DCE23 5th DOCTORAL CONGRESS IN ENGINEERING

Book of Abstracts

DCE23 - Symposium in Mining Engineering and Geo-Resources

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

DCE 23 5th DOCTORAL CONGRESS IN ENGINEERING

DCE23 - Symposium in Mining Engineering and Geo-Resources: Book of Abstracts

Editors:
Maria de Lurdes Dinis, Rui Sousa, Bárbara Fonseca

Porto
June 2023

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This volume contains the peer reviewed and accepted abstracts, presented at the Symposium in Mining Engineering and Geo-Resources, of the 5th Doctoral Congress in Engineering – DCE23, held at FEUP-U.Porto, Porto, Portugal, between June 15th and 16th, 2023.

Title: DCE23 - Symposium in Mining Engineering and Geo-Resources: Book of Abstracts

Edited by Maria de Lurdes Dinis, Rui Sousa, Bárbara Fonseca

Published by: FEUP Edições

Digital version Symposium on Mining Engineering and Geo-Resources – DCE 2023 (up.pt)

First edition June 2023

ISBN. 978-972-752-305-4

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WELCOME

The Symposium's Organizing Committee on Mining Engineering and Geo-Resources welcome you to the 5th Doctoral Congress in Engineering (DCE23), FEUP, Porto, Portugal. We are pleased to host the 3rd Symposium on Mining Engineering and Geo-Resources in the Faculty of Engineering of the University of Porto, organized in collaboration with the Instituto Superior Técnico (IST) and with the support of the Research Centre CERENA. The DCE is an excellent opportunity for doctoral and master students to share and discuss ongoing research with peers, professors, and professionals from the industry and develop networking opportunities. This year the organization of the Symposium had the collaboration of PhD and Master Students from the following programmes:

- Doctoral Programme in Mining Engineering and Geo-Resources (PDEMGR/FEUP)
- Doctoral Programme in Earth-Resources (DGEO/IST)
- Doctoral Programme in Petroleum Engineering (DEPet/IST)
- Master in Mining Engineering and Geo-Environment (M.EMG/FEUP)
- Master in Mining and Geological Engineering (MEGM/IST)
- Master in Energetic Resources (MERE/IST)

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. The research is preferentially concerned with the fundamental understanding of the basic processes that support the sciences and technologies involved in applying engineering principles to the Earth Sciences.

Topics for submission for the Symposium on Mining Engineering and Geo-Resources were focused on: Exploration and Feasibility; Mining Extraction; Mineral Processing; Environmental Mining Impact; Mining Life Assessment (including Resources Assessment, Mining Planning, Mine Closure, Recycling, Life Cycle Assessment, Occupational Assessment, etc.); Energy Resources Engineering; Critical Raw-Materials to leverage the energy and digital transition; and Sustainable Supply of Raw Materials.

We want to express our sincere thanks to the invited speakers: Nuno Faria (dst group), Júlio Vieira (EPIROC), Júlio Santos (Stoneset), John Pereira (Savannah Resources) and Margarida Mateus (Secil), who made themselves available to be speaking at DCE23.

Finally, we want to express our gratitude and appreciation for the reviewers who helped us maintain the high quality of manuscripts in this Symposium Book of Abstracts. We would also like to thank all members of the scientific committee and the organizing team, particularly Rui Sousa and Bárbara Fonseca, for their hard work and commitment to all organizational aspects.

Let us wish that all the participants of the 3rd Symposium on Mining Engineering and Geo-Resources will have a wonderful and fruitful time. We hope that you find it helpful, exciting, and inspiring.

Symposium Chair

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

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

15 - 16 June 2023

FEUP, Porto, Portugal

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15th June, Thursday

08:00-09:00	**Welcoming** (Reception)
9:00-09:30	**Opening Session** (Auditorium)
09:30-10:00	**Industry Keynote Lecture** (Auditorium)
10:00-11:00	**Round table:** Early-Stage Research in Industry (Auditorium)
	---------- **Coffee-break** ----------
11:30-13:00	**Plenary Session:** Sustainable Engineering for an Intelligent World (Auditorium)
	---------- **Coffee-break** ----------
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15:00-16:30	**Session I | Moderated by Bárbara Fonseca** **Nuno Faria (dst group) | Invited Speaker** **R. Miele** (IST/CERENA): Stochastic inversion of seismic data for facies models with physics-guided Generative Adversarial Networks (#183). **J. Narciso** (IST/CERENA: Geostatistical joint inversion of FDEM and ERT data for modelling near surface deposits (#379). **V. Miranda** (IST/CERENA): Assessment of Antarctic vegetation classification as a function of the spatial resolution and application to historical images of Barton Peninsula, King George Island (#352).
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17:00-18:30	**Session II | Moderated by Roberto Miele** **Júlio Vieira (EPIROC) | Invited Speaker** **C. Escada** (IST/CERENA): Deep Learning ERT inversion for groundwater modelling (#305). **A. Duarte** (IST/CERENA): Seismic oceanography imaging and modelling applied to Madeira abyssal plain (#355). **A. TravellaieNejad** (FEUP/CERENA): Evaluation of rice and Moth bean cultivation based on agricultural characteristics using machine learning (#162).

16th June, Friday

09:00-10:30	**Session III | Moderated by Ernesto Fernandes** **Júlio Santos (Stoneset) | Invited Speaker** **J. Monteiro** (FEUP/CERENA): Alternative Reagents for Lithium Extraction from Lepidolite Ore: A Preliminary Fractional Factorial Design Study (#337). **L. Cunha** (FEUP/CERENA): Cavali Project: Lithium sorption by ion Exchange (#342). **B. Fonseca** (FEUP/CERENA): Multivariate Analysis: Principal Component Analysis (PCA). Case study: Rio de Frades mine, Arouca, Portugal (#256).
	---------- **Coffee-break** ----------
11:00-12:30	**Session IV | Moderated by Roberta Lobarinhas** **Margarida Mateus (Secil) | Invited Speaker** **John Pereira (Savannah Resources) | Invited Speaker** **E. Fernandes** (FEUP/CERENA): Intergenerational Knowledge Transmission in Mining Engineering using new technologies (Virtual Reality and Argumented Reality) (#383). **O. Olufe** (FEUP/CERENA): Evaluation of Impacts of Geologic Structures on underground Mine production tunnels' stability of na iron ore mine (#387).
12:30-13:00	**Closing Session** – Mining Engineering and Geo-Resources Symposium
	---------- **Coffee-break** ----------
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16:00-16:30	**Closing Session** (Auditorium)
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Symposium Keynote Speakers

Nuno Faria, *dst group*

Topic: A quarry & aggregates plant designed to provide a green energy infrastructure: Innovation and Environmental Initiatives

Nuno Faria holds a Master in Mining and Geo-Environment Engineering from the Faculty of Engineering of the University of Porto. He joined DST Group in 2016 as the project director/technical director, with highlighting the project and execution, dismantling and landscape recovery of the Gouvães Quarry, which received the European award for "Good operational practices" and the certificate of excellence for "Environmental Best Practice" and "Operational best practice, process or product Innovation" in 2023.

Júlio Vieira, EPIROC

Topic: Rock Drilling Tools

Júlio Vieira is Mining Engineer from the University of Coimbra and holds a PhD in Mining Engineering and Geo-Resources from the Faculty of Engineering of the University of Porto. Júlio has 19 years of experience in the area shared by companies such as Jaime Queiroz Ribeiro Lda., Sovaletas - Construção Civil e Obras Públicas Lda., SGS – Sociedade de Granitos de Sátão Lda., Duromin - Equipment for mines, quarries and public works Lda. (Durit Group), having joined EPIROC in 2018 as a key account manager.

Júlio Santos, *STONESET Quarry*

Topic: Quarries in Portugal

Júlio Santos is a Geologist graduated at the Faculty of Sciences of the University of Porto and holds a MSc. in Geomaterials and Geological Resources. Júlio has 16 years of experience going through companies such as PEDRAL – Pedreiras de Crasto de Cambra S.A., Almina – Minas do Alentejo S.A., GEG – Engineering Structures for Life, CONGEO – Consultores de Geologia Lda., Lusidakota Minerals, Airelimestones, SPM, TTT Resource, currently being at STONESET Quarry since January 2023.

Margarida Mateus, *Secil*

Topic: Research, Development and Innovation in Secil

Margarida Mateus is a Researcher from the Faculty of Sciences of the University of Lisbon with a PhD in Physical Chemistry from the same university. Margarida has experience in scientific research in biofuels and energy, being currently at Secil as a Research Development Supervisor.

John Morris Pereira, *Savannah Resources PLC*

Topic: Barroso mine: presentation of the reformulated project

John Morris Pereira holds a Master degree in Mining Resources Evaluation from University of Porto. John has 18 years of experience divided by several companies such as Imerys, John Morris Soc. Unip. Lda., Medgold Resources Corp., Lusidakota – NOVO LITIO (NLI ASX) and currently as an independent Consultant in Exploration and Mining.

Oral Communications presented at the Symposium on Mining Engineering and Geo-Resources:

- Amir TavallaieNejad, Rui Camacho da Silva, Luís Cabral Borges, Maria Cristina Vila and Gustavo Paneiro. Evaluation of Rice and Moth Bean Cultivation Based on Agricultural Characteristics Using Machine Learning (#162).
- Roberto Miele and Leonardo Azevedo. Stochastic inversion of seismic data to facies models using a novel physics-guided Generative Adversarial Network. Roberto Miele and Leonardo Azevedo (#183).
- Bárbara Fonseca, Joaquim Góis, António Guerner Dias and Henrique Garcia Pereira. Multivariate Analysis: Principal Component Analysis (PCA). Case Study: Rio de Frades mine, Arouca, Portugal (#256).
- Ana F. Duarte, Renato Mendes and Leonardo Azevedo. Seismic oceanography imaging and modelling applied to Madeira abyssal plain (#265).
- Cláudia Escada and Leonardo Azevedo. Deep learning ERT inversion for groundwater modelling (#305).
- Joana Monteiro, Lídia Cunha, Aurora Futuro and António Fiúza. Alternative Reagents for Lithium Extraction from Lepidolite Ore: A Preliminary Fractional Factorial Design Study (#337).
- Lídia Cunha, Joana Monteiro, António Fiúza and Aurora Futuro. Cavali Project: Lithium sorption by ion Exchange (#342).
- Vasco Miranda, Pedro Pina and Sandra Heleno. Assessment of Antarctic vegetation classification as a function of the spatial resolution and application to historical images of Barton Peninsula, King George is (#352).
- João Narciso, Leonardo Azevedo and Ellen Van De Vijver. Geostatistical joint inversion of FDEM and ERT data for modelling near-surface deposits (#379).
- Ernesto Fernandes. Intergenerational Knowledge Transmission in Mining Engineering Using New Technologies (Virtual Reality and Augmented Reality) (#383).
- Oludare Joseph Olufe, Bjarne Almqvist and Michael Lowther. Evaluation of Impacts of Geology Structures on Underground Mine Production Tunnels' Stability in an Iron ore Mine (#387).

