown into a major diamond producer, with the Catoca kimberlite mine accounting for 75 % of the country's production (in carats). With the oil industry losing steam, the diamond industry is now a key driver of the Angolan economy, at least in the medium term. The Angolan diamond industry is in a key crossing point, with the convergence of disrupting external forces, of its own heritage issues and the new policies of a new Government (itself subject to budgetary, exchange rate and economic restrictions).

Author Keywords. Angola, Diamond Industry, Government Policy, Disruptive Forces, Heritage.
Type: Oral Communication
Open Access Peer Reviewed

1. Introduction

The Angolan diamond industry is in a key crossing point, with the convergence of disrupting external forces, of its own heritage issues and the new policies of a new Government (itself subject to budgetary, exchange rate and economic restrictions).

2. Methodology

With the oil industry losing steam, the diamond industry is now a key driver of the Angolan economy, at least in the medium term. This work discusses the policies for the Angolan diamond industry in the next decade:

- Is it possible to design policies and public tools to consolidate and further develop the diamond mining industry in Angola?
- Which of the possible policies are more favorable to the development of the industry and of the country as a whole?
- Which subsectors of the industry should be stimulated by public policies?

The discussion of the public policies is based on:

- A detailed knowledge of the current situation of the Angolan diamond industry.
- An estimate of the geological and economical characteristics of the known and possible Angolan diamond resource base.
- A SWOT analysis of the Angolan economy and of its diamond sector.
- A detailed mapping of the diamond cluster in Angola and its internal and external links.

- A compilation of and compared analysis of the public policies (fiscal, mining and trading) employed in other diamond producing countries and their results.

3. Discussion and conclusions

The future of the Angolan diamond industry lies at the confluence of three factors – the industry heritage, external forces, and new public policies.

The industry has both assets and liabilities; the later need to be corrected and the former used as a stepping stone for the industry's development: (a) **Assets**: Despite work by De Beers, ALROSA and the BHP-ESCOM JV, the exploration done by DIAMANG and CONDIAMA until 1974 represents the main knowledge base on the Angolan diamond deposits (Chambel et al. 2013). (b) **Liabilities**: lack of qualified human resources; poor infrastructure; lack of local investment capital, lack of specific know-how; the accumulated environmental impact of the diamond industry past activity; a fragile banking industry and an inexistent capital market; a fragile economy with a tight hard currency position and a tarnished reputation as an investment destination.

Some of the factors external to the industry and the country are opportunities, e.g the XRT technology that allowed the successful opening of the Lulo mine; others are challenging obstacles to the Angolan diamond industry: (a) **New clients – demography and geography**: The Millennials and beyond; China and India. (b) **Certification and branding** – the Kimberley Process (under reform), Responsible Sourcing and Blockchain. De Beers (and other key actors) move towards a source certification scheme (source branding initiative associated to responsible sourcing). (c)**Technology** – XRT, Digitalization and Data Science. (d) **Synthetics**. Despite being realized as a serious potential threat for some decades, synthetic diamonds are now mainstream in the gem industry following De beers' move to create a synthetic jewelry brand. (e) **Commoditization**. There are now two natural diamond markets, one for smaller diamonds (commoditized) and one for larger diamonds. (f) **Competition** – the industry is not a cartel anymore. In addition to De Beers and ALROSA, controlling two thirds of the natural diamond production, there are several smaller but lean and efficient diamond producers active in the industry. (g) **Migrations** originated in unstable countries.

The new Government new policy for the for the country' key diamond industry, setting or announcing new legislation or effectively implemented the existing one, namely: (a) A clamp down on illegal or uncontrolled artisanal diamond mining (garimpo) and unregulated buying offices. (b) Deportation of illegal immigrants involved in artisanal mining and rough diamond trade. (c) Changes in the export single-channel policy, with a new regulation allowing miners to auction and export part of their production. (d) The (re)establishment and development of downstream activities, e.g. cutting and polishing with the creation of a dedicated center in Lunda Sul. (e) The privatization of ENDIAMA and SODIAM, up until now the 100% state-owned diamond exploration, mining and trading companies. In addition to the measures already implemented, the Angolan diamond industry needs further work towards:

a. A permanent evaluation of the results of the newly implemented policies and, should it be found necessary, the consequent revision and update.

b. The development of a capital market for mineral project financing.

c. The creation of national standards and guidelines based on the CRIRSCO framework for the reporting of resources, reserves and mineral assets valuation.

d. Development of a permanently updated public online information system concerning concession ownership and Angolan legislation – both in Portuguese and English.