Evaluation of Rice and Moth Bean Cultivation Based on Agricultural Characteristics Using Machine Learning

Amir TavallaieNejad[1], Rui Camacho da Silva[2], Luís Cabral Borges[3], Maria Cristina Vila[4], Gustavo Paneiro[5]

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Abstract

Precision agriculture is a growing trend that provides farmers with valuable insights to make informed decisions about their farming strategies. However, current detection methods are labor-intensive, expensive, and not easily scalable, especially in developing regions. This study aims to investigate the relationship between soil field data and the cultivation of rice and moth beans by leveraging rainfall, climate, and fertilizer data specific to India. By analyzing various parameters, a predictive model is presented to recommend the most suitable crops for a rice and moth bean farm. To determine this correlation in soil, five classification machine learning models, namely decision tree, random forest, Naive Bayes, K-NN, and Rule Induction, are tested. The raw data is pre-processed by trimming, removing missing duplicates, and normalizing it. The predictors used in this research are categorized under temperature, rainfall, humidity, and soil chemical properties. Among these, rainfall is identified as the most significant feature based on the feature selection methods employed in this study. The performance of each method is evaluated after optimizing their parameters. Out of the five methods, random forest demonstrates a strong correlation (overall accuracy (OA) = 99.1, kappa = 0.944, R2 = 0.897, and normalized root mean squared error [re-scaled to [0,1]] = 0.088), making it the most reliable approach as indicated by the ROC curve. Following random forest, K-NN with 11 nearest neighbors emerges as the second-best method. Overall, these findings highlight the practicality of this methodology, which effectively recommends suitable soil conditions for rice and moth bean cultivation.

Author keywords. Machine Learning, Cultivation, Soil Characteristics, Agriculture, Modelling.

1 Introduction

Agriculture plays a crucial role in many countries, providing food, resources, and employment (Akpoti et al., 2019). However, the agriculture sector faces challenges like irregular precipitation, floods, drought, and environmental change. To support farmers, technological solutions are needed. Effective utilization of data sources such as soil type, water availability, and weather conditions can enhance crop productivity (Akpoti et al., 2019). Information mining and machine learning techniques offer promising approaches to address these challenges, utilizing extensive agricultural datasets (Astorga et al., 2018; Freeman et al., 2019; Raghavan et al., 2019; Simões & Peterson, 2018).

Agricultural land suitability analysis (ALSA) is a quantitative tool used to optimize land use for crop production, with different methods having advantages and disadvantages (Akpoti et al., 2019). Recent advancements in ecological niche modelling and machine learning algorithms present opportunities for agricultural spatial predictive analytics (Beck, 2013). However, there are limitations in modelling species habitat suitability, such as biased samples and variables without biological significance (Jarnevich et al., 2015).

Choosing appropriate models and parameters is essential for building effective models (Jarnevich et al., 2015).

Previous studies have applied machine learning techniques like Random Forest and maximum entropy modeling to analyze rice presence in different regions and assess land suitability for crops like Hass avocados (Djagba et al., 2018; Dossou-Yovo et al., 2019; Ramírez-Gil et al., 2018; Ramírez-Gil et al., 2019; Laborte et al., 2012; Heumann et al., 2011; Wang, 1994).

This study aims to use an ensemble environmental niche modeling approach to map land suitability for rice in India at a national scale. The analysis will utilize a dataset compiled from Kaggle.com, incorporating rainfall, climate, and fertilizer data. The hypothesis is that the current distribution of cultivated areas serves as a reliable indicator of lowland rice's ecological requirements.

2 Materials and Methods

2.1 Dataset

The preserved soil samples from the study area can be found on the Kaggle.com website. A comprehensive dataset comprising 2200 samples was collected to analyze various soil types. This dataset was constructed by combining information from existing datasets on rainfall, climate, and fertilizer data specifically available for India. The dataset includes the following fields and their respective units:

- **N:** Ratio of Nitrogen content in soil
- **P:** Ratio of Phosphorous content in soil
- **K:** Ratio of Potassium content in soil
- **Temperature:** Temperature in degrees Celsius
- **Humidity:** Relative humidity in percentage
- **pH:** pH value of the soil
- **Rainfall:** Rainfall in millimeters

2.2 Pre-processing

Data pre-processing is an essential step in Machine Learning, involving the cleaning, organizing, and transformation of raw data to prepare it for model building and training. This encompasses tasks such as filtering, removing duplicates, and trimming the data to ensure comparability during training. To handle variations in data ranges, normalization was performed to standardize features across variables like humidity, pH, rainfall, and soil fertilizer. Additionally, three effective feature selection techniques were employed: Univariate Selection, Feature Importance, and Correlation Matrix with Heatmap.

2.2.1 Univariate Selection

In Python, the scikit-learn library offers the SelectKBest class, which enables feature selection using various statistical tests. For this dataset, the chi-squared (chi^2) statistical test was applied to select the most relevant features from the rice and moth bean farm dataset (Table 1).

Table 1: Univariate Selection Score of the rice and moth bean cultivation

Feature	Score
Rainfall	3440.738683
K	1496.746020
P	127.802860
Humidity	43.630890
Temperature	0.912072
pH	0.857998
N	0.055749

2.2.2 Feature Importance

Feature importance assigns a score to each feature in the data, indicating its relevance or importance to the output variable. This score is higher for features that have a greater impact on the output. In this study, we utilized the Extra Tree Classifier, a Tree-Based Classifier, to extract the top features from the dataset, Figure 1 highlights rainfall as the most influential feature.

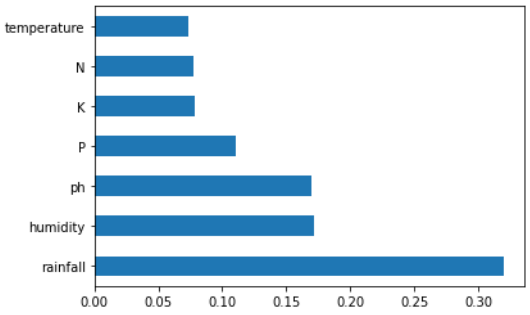

Figure 1. Univariate Selection Score of the rice and moth bean cultivation.

2.3 Correlation Matrix with Heatmap

Correlation analysis reveals the relationships between features and the target variable. Positive correlation indicates that an increase in one feature corresponds to an increase in the target variable, while negative correlation suggests a decrease in the target variable. To visualize these relationships, we employed the Seaborn library to create a heatmap of correlated features. Figure 2 highlights that K and P are the most strongly correlated features.

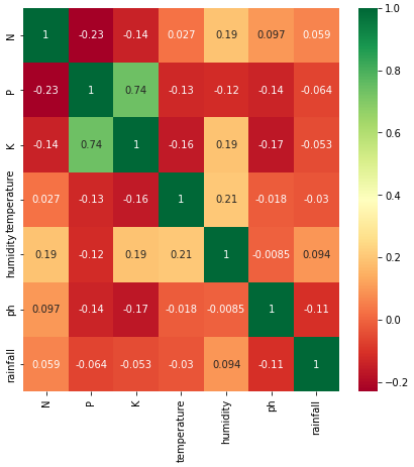

Figure 2. Univariate Selection Score of the rice and moth bean cultivation.

3 Discussion

By examining the average values of the 2200 datasets, we found that rainfall has the greatest overall impact, followed by a substantial difference in the significance of the P-value. Figure 3 displays the average values of each field for the cultivation of rice and moth beans on suitable farms.

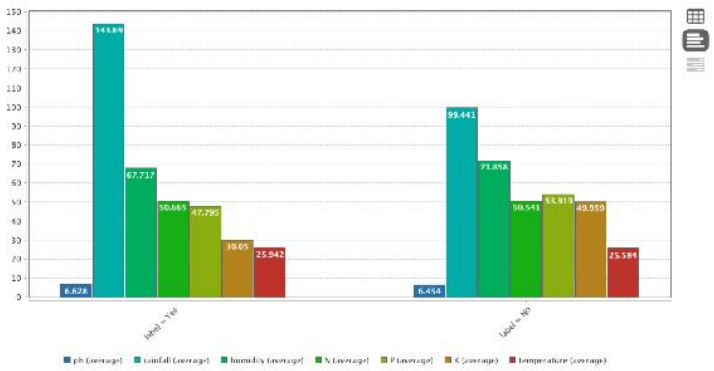

Figure 3: The average row values of each field for the rice and moth beans proper farm for cultivation.

Optimizing the parameters of all five algorithms is essential to enhance the accuracy and minimize errors in the machine learning model. The following section focuses on optimizing the parameters of each algorithm to achieve these objectives.

3.1 Decision Tree

The decision tree algorithm's training and testing process involves optimizing several parameters, including criterion, maximum depth, confidence, minimal gain, minimal leaf size, minimal size of the split, and various pruning options. The Table 2 provides the optimal parameter values for the dataset.

Table 2: The optimum values of decision tree

Criterion	Maximum depth	Confidence	Minimal gain	Minimal leaf size	Minimal size of split	Number of prepruning alternative
gini_index	29	0.3	0.01	1	1	360

3.2 Random Forest

During the training and testing of random forest algorithms, various parameters are considered, such as the number of trees, criterion, maximal depth, subset ratio, voting strategy, pruning, apply preparation, and random splits. The Table 3 presents the optimal parameter values for the dataset.