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Risk undervaluation in mineral projects: first approach to a solution

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Abstract

Projects generally fail to create the value predicted in feasibility studies. Despite acknowledging the critical role of risk in valuation, the industry fails to measure it accurately and grossly overstates mineral projects' values.

Overall, the discount rates used in the 82 studied project reports are too low and their values, with exceptions, are not discussed or justified. Frequently, there is no risk discrimination between projects located e.g. in sub-Saharan Africa, Western Europe or Canada, further stressing the need for guidelines in mineral projects valuation.

Using a cross-validation principle in the definition of (a range of reasonable) discount rates is a possible approach towards the definition of better discount rates. The concurrent use of several different methodologies – e.g. the risk build-up and the Capital Asset Pricing Model - in conjunction with benchmarking values against e.g. the country's long-term treasury notes is a useful approach.

Author Keywords. Risk, Discounted Cash Flow Model, Guidelines.

Type: Oral Communication

1. Introduction

Either due to price volatility, political, operational, financial, or technological uncertainty or human failure in modelling or reporting reality, risk is ubiquitous in mineral projects, in a degree perhaps surpassing most industries. The industry and regulators acknowledge the key role of risk in the valuation process, yet the industry fails to incorporate a good measure of risk in project analysis. As a rule, projects fail to create the value predicted in feasibility studies.

2. Methodology

The commodity price forecasts and the project's discount rate are, arguably, the two variables with most impact in the valuation of a mining project. Discounted Cash Flow (DCF) models are useful in mineral assets valuation (cases with information precise enough about the deposit, the market and on the mining process and its costs – including assets in the stages of pre-feasibility, feasibility studies and, obviously, operating mines). DCF models are based in:

1. Estimates of the project's revenues, costs and investment: revenues depend on planned output and the commodity's expected price (both dependent on the market and output also on the deposit's reserves); the costs include several components (human resources, energy, marketing, administration, spares, etc.) – as these are relatively easy to estimate; investment is also relatively easy to calculate. These variables are calculated along the project's life and annual cash-flows estimated.

2. To compare (and sum) cash flows in different points in time you must compensate the effect of uncertainty (risk) in estimates of future revenues, costs and investment. Uncertainty (risk) has many causes: market prices vary (commodities, energy, labor, etc.); joint-ventures may be unstable; management incompetent; governments fall; their policies change; exchange rates and inflation variate; the models used in resource and reserve estimation have an inherent error; available information is incomplete (not enough samples, e.g.). To compensate for risk (uncertainty), the model uses a discount rate (compounded in successive periods); the higher the perceived risk, the higher the discount rate applied to the future cash flows (investors demand a higher premium for riskier projects).

3. With estimates of revenue, investment and cost compensated by the discount rate, the project's net present value is a simple sum of discounted annual cash flows.

Being such a key variable in DCF models (themselves widely used in this class of assets), it is of crucial importance to use a good discount rate (a measure of the project's risk and the minimum profitability an investor would demand from a project with that risk profile).

This study compiles and analyses information - the projects' stage, commodities involved, country, deposit type, effective and publication dates, reporting standard, discount rate used, IRR and author - on 82 feasibility or pre-feasibility studies of mineral projects subject to valuation based on DCF models.

3. Discussion

The analysis concluded that:

1. Overall, the discount rates used in the reports are too low and their values, with exceptions, are not discussed or justified.

2. Most CP/QP don't explain how they derive discount rates and frequently, in the rare occasions they do it, the method used is wrong. The frequently cited WACC (Weighted Average Cost of Capital) is not a good way to calculate the discount rate to be used in project evaluation. The value of a project should be calculated independently of its financing. The more capital you borrow, the more is your apparent ROI, yet, the more we borrow, the higher our risk.