Table 3: The optimum values of decision tree

Number of trees	Criterion	Maximal depth	Subset ratio	Voting strategy	Apply pruning	Apply prepruning	Random splits
70	gini_index	100	0.2	Confidence vote	No	No	No

3.3 Nave Bayes

The parameters of Naive Bayes algorithms involved in training and testing include place correction. The optimum values for the data are determined during the calculation.

3.4 K-NN

The parameters of K-NN algorithms involved in training and testing include K, which represents the number of nearest neighbors. The number of neighbors is a crucial deciding factor. The optimum value for the number of neighbors is 11.

3.5 Rule Induction

The parameters of rule induction algorithms involved in training and testing include criterion, sample ratio, pureness, and minimal prune benefit. The optimum values for the data are mentioned in Table 4.

Table 4: The optimum values of decision tree

Criterion	Sample ratio	Pureness	Minimal prune benefit
Information gain	0.4	1.0	1.0

4 Results

In Figure 4, the AUC of different models is displayed after optimization. Among the models, Random Forest demonstrates the highest predictive accuracy. Following closely, K-NN exhibits reliable results.

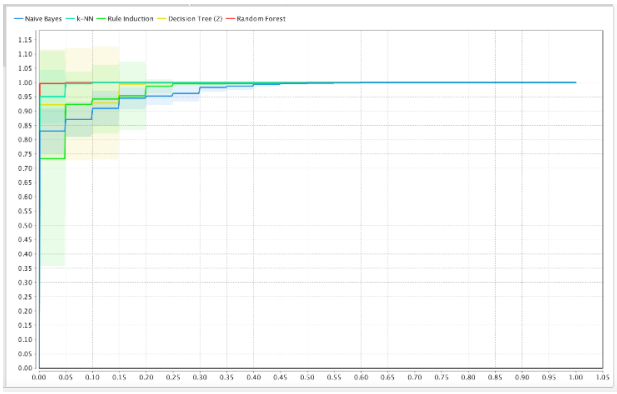

Figure 4: ROC between five different algorithms used in this study.

The performance analysis after optimization is presented in Table 5, showing that the values for Random Forest indicate a more reliable method compared to the others for these datasets.

Table 5: OA, R2, kappa, RMSE of the data for the methods

Name of Method	OA	R2	kappa	RSME
Decision Tree	98.5	0.838	0.912	0.115
Random Forest	99.1	0.897	0.944	0.088
Nave Bayes	92.3	0.430	0.630	0.233
K-NN	98.4	0.817	0.897	0.105
Rule-Induction	97.82	0.762	0.869	0.130

5 Conclusions

This study demonstrates the feasibility of utilizing machine/deep-learning models trained with laboratory-derived spectra to accurately predict the most suitable farm for rice and moth beans cultivation. Three feature selection methods were employed to identify essential features and their dependencies. Five classification machine learning models, including decision tree, random forest, Naive Bayes, K-NN, and Rule Induction, were tested to establish correlations in soil classification. Pre-processing involved trimming raw data, removing missing duplicates, and normalizing the dataset. Predictors related to temperature, rainfall, humidity, and soil chemical properties were considered. The performance of each model was evaluated after optimizing their respective parameters. Among all five methods, random forest demonstrated strong correlation (overall accuracy (OA) = 99.1, kappa = 0.944, R2 = 0.897, and normalized root mean squared error = 0.088). The ROC curve analysis further confirmed the reliability of random forest compared to the other methods. Following random forest, K-NN with 11 nearest neighbors performed as the second-best method. Overall, these results suggest the practicality of this methodology in recommending suitable soil conditions for rice and moth beans cultivation.

References

Akpoti, K., A. T. Kabo-bah, and S. J. Zwart. 2019. "Agricultural Land Suitability Analysis: State-of-the-Art and Outlooks for Integration of Climate Change Analysis." Agricultural Systems 173 (July): 172–208. https://doi.org/10.1016/j.agsy.2019.02.013.

Astorga, F., L. E. Escobar, D. Poo-Muñoz, J. Escobar-Dodero, S. Rojas-Hucks, M. Alvarado-Rybak, M. Duclos, et al. 2018a. "Distributional Ecology of Andes Hantavirus: A Macroecological Approach." International Journal of Health Geographics 17 (1): 22. https://doi.org/10.1186/s12942-018-0142-z.

Beale, C. M., and J. J. Lennon. 2012a. "Incorporating Uncertainty in Predictive Species Distribution Modelling." Philosophical Transactions of the Royal Society B: Biological Sciences 367 (1586): 247–58. https://doi.org/10.1098/rstb.2011.0178.

Beck, J. 2013a. "Predicting Climate Change Effects on Agriculture from Ecological Niche Modeling: Who Profits, Who Loses?" Climatic Change 116 (2): 177–89. https://doi.org/10.1007/s10584-012-0481-x.

Djagba, J. F., L. O. Sintondji, A. M. Kouyaté, I. Baggie, G. Agbahungba, A. Hamadoun, and S. J. Zwart. 2018. "Predictors Determining the Potential of Inland Valleys for Rice Production Development in West Africa." Applied Geography 96 (July): 86–97. https://doi.org/10.1016/j.apgeog.2018.05.003.

Dossou-Yovo, E., S. Zwart, A. Kouyaté, I. Ouédraogo, and O. Bakare. 2018. "Predictors of Drought in Inland Valley Landscapes and Enabling Factors for Rice Farmers' Mitigation Measures in the Sudan-Sahel Zone." Sustainability 11 (1): 79. https://doi.org/10.3390/su11010079.

Elith, J., and J. R. Leathwick. 2009a. "Species Distribution Models: Ecological Explanation and Prediction Across Space and Time." Annual Review of Ecology, Evolution, and Systematics 40 (1): 677–97. https://doi.org/10.1146/annurev.ecolsys.110308.120159.

Freeman, B., P. R. Roehrdanz, and A. T. Peterson. 2019a. "Modeling Endangered Mammal Species Distributions and Forest Connectivity across the Humid Upper

Guinea Lowland Rainforest of West Africa." Biodiversity and Conservation 28 (3): 671–85. https://doi.org/10.1007/s10531-018-01684-6.

Heumann, B. W., S. J. Walsh, and P. M. McDaniel. 2011. "Assessing the Application of a Geographic Presence-Only Model for Land Suitability Mapping." Ecological Informatics 6 (5): 257–69. https://doi.org/10.1016/j.ecoinf.2011.04.004.

Jarnevich, C. S., T. J. Stohlgren, S. Kumar, J. T. Morisette, and T. R. Holcombe. 2015a. "Caveats for Correlative Species Distribution Modeling." Ecological Informatics 29 (September): 6–15. https://doi.org/10.1016/j.ecoinf.2015.06.007.

Karthik, L., G. Kumar, T. Keswani, A. Bhattacharyya, S. S. Chandar, and K. V. Bhaskara Rao. 2014a. "Protease Inhibitors from Marine Actinobacteria as a Potential Source for Antimalarial Compound." PLoS ONE 9 (3): e90972. https://doi.org/10.1371/journal.pone.0090972.

Laborte, A. G., A. A. Maunahan, and R. J. Hijmans. 2012. "Opportunities for Expanding Paddy Rice Production in Laos: Spatial Predictive Modeling Using Random Forest." Journal of Land Use Science 7 (1): 21–33. https://doi.org/10.1080/1747423X.2010.519788.

Peterson, A. T. 2006a. "Uses and Requirements of Ecological Niche Models and Related Distributional Models." Biodiversity Informatics 3 (0). https://doi.org/10.17161/bi.v3i0.29.

Qiao, H., J. Soberón, and A. T. Peterson. 2015a. "No Silver Bullets in Correlative Ecological Niche Modelling: Insights from Testing among Many Potential Algorithms for Niche Estimation." Methods in Ecology and Evolution 6 (10): 1126–36. https://doi.org/10.1111/2041-210X.12397.

Ramírez-Gil, Joaquín Guillermo, M. E. Cobos, D. Jiménez-García, J. G. Morales-Osorio, and A. T. Peterson. 2019. "Current and Potential Future Distributions of Hass Avocados in the Face of Climate Change across the Americas." Crop and Pasture Science 70 (8): 694. https://doi.org/10.1071/CP19094.

Ramírez-Gil, Joaquin Guillermo, J. G. Morales, and A. T. Peterson. 2018. "Potential Geography and Productivity of 'Hass' Avocado Crops in Colombia Estimated by Ecological Niche Modeling." Scientia Horticulturae 237 (July): 287–95. https://doi.org/10.1016/j.scienta.2018.04.021.

RapidMiner documentation. 2014. "The information about the types of algorithms and additional data." Https://Docs.Rapidminer.Com/. February 2014.

Simões, M. V. P., and A. T. Peterson. 2018a. "Importance of Biotic Predictors in Estimation of Potential Invasive Areas: The Example of the Tortoise Beetle Eurypedus Nigrosignatus, in Hispaniola." PeerJ 6 (December): e6052. https://doi.org/10.7717/peerj.6052.

Wang, F. 1994. "The Use of Artificial Neural Networks in a Geographical Information System for Agricultural Land-Suitability Assessment." Environment and Planning A: Economy and Space 26 (2): 265–84. https://doi.org/10.1068/a260265.

Acknowledgments

This work was financially supported by: Base Funding - UIDB/04028/2020 of the Research Center for Natural Resources and Environment – CERENA - funded by national funds through the FCT/MCTES (PIDDAC).

Stochastic inversion of seismic data to facies models using a novel physics-guided Generative Adversarial Network

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Abstract

Predicting facies distributions directly from seismic reflection data is of great importance for subsurface characterization and fluid flow modeling, e.g., in hydrocarbon reservoir characterization or CO2 geological storage. Generative Adversarial Network (GAN) is a promising technique capable of generating realistic geologic models, conditioning the results on the observed seismic data is still an unsolved challenge. We propose a seismic inversion algorithm accounting for a novel GAN, the W-Net GAN, to invert seismic data in an adversarial framework. The network learns the physics-based correlation between facies and seismic data, represented in the training dataset and including the spatial uncertainty of elastic rock properties. Then, it generates facies models fitting the observed seismic, based on the learned parameters. We demonstrate the method on a synthetic dataset, showing that the W-Net GAN can invert seismic data overcoming the limitations of conventional GANs networks.

Author keywords. Deep learning, seismic inversion, generative adversarial networks, facies modeling

1 Introduction

Predicting geologically accurate spatial distribution of facies in the subsurface is pivotal for many applications in geoscience, e.g., in the assessment of the presence of natural resources in geological reservoirs. Generative Adversarial Networks (GANs) (Goodfellow et al., 2014) have been widely used to generate realistic facies models, both in conditioned and unconditioned frameworks (Azevedo et al., 2020; Dupont et al., 2018). To this purpose, a generative network (G) is trained to map a low-dimensional latent vector into a facies model reproducing the distribution represented in a training dataset as a set of facies patterns. A discriminator network (D) maps an input image into a probability value and is trained to distinguish if the input belongs to the training dataset or was generated by G. The objective is to maximize the probability that G generates facies models indistinguishable from those of the training dataset (Goodfellow et al., 2014).

Elastic properties, such as acoustic impedance I_P, can be associated to each facies to retrieve the possible seismic reflection data that a facies pattern can generate, using a forward physics modeling. Conventional GANs-based use pre-trained GANs and an additional inference network. The latter is used to find the solutions that fit the observed data, given a geophysical forward model (e.g., Laloy et al., 2019). Nonetheless, these methods do not account for the spatial uncertainty associated with the facies' elastic properties and can retrieve only deterministic solutions. Seismic data inversion problems are ill-posed, with multiple possible solutions, hence, accounting for rock properties uncertainties is fundamental in subsurface characterization (Tarantola, 2005). To overcome these limitations, we propose a GAN for stochastic seismic data inversion, to directly retrieve equiprobable facies patterns fitting the observed seismic.

The method accounts for a novel discriminator architecture, W-Net Discriminator, that learns the physics-based correlation between facies and seismic data from a training dataset, and conditions the generation of the facies of G. The training dataset includes spatial uncertainty by representing a set of facies patterns and, for each, another conditioned distribution of possible seismic reflection responses. A synthetic application is used to illustrate the method.

2 Materials and Methods

The proposed W-Net GAN (Figure 1) integrates an unconditioned generator (G), being a convolutional neural network (CNN) mapping a facies pattern from a 1D latent vector. The W-net discriminator (D_W) used in the network is a three-branched CNN (Figure 1b) that reads the facies image and seismic reflection data as input. D_W and outputs two probabilities, one evaluating if the facies pattern belongs to the training dataset – P(Facies) – and a joint probability – P(Facies, Seismic) – representing the goodness of fit between the facies and the seismic data. The evaluation of the joint probability is possible by mapping the combination of facies and seismic data at different scales, using skip connections.

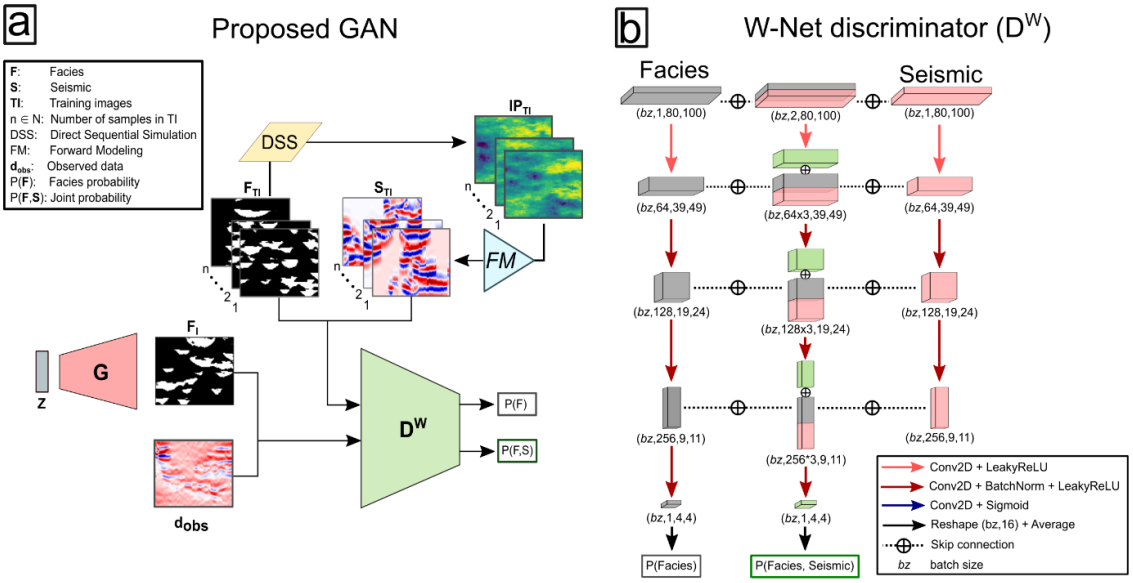

Figure 1: a) proposed algorithm using W-Net GAN for seismic inversion; b) W-Net Discriminator architecture.

For seismic inversion, we first assume that for a given facies distribution, there is a set of corresponding seismic responses given the spatial uncertainty on elastic properties. This is represented in a training dataset (Figure 1a) of facies and corresponding seismic data generated following the steps:

a) We simulate an a priori distribution of facies patterns (**F_{TI}**) through geostatistical simulation conditioned to multi-point statistics (Strebelle, 2002);

b) For each facies model, we simulate a predetermined number of acoustic impedance realizations (**IP_{TI}**) using direct sequential simulation (DSS) conditioned on **F_{TI}** (Nunes et al., 2017);

c) The corresponding distribution of seismic responses (**S_{TI}**) is calculated using a geophysical forward model for full-stack seismic (Russell and Hampson, 1991).

Then, the seismic inversion is carried by means of the adversarial training of the network:

a) D_W is trained to learn the distribution of facies-seismic responses by associating high probability values to the training dataset and low probability values when the facies generated by G is associated with seismic data from the training dataset.

b) G is trained to maximize the probability values of D_W when it reads the observed seismic $\mathbf{d}_{obs}$ and the generated facies model.

3 Results

We demonstrate the method on a synthetic, 2D data set (Figure 2). The targeted facie model is shown in Figure 2a and represents channelized sand bodies in a shaly background. We define facies-dependent variogram models and distribution for the geostatistical simulation of I_P. We then calculate the $\mathbf{d}_{obs}$ (Figure 2b) we intend to invert by convolving it with a controlled wavelet. We ran a total of 200 epochs. Already after 80 epochs the generated facies models reached a maximum fit with the observed seismic given the I_P spatial distributions. The results are represented in Figure 2c as the probability of sand occurrence calculated from a set of 100 facies models generated by G. The Mean Squared Error (MSE) distance between the most likely facies obtained from these models and the target is 0.203. We also calculated the seismic reflection data from this model, using the point-wise average of 32 DSS simulations of I_P (Figure 2d). The MSE between the predicted seismic and $\mathbf{d}_{obs}$ is 0.006.

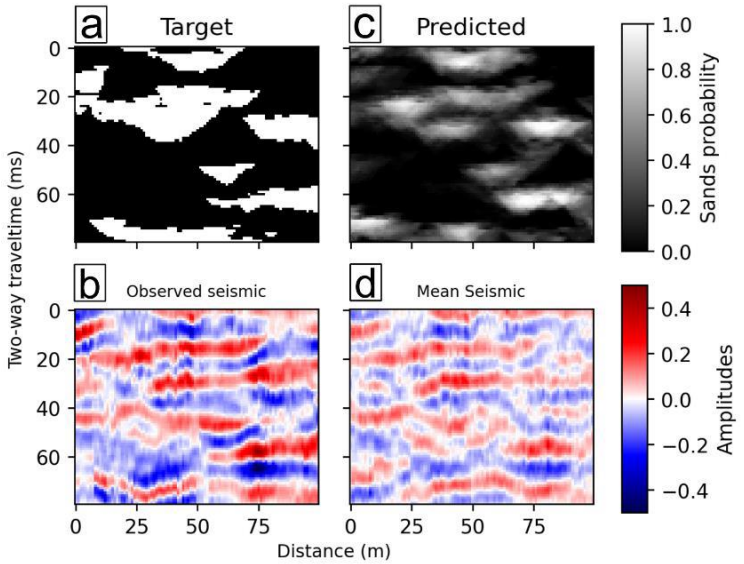

Figure 2: a) Targeted facies pattern; b) seismic data obtained from a) ($\boldsymbol{d_{obs}}$); c) predicted probabilities from 100 realizations obtained with the proposed GAN; d) seismic data from to the average Ip distribution derived from c).

4 Conclusions

The proposed method is a W-Net GAN for the direct stochastic inversion of facies model from seismic reflection data. Differently from conventional approaches using GAN for facies modeling, the novel discriminator architecture allows the generation of facies models that fit the seismic data directly in a single-step training. After training the

proposed GAN, each draw from the 1D latent vector corresponds to a facies model that fits the seismic, according to what the discriminator learned on physics forward modeling and I_P spatial uncertainty. Since the generated facies models are dependent on the discriminator training performances, further improvements may be obtained by including seismic data misfit in the loss function of the generator. Nonetheless, this would require a more computationally- and time-consuming simulation step after the facies generation and the tuning of hyperparameters, i.e., the weights of the loss function.

References

Azevedo, Leonardo, Gustavo Paneiro, Arthur Santos, and Amilcar Soares, 2020. "Generative Adversarial Network as a Stochastic Subsurface Model Reconstruction." *Computational Geosciences* 24 (4): 1673–92. https://doi.org/10.1007/s10596-020-09978-x.

Dupont, Emilien, Tuanfeng Zhang, Peter Tilke, Lin Liang, and William Bailey, 2018. "Generating Realistic Geology Conditioned on Physical Measurements with Generative Adversarial Networks." arXiv. http://arxiv.org/abs/1802.03065.

Goodfellow, Ian J., Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio, 2014. "Generative Adversarial Networks." *ArXiv:1406.2661 [Cs, Stat]*, June. http://arxiv.org/abs/1406.2661.

Laloy, Eric, Niklas Linde, Cyprien Ruffino, Romain Hérault, Gilles Gasso, and Diederik Jacques, 2019. "Gradient-Based Deterministic Inversion of Geophysical Data with Generative Adversarial Networks: Is It Feasible?" *Computers & Geosciences* 133 (December): 104333. https://doi.org/10.1016/j.cageo.2019.104333.