3. Competent persons authoring the reports often seem to lack the knowledge or the critical thinking to discriminate different projects' risk levels, with the same rate being used in projects located in sub-Saharan Africa, Western Europe or Canada, for instance.

4. That common bias towards lower than justified discount rates stresses the need for guidelines in the definition of the discount rate used in mineral projects evaluation.

4. Conclusions

This work suggests a possible approach towards the definition of a discount rate closer to reality, by using a cross-validation principle in the definition of (a range of reasonable) discount rates. The concurrent use of several different approaches – e.g. the risk build-up approaches of (Guarnera & Martin 2011) and other authors – e.g. (Park & Nelson 2013 a,b) and the Capital Asset Pricing Model, in conjunction with publicly benchmarking values (e.g. the country's long-term treasury notes) is an useful approach in the discussion and choice of a discount rate (or of a reasonable value range).

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Responsible Mining Towards Sustainable Legacy

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Abstract

Mining is crucial to society. It has the responsibility to provide raw materials and the responsibility to manage the impacts arisen by their exploitation properly. A responsible mining company must seek to make a profit, complying with the law, according to the principles of ethics and behaving like a good corporate citizen Under the umbrella of Corporate Social Responsibility, stakeholder management is a determining factor for companies pursuing sustainable development goals. This research follows a theoretical perspective that brings together marketing and economic, and organizational sociological theories, respectively, Interaction Processes approach and Corporate Social Responsibility Communication. It introduces a conceptual framework that enables analysing stakeholder relationships and allows the understanding on how stakeholders' interactions influence the way a company develops sustainable management. This study introduces a conceptual framework that enables analysing stakeholder relationships and allows the understanding on how stakeholders' interactions influence the way a company develops sustainable management.

Author Keywords: Corporate social responsibility, corporate social responsibility communication, stakeholder management, interaction processes, responsible mining, and brownfield redevelopment.

Type: Oral Communication

1. Introduction

A responsible company must seek to make a profit, complying with the law, according to the principles of ethics and behaving like a good corporate citizen. These are the steps of the Pyramid of Corporate Social Responsibility (Carroll 1991, 1999). The Corporate Social Responsibility (hereafter known as CSR) concept has been widely discussed, leading to differing definitions but still inconclusive. According to (Dahlsrud's 2008) and agreed by the author, the definition of CSR is irrelevant, as what matters is being able to contextualize CSR and integrate its principles, implement support tools and continually improve the business management of CSR.

The ethics pillar of CSR, stakeholder management, gave birth to stakeholder theory. Freeman defined "a stakeholder in an organization is any group or individual who can affect and be affected by the achievement of the organization's objectives" (Freeman 1984). Thus, stakeholder participation is a determining factor for achieving lasting social, economic, and environmental development (Sardinha et al. 2013). Corporate Social Responsibility Communication (hereafter known as CSRC) becomes crucial for stakeholder relationship management since it is a vehicle for companies to influence their stakeholders, managing relationships and attain legitimacy (Crane and Glozer 2016). The study of these relationships can benefit from the Interaction Processes (Industrial Marketing Purchasing approach) since it best captures the development of the relationships between actors.

This study aims to develop a framework to understand the Interaction Processes (hereafter known as IP) in the relationships between corporations and their stakeholders, within CSRC, and to contribute to the development of stakeholder management that promotes sustainability grounded on lasting relationships.

2. A conceptual framework for researching stakeholder relationships

A conceptual framework is proposed which allows the analysis of stakeholder relationships under the principal dimensions of sensegiving/sensemaking, consistency, transparency, exchange, adaptation, and the coordination, ascription, or explanation of these dimensions by the actors involved.