Russell, Brian, and Dan Hampson. 1991. "Comparison of Poststack Seismic Inversion Methods." In *SEG Technical Program Expanded Abstracts 1991*, 876–78. Society of Exploration Geophysicists. https://doi.org/10.1190/1.1888870.

Strebelle, Sebastien, 2002. "Conditional Simulation of Complex Geological Structures Using Multiple-Point Statistics." *Mathematical Geology*, 21.

Tarantola, Albert, 2005. *Inverse Problem Theory and Methods for Model Parameter Estimation*. Philadelphia, PA: Society for Industrial and Applied Mathematics.

Acknowledgments

This work was supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project 2020.05571.BD.

Multivariate Analysis: Principal Component Analysis (PCA). Case Study: Rio de Frades mine, Arouca, Portugal

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Abstract

The present work aims to analyse the data from the geochemical study of mining heaps derived from abandoned mining areas, through multivariate analysis, more specifically the principal components analysis. The case study refers to the Rio de Frades mine, in Arouca, Portugal, with main mineralization in W-Sn. The analysis included samples of soil and sediment, as well as samples of plants of the species Erica umbellata. The Principal Components analysis allowed inferring (i) the existence of a clear distinction, at the chemical level, between geological samples and biological samples; (ii) the association of chemical elements with the samples; (iii) the plant of the species Erica umbellata does not have the capacity to accumulate the chemical elements studied.

Author keywords. Abandoned mining areas, principal component analysis, wolframium mines, geostatistic.

1 Introduction

Multivariate analysis refers to all statistical techniques that simultaneously analyse several variables in each sample element (Hair et al., 2018), with the objective of measure, explain and predict the degree of relationship between variables, since the multivariate character is based on multiple variables and not just on the number of variables or observations (Hair et al., 2018). These techniques aim to simplify the interpretation of the analysis to be carried out (Hair et al., 2018). In the present work, only exploratory factor analysis was carried out, more specifically principal component analysis (PCA), with the aid of the ANDAD software. Principal component analysis is a statistical approach that aims to analyse the data in a reduced way, eliminating overlaps, allowing the most representative choice of data from linear combinations of the original variables (factors), which allows: (i) analyse the interrelationships between a large number of variables; (ii) explain these variables in terms of their common underlying dimensions (factors) (Hair et al., 2018).

The principal component analysis of this work was based on geochemical data from soil and sediment samples, as well as data from the chemical analysis of plant samples of the *Erica umbellata* species derived from the work carried out at the Rio de Frades mine, Arouca, Portugal. The determination of the contents of the chemical elements to be analyzed was carried out using the method of inductively coupled plasma mass spectrometry (ICP-MS).

2 Discussion

The content of the two types of collected samples were analysed, biological and geological samples, through PCA using ANDAD software, where it was verified that the analysis would fall under axis 1, 2, 3 and 4, the remaining ones being eliminated. The interpretation of the mentioned axes allowed organizing the data according to Table 1.

Table 1: Correlation between chemical elements and samples in the distinct factors (axis), regarding to the analysis of biological and geological samples

	Chemical Elements	Samples
Axis 1 +	Fe, W, Sn, As, Cu, Na, Mg, Al, Cr	SO3, SO5, SO6, SO8, bS9, bS9r, SO10, SO11, SO12, SO13, SO14, SO15
Axis 1 -	Ca, K	P2, P3, P5, P6, P7, P8, bP9, P10, P11, P12, P13, P13r, P14, P14r
Axis 2 +	Mn, W, Ca	SO13, SO15, P12
Axis 2	-	SE1, SO2, SO7, bS9, bS9r

Analyzing the graph in Figure 1, the distinction between biological samples and geological samples is noticeable, since the first type of samples mentioned is on the negative axis and the second type of samples on the positive side, existing a clear distinction in the correlation between these two types of samples, as well as the elements associated with them.

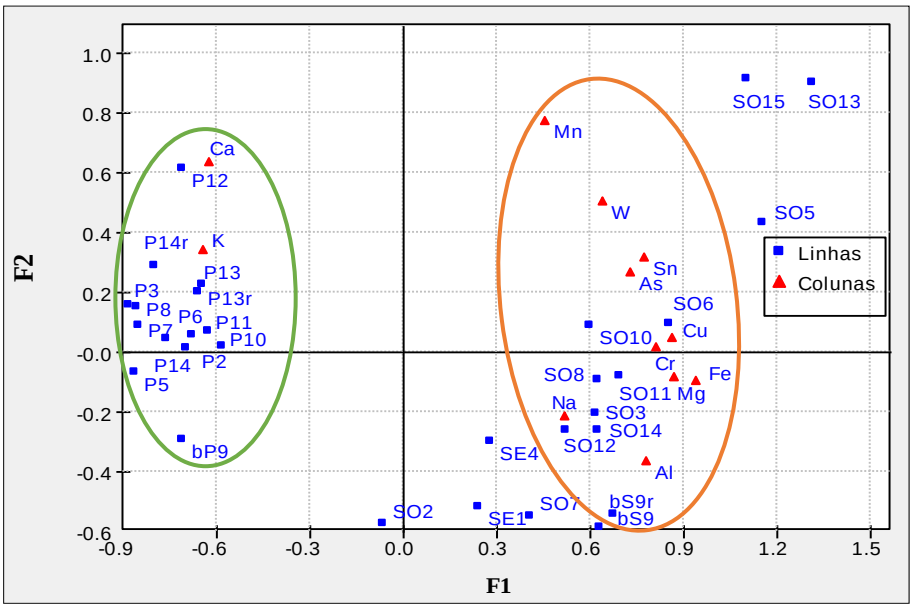

Figure 1: Projection of individuals and variables, referring to the analysis of biological and geological samples.

2.1 Geological Samples

In this analysis, the same chemical elements were selected, but only the geological samples, in order to understand the distribution of these same elements by the sampling sites. The analysis fell under axes 1, 2, 3 and 4, with the rest being eliminated. By observing the aforementioned axes, we obtain the elements and samples organized as shown in Table 2.

Table 2: Correlation between chemical elements and samples in the distinct factors (axis), regarding to the analysis of geological samples.

	Chemical Elements	Samples
Axis 1 +	Fe, Mn, Sn, Cu, Mg, K	SO5, SO13, SO15
Axis 1 -	-	SE1, SO2, SE4
Axis 2 +	As, W, Ca, Cr	SO13, SO15
Axis 2 –	Al	SO7, bS9, bS9r

By analyzing the Table 2, it is possible to state that samples SE1, SO2 and SE4 are not related to any element. These values can be explained by the fact that two of the samples are of sediments, meaning that the levels in the sediments are lower than those of the soils collected near the place where these samples were collected, which could be associated with the dispersion caused by the river downstream. The background samples are more related to Al, which means that these samples refer to silicate minerals, that is, support minerals. The correlation on the positive axis 2 between W and Ca confirms the presence of scheelite (calcium tungstate – $CaWO_4$) in the minerals present in the paragenesis, something that is mentioned in the bibliography as hypothetical (Favas, 2008). Sample SO_{13} is related to these four elements, as it is located at the entrance to an old mining gallery, which may indicate the presence of minerals such as wolframite, scheelite, arsenopyrite and minerals enriched in Cr (Figure 2).

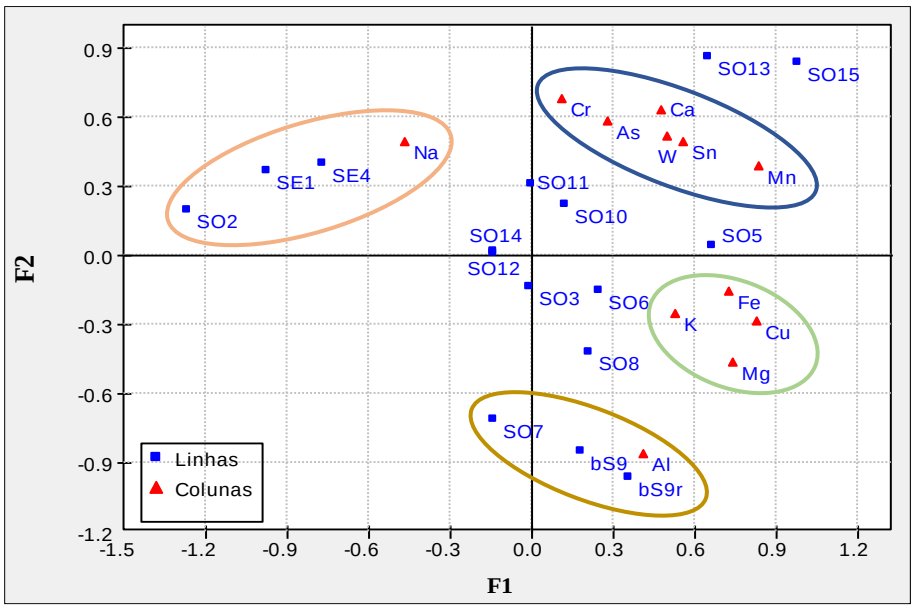

Figure 2: Projection of individuals and variables, referring to the analysis of geological samples.

2.2 Biological Samples

In this analysis, the same chemical elements were selected, but only the biological samples, in order to understand the distribution of these same elements with the sampling sites. The analysis falls under axes 1, 2, 3, 4 and 5, the rest being eliminated. Samples were organized as shown in Table 3.

Table 3: Correlation between the chemical elements and the samples in the distinct factors (axis), regarding to the analysis of biological samples

	Chemical Elements	Samples
Axis 1 +	Fe, Mn, Sn, Ca, Cu, Na, Mg, Al	P12, P13, P14r
Axis 1 -	-	P5, P6, P8
Axis 2 +	Cu	-
Axis 2 –	Fe, W, As	P3

By analysing the Table 3, it is possible to state that samples P12, P13 and P14r are mostly related to chemical elements that are part of the structure of this type of samples, being designated macro and micronutrients, with the exception of Sn. Most of the samples are not correlated with contaminating elements, so we can state that this species (*Erica umbellata*) does not accumulate this type of chemical elements (Figure 3).