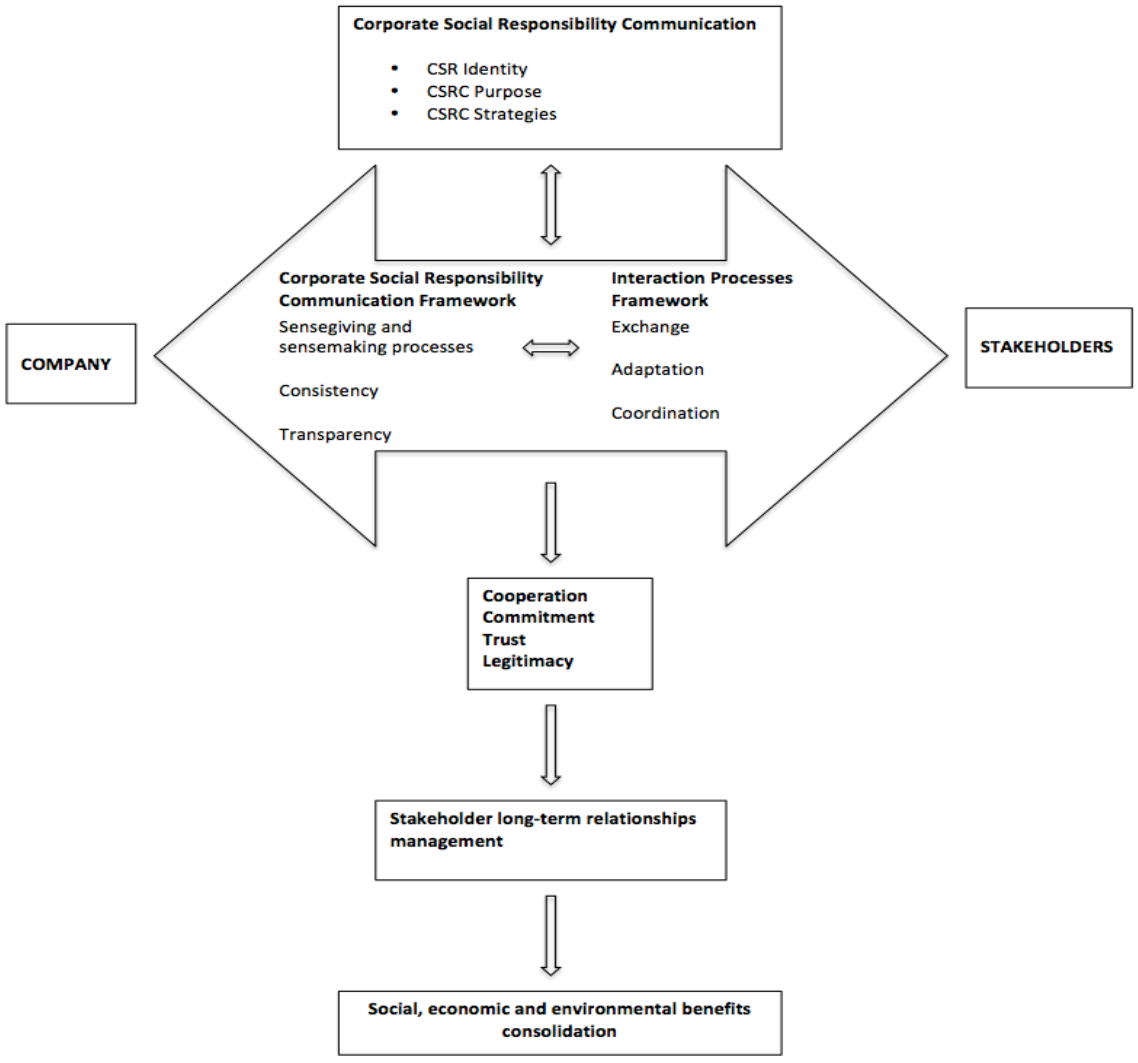

Figure 1: A Proposed conceptual framework.

3. Methodological considerations for further empirical research

Methodological challenges include testing this framework in the research setting of mining and mine brownfields redevelopment. Relationships between mining company and public bodies, and regulators, and communities/society will be comprehensively investigated through the IP under the realm of CSRC. The proposed future sample is comprised of brownfield redevelopment and mining operations located in the Iberian Pyrite Belt. The

aim is to study two brownfields and two operational mines – Lousal and São Domingos and Aljustrel and Neves-Corvo.

The proposed data collection methods are documentation, interviews, and observation. (Potter 2013) argues that these evidence-gathering methods are appropriate for a qualitative approach. Informal conversational interviews will be held with some stakeholders (Patton 1990); however semi-structured interviews (Saunders, Lewis and Thornhill 2016) is the main source of the primary data. Non-participant observation may also be used in the visits to the mines as a complementary method of data collection. Direct observations can range from formal to casual data collection (cf., Yin 1994). Content analysis will be implemented following Miles and Huberman (1994) using cross-case analysis logic.

4. Conclusions

The objective, to understand the relationships between organizations and its key stakeholders, such as public bodies and communities and to develop sound CSRC for sustainable management, is achieved through adopting the disciplinary approach of the IP and CSRC.

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POSTERS

Reprocessing the tailings from the Cabeço do Pião Dam – recovery of copper and zinc by differential flotation

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Abstract

The reprocessing of old mine tailings can represent be an alternative for the European mining industry. Advances on mineral separation technologies would provide the possibility to recover valuable minerals from tailings produced by former mineral processing techniques (Lutandula and Maloba 2013, Alcalde, Kelm et al. 2018, Figueiredo, Vila et al. 2019).

The main objective of this work is to study the reprocessing of the tailings from the Cabeço do Pião Dam by froth flotation. This study is an important contribution due to the environmental concerns related to the high arsenic content of these tailings.

A three-stage differential flotation is proposed, producing three different products - copper, zinc and arsenic concentrates. Copper and the zinc concentrates can be furtherly commercialized or added to the actual flotation plant. Arsenic concentrates and the final residues, with low sulphide content, can be properly stored so as to reduce environmental liabilities and concerns.

Author Keywords. Sulphides differential flotation, environmental concerns, tailings reprocessing

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Use of accelerometers for the measurement of vibrations from rock blasting: a Taylor's approach

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Abstract

The vibrations from rock blasting are one of the side effects generated by the blasting activity. In order to monitor and prevent these events seismographs are widely used not only preventively but also to improve the blast plan design elaboration. Using micro controllers and accelerometers that are widely available in the market, it was possible to measure the accelerations generated by rock blasting and transforming the data into velocity using the Taylor's series. A device was developed and intensively tested in a series of blasts in a quarry in the North of Portugal, where it was possible to compare the obtained results by the traditional seismographs against the newly developed device. Finally, using a residue analysis was possible to check that the residue generated by the difference of the data was statistically contained within zero, which led us to conclude that both devices were equivalent. It was also possible to generate attenuation laws with both devices and the result's analysis demonstrate a big potential for the new equipment.

Author Keywords. Seismograph, vibration, blasting, accelerometer.

Depression of Galena using dextrin in a Chalcopyrite flotation circuit: optimization of operational conditions for an Industrial Trial at SOMINCOR's Copper plant

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Abstract

The specifications for plants' final concentrates require cleaner final products, with low penalty elements content. In the case study, problems related to high contamination of lead in the copper concentrate are becoming more and more significant.

Dichromate is galena's depressor by excellence. Due to its toxicity and the increasing environment and health concerns, new alternatives must be pursued. Dextrins are polysaccharides that may substitute inorganic depressors in the way needed.

Floatation tests were done focusing on the rougher stage. DPS36 dextrin was chosen to carry out the industrial trial, being the reagent that has shown best results in terms of selectivity considering its low price, easy preparation, and maintenance needs.

This work aims to find the optimal conditions for the industrial trial. A combination of dextrin with zinc sulphate is now in a study on the fine rougher stage due to the incapacity of dextrin to depress zinc.

Author Keywords. Chalcopyrite flotation, Complex sulphide ore, Galena depression, Dextrin, Industrial Trial.

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Feasibility of establishing a landfill of inert waste in karst zones. Proof of concept from an industry perspective 4.0.

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Abstract

Construction and demolition waste represents a quantity and variety of products that can not be neglected, particularly in urban areas. This variety comes from the size, shape, physical and chemical characteristics of the multiple products used in the construction industry. Considering these residues as a whole, and particularly when mixed, they pose a danger to both the environment and the people who handle them. Managing this problem in all its aspects is one of the main challenges for sustainable development. However, the possibility of creating synergies with the environmental and landscape recovery of abandoned mines and quarries can give an important contribution to this sustainability.