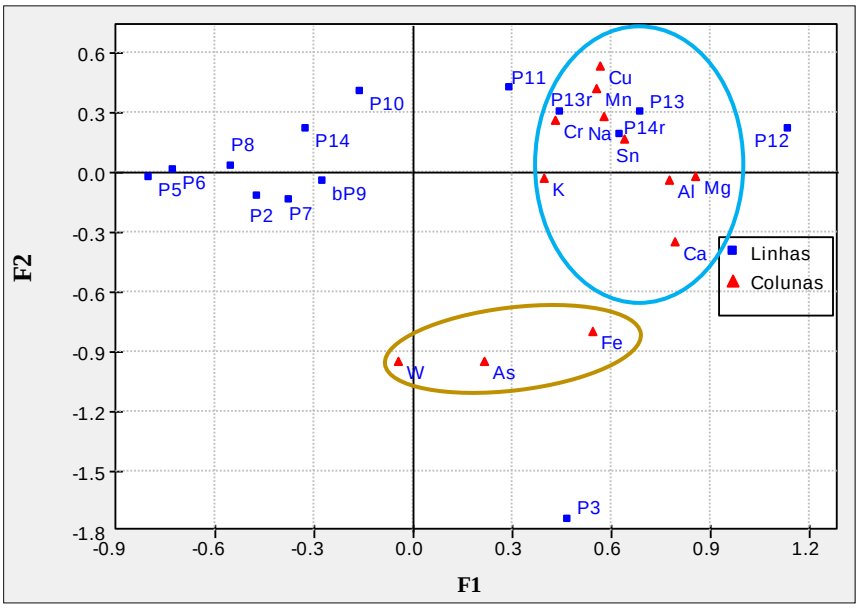

Figure 3: Projection of individuals and variables, referring to the analysis of biological samples.

3 Conclusions

The main objective of this work was the multivariate analysis of data from the Rio de Frades mine, focusing on the principal part analysis (PCA) method. With the work done for this paper, it is possible to state that the utilization of Principal Component Analysis allowed to stablish relationships between the different PTE and the samples, as well as observe the behaviour of the PTE according to the type of sample.

References

Favas, P. J. d. C. (2008). Biogeoquímica em áreas minerais estano-volframíticas.

Hair, J., Black, W., Anderson, R., & Babin, B. (2018). Multivariate data analysis (8, ilustra ed.). *Cengage Learning EMEA*, *27*(6), 1951-1980.

Noronha, F. (2006). Especialização metalogenética das rochas graníticas da ZCI. VII Congresso Nacional de Geologia,

Romão, J. (2000). *Estudo tectono-estratrigráfico de um segmento do bordo SW da Zona Centro-Ibérica, e as suas relações com a zona Ossa-Morena* Faculdade de Ciências da Universidade de Lisboa.

Souza, K. G. (2012). Importância dos elementos químicos nas plantas.

Vilar, A. d. A. S. (1998). *O volfrâmio de Arouca no contexto da Segunda Guerra Mundial, 1939-1945*.

Acknowledgments

This work was financially supported by: Base Funding - UIDB/04028/2020 and 425 Programmatic Funding - UIDP/04028/2020 of the Research Center for Natural 426 Resources and Environment – CERENA - funded by national funds through the 427 FCT/MCTES (PIDDAC), through a PhD scholarship with reference 428 UI/BD/152297/2021.

Seismic oceanography imaging and modelling applied to Madeira abyssal plain

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Abstract

We illustrate the ability of seismic oceanography to reveal oceanographic phenomena co-occurring on both large- and small-scales. We processed and inverted three parallel two-dimensional multichannel seismic reflection sections acquired in the Madeira Abyssal Plain in June 2006. The resulting images capture detailed fine-scale water column structures at 2 km depth. The processing methodology preserved the relative seismic amplitudes while effectively suppressing the direct arrival, enhancing shallow water column structure. The final processed seismic oceanography sections exhibit several features of interest related to the Mediterranean Outflow Water. An iterative geostatistical seismic oceanography inversion methodology was applied to predict the spatial distribution of temperature and salinity along each section, utilizing information from multiple sources.

Author keywords. Seismic Oceanography; Thermohaline Staircases; Ocean sub-mesoscale; Physical Ocean.

1 Introduction

Between scales of 1 and 10 kilometers, it is difficult to sample directly and exhaustively the ocean. The currently available ocean data is insufficient to fully characterize the ocean dynamics at these spatial scales. However, these scales are crucial for ocean productivity and promoting vertical carbon export to the deep ocean, essential for reducing climate change impacts (Thomas and Yamada, 2019).

While conventional oceanographic surveys provide low-spatial resolution data, seismic oceanography (SO) data - produced through a specific method of processing multi-channel seismic reflection data - offer static snapshots of thermohaline circulation at the spatial scales. These data are obtained through the reflection of an acoustic wavefield generated by a source, which reflects at the thermohaline structures, particularly at interfaces associated with temperature, T, variations (Lavergne, 2016). Temperature changes contributes significantly to the reflection coefficient, accounting for an average of 80%. At the same time, salinity, S, plays a smaller role, with the reflected signal originating from the interfaces of water masses with property gradient differences (Ruddick, 2008; Sallarès, 2009).

From an oceanographic standpoint, these data capture multi-scale oceanic phenomena with near-synoptic coverage not provided by traditional surveys. Despite the potential of SO in physical oceanography, its applications remain limited, possibly due to the indirect relationship between ocean temperature and salinity and the recorded seismic amplitudes.

Understanding the spatial and temporal distribution of sub-mesoscale fronts, water mass mixing, and sub-mesoscale structural changes at different depths is crucial (Fortin,

2017; Micallef, 2020) and linked directly to the spatial distribution of the ocean water properties, such as temperature and salinity. Predicting the spatial distribution of temperature and salinity from SO data requires solving a geophysical inverse problem (i.e., SO inversion). In this work, we predict the ocean temperature and salinity with geostatistical SO inversion methods. Geostatistical inversion methods are iterative procedures that use geostatistical simulation as a model perturbation technique and use the misfit between observed and predicted SO data to drive the iterative procedure (Azevedo and Soares, 2017). A challenge in SO studies is conditioning the predicted models to direct observational data. In this study, we predict temperature and salinity by integrating data from multiple sources.

2 Methods and Data

2.1 Dataset

To study the Madeira abyssal plain (MAP), we use a set of three two-dimensional multichannel seismic reflection sections acquired in 2006 by the Portuguese Task Force for the Extension of the Continental Shelf and conductivity-temperature-depth (CTD) data acquired from a research campaign during 2005 for the same region (Müller, 2008) (Figure 1).

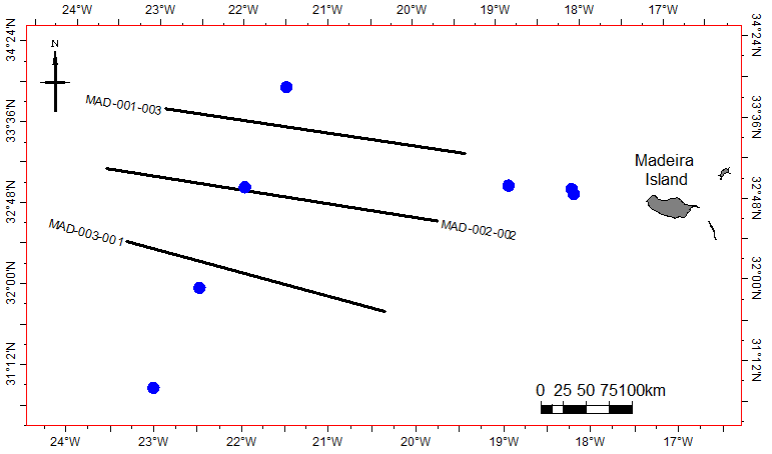

Figure 1: Location of the 2D seismic section (black lines) and the CTD direct measurements (blue dots).

2.2 Seismic oceanography processing

The seismic processing workflow differs from conventional seismic processing by recovering and enhancing the reflections originated within the water column. This represents a challenge not only due to the weak amplitudes of the reflected signal but also because of the direct wave energy that travels from the source to the receivers masking the reflections from the first few meters. To accomplish SO seismic processing, the workflow has two objectives, first to attenuate the direct arrival effect using a combination of linear moveout, horizontal median filtering and amplitude subtraction, and second, to preserve the true amplitudes of the water reflections to be later used in the seismic inversion.

2.3 Seismic oceanography inversion

We used the iterative geostatistical SO inversion method to predict the sub-mesoscale spatial distribution of ocean temperature and salinity along the three SO profiles (Soares, 2001). First, we build the background models for the inversion grid based on the average of direct observations. Then, the stochastic simulation of T and co-simulation of S models starts using the nearest direct measurements as distribution conditioning. Calculate the reflection coefficient, using the International thermodynamic equation of seawater (TEOS-10, 2010), for each pair of simulated ocean models, which are then convolved with an extracted statistical wavelet from the observed seismic, build models of synthetic seismic.

Those models proceed to be validated by calculating the trace-by-trace mismatch based on similarity and by comparison with the background models for the T S pairs. Then, the best pairs are stored with the corresponding correlation coefficient to be used in the subsequent iterations as a secondary variable. The process iterates until the global correlation coefficient between real and synthetic SO data reaches a threshold.

3 Results and Discussion

After applying the processing workflow, we obtain a snapshot of the different water layers (Figure 2a) cropped to the region with reflections. The water is not homogenous, up to 3000 meters deep.

By comparing with the SO observed data, the inverted temperature and salinity models have been found to capture crucial oceanic features at a finer resolution accurately. The effectiveness of these models lies in their ability to account for intricate and dynamic oceanic complexities often overlooked by other inversion methods, rendering them less precise in making predictions or identifying anomalies (Azevedo et al., 2021).

The filamentation patterns observed in the 800ms depth reveal inverted temperature and salinity models that highlight significant amplitudes within real seismic data (Figure 2 c, d). These amplitudes exhibit correspondingly abnormal temperature and salinity readings in this specific area.

Using background temperature and salinity models makes it feasible to recreate the projected vertical distribution of these two properties as derived from ocean models.