This study aims to demonstrate through a case study that the conversion of abandoned quarries into landfills of inert materials is a technically feasible, economically viable and environmentally responsible alternative. For this, the best techniques for implementing this type of project in an Industry 4.0 digital twin perspective were introduced. In order to illustrate the concept, it is applied to a real situation of an abandoned quarry in Portugal.

Author Keywords. Landfill, Construction and demolition waste management, Environmental recovery.

Study of the structure cost of the Extractive Industry in Portugal - Optimization of the mortar Plants

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Abstract
The main goal is to analyze an optimization process within the cost structure of two twin dry-mixed mortar plants.

The final product, dry-mixed mortar is a uniform granular powder mixture. Is composed of pretreated aggregate, considerable cementing material and trace amounts of high-tech additives, with automatic measurement according to the formula and homogeneously mixed.

Limestone aggregate (size 25 - 50 mm), the main raw material supplied by two different quarries, is crushed, grinded, sieved and stored on both plants in 5 classes of sizes. The crushing process uses a Vertical Shaft Impactors (VSI), a rock-on-rock autogenous crushing impactor. Final aggregate products output (0.0 - 4.0 mm) should meet the following requirements: moisture content (<0.5 %) and mud content (<1.0 %).

Main operational costs are related Limestone aggregates on electric power spending to crushing and shipment by road-to-plant.

To identify major cost-performance indicators throughout the process and improvements proposal on the CIARGA dry-mixed plants are the intended core results.

Author Keywords. Dry-mixed mortar plants, Limestone aggregates, Cost-performance indicators, process optimization.

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Development of software platform for dimensioning of mineral processing equipment

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Abstract

In the development of a mining project, in particular in the design of the flowsheet of the ore processing facility, several simulations are carried out in order to anticipate possible problems and minimize them. There are computational resources that solve these problems, however they are usually complex and, in addition to costly ones, do not have the objective of dimensioning equipment.

In addition, it can be noted that software is only used in large capacity installations, not responding to the needs of some sectors of the mineral industry, such as quarrying, or to answer such simple questions as: In the present installation is it possible or not to increase the volume of material processed?

The aim of the work is to construct a computer platform that combines selection and sizing routines for equipment used in mineral processing facilities, namely: crushers and granulators, ball and bar mills, sieves, hydroclassifiers, decanters and cyclones.

Author Keywords. Mining equipment´s, Mining equipment´s dimensioning, Mineral processing, Software platform

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Methodology for Optical Control of Aggregate Calibration in Raw Materials Processing – Masters Dissertation

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Abstract

Size control in mines and quarries is still an aspect that delays the raw material treatment process due to the mechanical granulometric distribution model where it's necessary to stop the process and withdraw a sample for analysis, but all this could be eliminated if the particle size distribution was performed through an optical analysis.

The field of size particles has been gaining importance in the mining industry in recent years and one of the developments made more relevant is the use of optical analysis to infer it. Although this idea is not recent, a software was purposely developed for this achievement, WipFrag.

To study the results of WipFrag and know if they are as accurate as it would be by mechanical means a comparison is necessary. Using material supplied by the mining engineering department, a sifting will be performed by obtaining a granulometric distribution model by mechanical means, and the same material will be photographed and analyzed by WipFrag. Finally the results provided by WipFrag and the ones from the initial sieving will be compared.

Author Keywords. WipFrag, optical analysis, mechanical analysis, caliber control, sifting.

Modelling the transport and fate of radionuclides in a sludge heap from the processing of phosphate ores

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Abstract

The research project "Belgium NORM Site", coordinated by the *Belgian Nuclear Research Centre* (SCK•CEN), aims to prepare a study of the environmental impact generated by the sludge of calcium difluoride with radioactive elements, resulting from the phosphate industry. The phosphate rock, depending on its geological origin, may be enriched in natural radionuclides either from the uranium or thorium series (NORMs). Consequently, the processing of these types of ores generate by-products and residues also enriched in natural radionuclides (IAEA 2013).

In this context, the physical, chemical and radiological characterization of soil samples and residues from the study site were performed. Also, natural leaching tests with different variants and determination of the coefficients of distribution among the main environmental compartments, were carried out.

The results obtained will allow to develop mathematical models to describe the transport and transfer of the radionuclides (Dinis 2007), as well as other contaminants, and propose measures for the rehabilitation of the site.

Author Keywords. Phosphate, NORM, Modelling, Soil Remediation, Site Rehabilitation

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Mapping the International Standards and Guidelines in Exploration Results, Mineral Resources, Reserves and Value Reporting

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Abstract

International standards and guidelines for reporting exploration results, mineral resources, reserves and valuations have grown in number and complexity, creating an intricate landscape for global exploration and mining companies. This work maps that landscape, illustrating the relations between the international reporting standards and guidelines, their frameworks, the organizations that developed them and the countries to which they apply.

Resources and reserves (and exploration results) are reported based on two main paradigms:

- The CRIRSCO framework and
- The UNFC framework.

Valuation standards are based on two international paradigms:

- The IMVAL template and
- The International Valuation Standards.

The most important national standards based on the CRIRSCO template are:

- USA's SME GUIDE and the SME VALUATION STANDARDS
- South Africa's SAMREC and SAMVAL.
- Canada's CIM Definition Standards on Mineral Resources and Reserves, NI 43-101 and CIMVal.
- Europe's PERC Reporting Standard.
- Australia's JORC and VALMIN.

Author Keywords. Exploration, Resources, Reserves, Valuation, Mineral, International Standards, Guidelines.

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Reporting in the Mineral Industry: Exploration, (E)Valuation and (Social, Environmental and Source) Responsibility

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Abstract
International standards and guidelines for reporting exploration results, resources and reserves and mineral assets valuation became an obvious necessity to protect investors from unsubstantiated disclosures about mineral assets.

In addition to those standards and guidelines (mostly directed towards reinforcing the trust of markets), the last two decades witnessed the setting of standards and guidelines and best practice recommendations regarding the activity of exploration and mining companies and its environmental and social impacts. This document presents and discusses the international policies, reporting frameworks, standards, good practices and guidelines for mineral projects and assets. Those standards can be subdivided into two great groups:

- Reporting to markets:
  - Exploration Results, Resources and Reserves,
  - Valuation and
  - Critical Raw Materials.
- Reporting to society:
  - Sustainability and
  - Social responsibility:
  - Responsible sourcing.
  - Mine closure.
  - Indigenous people and local communities and
  - Governance and corruption.

Author Keywords. Reporting, Mineral Industry, Standards and Guidelines, Society, Markets, Environment.

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The Circular Economy of the Portuguese Natural Stone Industry: conceptual model and first results

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Abstract

Natural stone is one of the most important Portuguese industrial clusters. The cluster generates a large volume of excess material (currently classified as waste but, in our view, sub-products, by-products and excess raw materials with additional potential uses).

This work is part of a wider research project concerning the generalization of the circular economy concepts into the full raw materials value cycle; it evaluates the volumes and flows of stone raw materials (and their products) within the natural stone cycle and identifies possible solutions to minimize or use excess stone raw materials and products.

This work's first results include a conceptual model of the natural stone value cycle, a first assessment of the annual volumes (by lithology and material types) generated in Portugal and an early estimate of the current stocks of those materials (quantified and classified as measured resources, not as waste piles).

Author Keywords. Natural Stone, Circular Economy, Portugal, Raw Materials, Resources.

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AWARDS

Best student oral communication award for the Symposium on Mining Engineering and Geo-Resources

Rui Sousa, Aurora Futuro, António Fiúza and Mário Machado Leite. Design of a Lepidolite flotation pilot plant based on lab scale tests (#47).

Best student poster presentation award for the Symposium on Mining Engineering and Geo-Resource

Catarina Mendes, Rui Sousa, Diogo Martins and Aurora Futuro, Reprocessing the tailings from the Cabeço do Pião Dam – recovery of copper and zinc by differential flotation (#67).

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