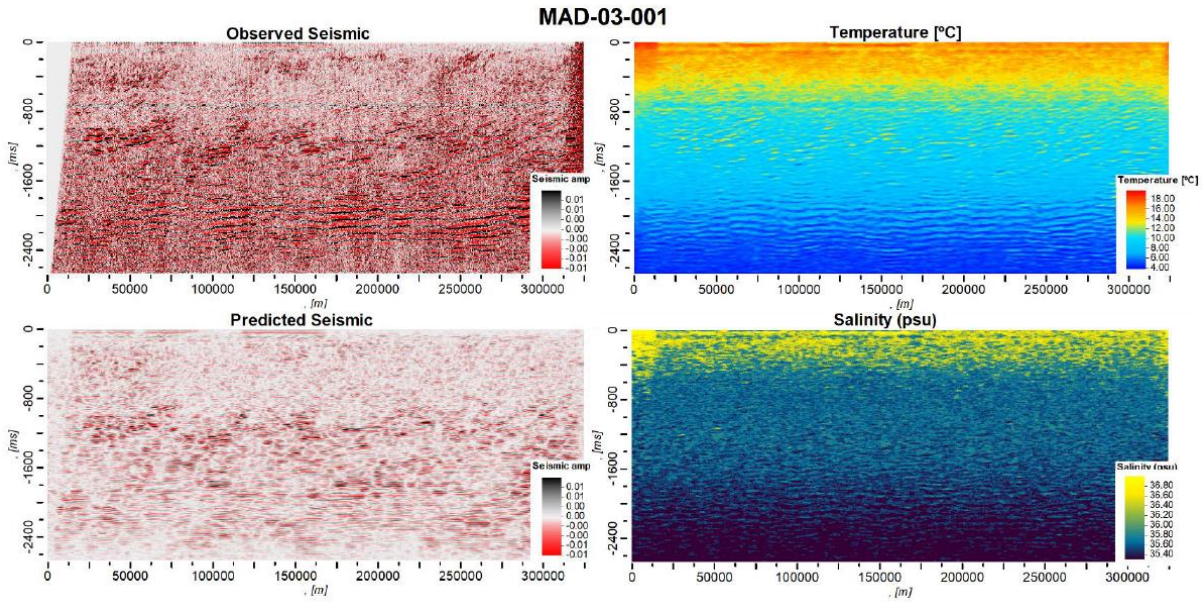

Figure 2: Final results of the MAD-03-001 line; a) Observed seismic data; b) Synthetic seismic data resultant from the inversion; c) Mean temperature model after inversion; d) Mean salinity model after inversion.

4 Conclusions

This study presents an integrated analysis of three SO sections obtained from the Madeira abyssal plain region. The data was processed to mitigate the direct arrival effect and inverted using geostatistical SO inversion, providing experimental data for further simulating ocean temperature and salinity in three dimensions.

The processing method successfully reduced the direct wave's impact, revealing reflections in the first few hundred meters below the sea surface. The section's upper part contained interesting oceanographic features associated with the Mediterranean outflow water and double-diffusive phenomena.

The inverted sections enabled the characterization of sub-mesoscale oceanic features directly in the temperature and salinity domain, which are difficult to capture through sparse direct measurements.

References

Azevedo, Leonardo, and Amílcar Soares. "Geostatistical Methods for Reservoir Geophysics." Advances in Oil and Gas Exploration & Production, 2017. https://doi.org/10.1007/978-3-319-53201-1.

Fortin, W. F. J., W. S. Holbrook, and R. W. Schmitt. "Seismic Estimates of Turbulent Diffusivity and Evidence of Nonlinear Internal Wave Forcing by Geometric Resonance in the South China Sea." Journal of Geophysical Research: Oceans 122, no. 10 (October 2017): 8063–78. https://doi.org/10.1002/2017jc012690.

IOC SCOR and IAPSO The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties", Intergovernmental Oceanographic Commission Manuals and Guides No. 56 UNESCO (English), pp. 196, 2010. https://doi.org/10.25607/OBP-1338

L. Azevedo and A. Soares, “Geostatistical methods for reservoir geophysics”, Advances in Oil and Gas Exploration & Production, 2017.

Lavergne, Casimir de, Gurvan Madec, Xavier Capet, Guillaume Maze, and Fabien Roquet. “Getting to the Bottom of the Ocean.” Nature Geoscience 9, no. 12 (November 30, 2016): 857–58. https://doi.org/10.1038/ngeo2850.

Micallef, Aaron, Mark Person, Amir Haroon, Bradley A. Weymer, Marion Jegen, Katrin Schwalenberg, Zahra Faghih, et al. “3D Characterisation and Quantification of an Offshore Freshened Groundwater System in the Canterbury Bight.” Nature Communications 11, no. 1 (March 13, 2020). https://doi.org/10.1038/s41467-020-14770-7.

Müller, Thomas J. "Cruise Report RV POSEIDON POS321.", 2008. https://doi.org/10.3289/CR_POS321

Ruddick, Barry, Haibin Song, Chongzhi Dong, and Luis Pinheiro. “Water Column Seismic Images as Maps of Temperature Gradient.” Oceanography 22, no. 1 (March 1, 2009): 192–205. https://doi.org/10.5670/oceanog.2009.19.

Acknowledgments

The authors would also like to thank EMEPC for acquiring and making this seismic profile available. Schlumberger for the donation of academic licenses of Petrel®. Parallel Geoscience Corporation for SPW 4.0 used to process the seismic data.

Acknowledgements to the support of the CERENA (strategic project FCT-UIDB/04028/2020) and Multi-source Modelling of The Ocean: Coupling Earth Observations with Acoustic Waves (UTAP-EXPL/IET/0011/2021) project. Direct measurements of temperature and salinity were collected and made freely available by NOAA in World Ocean Database.

Deep learning ERT inversion for groundwater modelling

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Abstract

Climate change threats groundwater resources requiring long-term sustainable management of this critical asset. Widely applied in hydrogeology, electric resistivity tomography (ERT) has been a preferable tool for imaging and characterizing these types of natural resources. However, the prediction of the spatial distribution of the fluid relevant subsurface properties from ERT data requires solving a challenging geophysical inversion problem. Existing ERT inversion methods are computationally expensive and require a large degree of expertise. This study explores deep learning methods for ERT inversion to predict subsurface properties relevant for groundwater modelling avoiding the two main limitations mentioned above. The proposed methodology is illustrated in synthetic data obtained from a sandbox experiment.

Author Keywords. Variational Autoencoder (VAE), Electrical Resistivity Tomography (ERT), Geophysical inversion, Groundwater

1 Introduction

Groundwater is the world's largest natural storage of freshwater. This natural resource accounts for many water-demanding activities, such as agriculture, industrial and/or domestic usage, therefore, playing a vital role in sustaining global water and food security. For these reasons it is imperative to adopt innovative and sustainable management of this important resource. This goal can be achieved through better subsurface modelling and characterization tools that can be applied to deepen our current knowledge of complex groundwater systems.

Deep learning techniques are widely used in various scientific areas. In geoscience, these methods have been applied to predict the spatial distribution of a subsurface property from a set of sparse measurements acquired at the surface from a geophysical survey. In other words, deep learning methods have been successfully used to solve geophysical inverse problems with different natures (e.g., Laloy et al. 2017; Lopez-Alvis et al. 2021; Bürkle, Azevedo, and Vellasco 2023). We propose herein the characterization and spatial prediction of relevant subsurface properties of groundwater resources through ERT inversion using a deep learning data-driven approach.

2 Methodology

We use a variational autoencoder (VAE)-based ERT inversion method to predict electrical resistivity from ERT data. In this case, the chosen VAE-based architecture allows a low-dimensional representation of the input model into latent variables. The proposed methodology follows three main steps (Figure 1): i) ERT data acquisition; ii) VAE training; and iii) ERT data inversion.

Data acquisition comprises the common practice of converting the observed voltage measurements into apparent resistivity values. The second step, the most time-consuming, involves the training of the VAE based on a data-to-data architecture

avoiding the need of training data set. In the proposed network architecture, apparent resistivity data are the input of the VAE. The deep network outputs predicted electrical resistivity models that are then forward modelled (Cockett et al. 2015) to predict synthetic data (i.e., synthetic apparent resistivity). These data are then compared with the recorded data. The misfit between the observed and predicted data is used to calculate the loss and iteratively update the weights and biases of the neural network using an optimizer (i.e., ADAM).

The ultimate task is the ERT data inversion where the decoder act as a generator by sampling the latent vector and passing it through the decoder to obtain the predicted model.

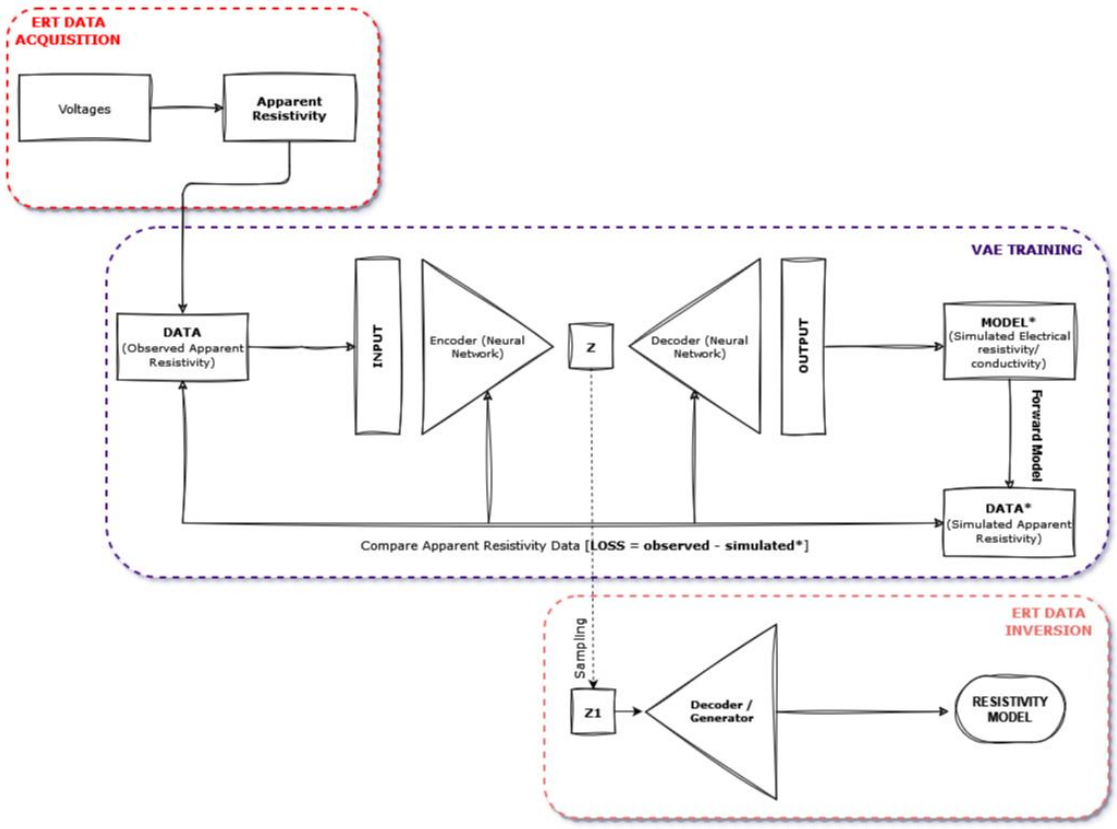

Figure 1: Methodology scheme of the proposed method.

2.1 Synthetic application example

The described methodology is applied to a synthetic data set obtained from a sandbox experiment that mimics a typical groundwater system (Chen et al., 2018; Citarella et al., 2015). For this synthetic application example, a laboratory sandbox is set up to reproduce a homogeneous porous medium by filling it with glass beads of the same dimension. Furthermore, an impermeable barrier is positioned at the top centre of the sandbox. The simulation of the pollutant dispersion in a groundwater system is reproduced by the injection of a tracer solution. The spatial distribution of the pollutant after injection is converted in electrical resistivity. This property was used as input of a

forward model to compute numerically the observed ERT data (Figure 2b). These data are characterized by a V-shape (induced by the impermeable barrier) plume spread with low resistivity values (Figure 2a) within a high-resistive background.

The proposed methodology was successfully applied to this synthetic example. The predicted electrical resistivity models show similar patterns to those observed in the true model. The predicted models also reproduce the imposed histogram and variogram models. Moreover, the inversion yields a low data misfit.

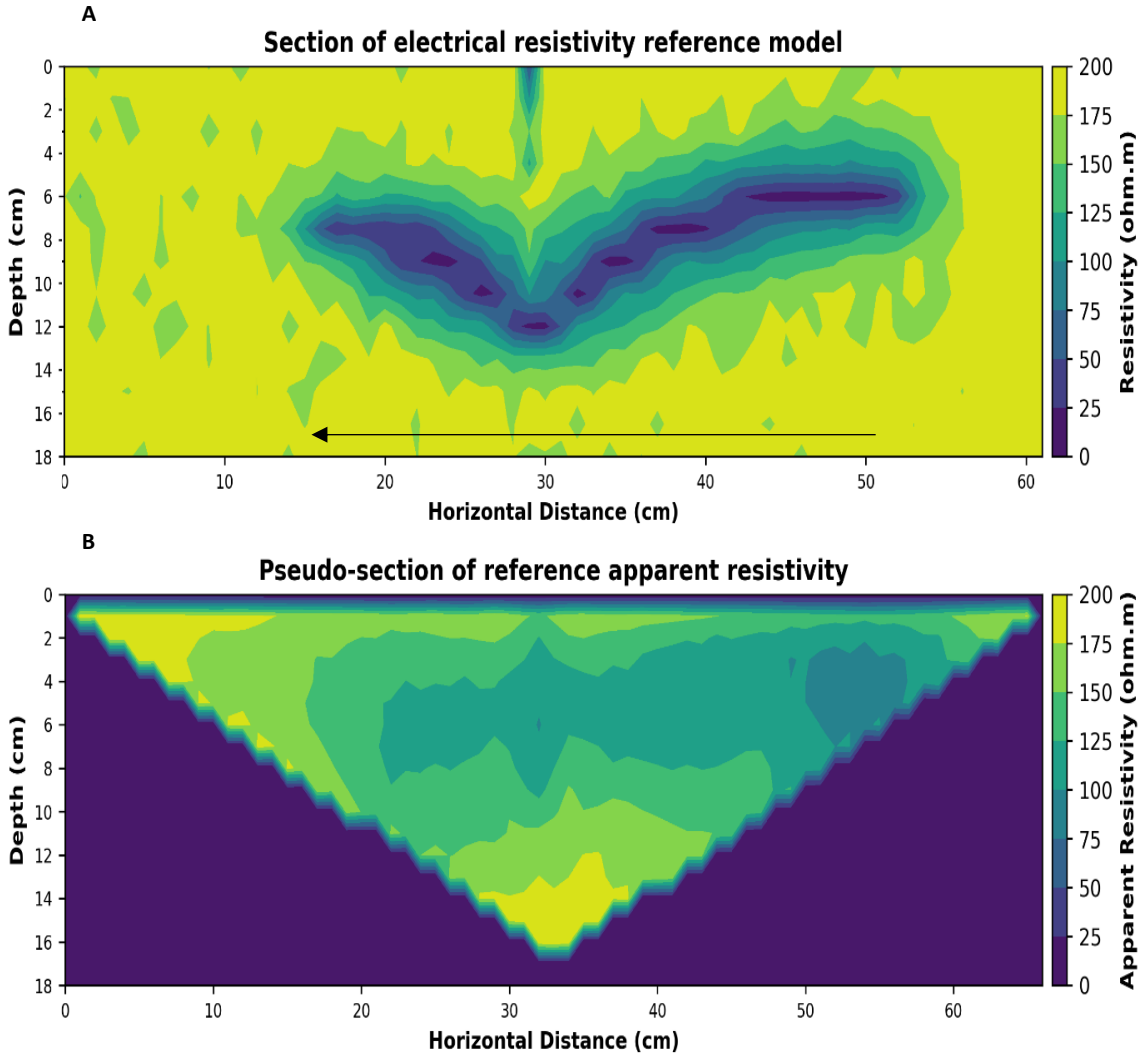

Figure 2: **a)** Section of electrical resistivity reference model reproducing the pollutant dispersion in groundwater system, where the plume dispersion occurs from right to left, as indicated by the black arrow; **b)** Pseudo-section of reference apparent resistivity obtained by solving the forward model and considering a Wenner-Schlumberger survey array.

3 Discussion

Geophysical inversion is a challenging task to solve, being an ill-posed, nonlinear problem with a non-unique solution. The proposed methodology overcomes the limitations of most conventional deterministic approaches when spatially predicting geological subsurface properties, namely being computationally expensive, requiring a

large degree of expertise, predicting a single model unable to capture the small-scale details of subsurface geology, having limited uncertainty assessment and not reproducing borehole data.

4 Conclusions

This study allows exploring how data-to-data deep generative methods can be used to successfully invert ERT data to subsurface properties while accounting for the uncertain nature of the geophysical inverse problem.

References

Bürkle, Paula Yamada, Leonardo Azevedo, and Marley Vellasco. 2023. "Deep Physics-Aware Stochastic Seismic Inversion." *GEOPHYSICS* 88 (1): R11–24. https://doi.org/10.1190/geo2021-0551.1.

Chen, Zi, J. Jaime Gómez-Hernández, Teng Xu, and Andrea Zanini. 2018. "Joint Identification of Contaminant Source and Aquifer Geometry in a Sandbox Experiment with the Restart Ensemble Kalman Filter." *Journal of Hydrology* 564 (September): 1074–84. https://doi.org/10.1016/J.JHYDROL.2018.07.073.

Citarella, Donato, Fausto Cupola, Maria Giovanna Tanda, and Andrea Zanini. 2015. "Evaluation of Dispersivity Coefficients by Means of a Laboratory Image Analysis." *Journal of Contaminant Hydrology* 172 (January): 10–23. https://doi.org/10.1016/J.JCONHYD.2014.11.001.

Cockett, Rowan, Seogi Kang, Lindsey J. Heagy, Adam Pidlisecky, and Douglas W. Oldenburg. 2015. "SimPEG: An Open-Source Framework for Simulation and Gradient Based Parameter Estimation in Geophysical Applications." *Computers and Geosciences* 85 (December): 142–54. https://doi.org/10.1016/j.cageo.2015.09.015.

Laloy, Eric, Romain Hérault, John Lee, Diederik Jacques, and Niklas Linde. 2017. "Inversion Using a New Low-Dimensional Representation of Complex Binary Geological Media Based on a Deep Neural Network." *Advances in Water Resources* 110 (December): 387–405. https://doi.org/10.1016/j.advwatres.2017.09.029.

Lopez-Alvis, Jorge, Eric Laloy, Frédéric Nguyen, and Thomas Hermans. 2021. "Deep Generative Models in Inversion: The Impact of the Generator's Nonlinearity and Development of a New Approach Based on a Variational Autoencoder." *Computers and Geosciences*. Elsevier Ltd. https://doi.org/10.1016/j.cageo.2021.104762.

Acknowledgments

This research is supported by the PRIMA program under grant agreement No1923, project InTheMED. The PRIMA program is supported by the European Union.

Acknowledgements to the support of the CERENA (strategic project FCT-UIDB/04028/2020).

Alternative Reagents for Lithium Extraction from Lepidolite Ore: A Preliminary Fractional Factorial Design Study

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Abstract

Lepidolite, holds significant potential as an attractive alternative for the recovery and extraction of strategic metals. This study focuses on evaluating the influence of alternative reagents, including calcium carbonate and calcium sulfate, as additives during the roasting stage for lithium recovery in the hydrometallurgical process. Additionally, the combined effects of various factors on process efficiency were assessed using a fractional factorial design. The best configuration achieved 82% removal of lithium during the leaching stage. Results indicate that roasting temperature had the greatest influence, followed by roasting time and leaching temperature. These findings emphasize the importance of controlling roasting conditions, especially temperature, to enhance lithium recovery. Furthermore, the use of alternative reagents offers potential for improving the extraction process and producing high-purity lithium compounds. This research contributes to sustainable strategies for recovering lithium from alternative sources and highlights the need to consider multiple factors and their interactions for efficient hydrometallurgical extraction.

Authors keywords: Lithium, Hydrometallurgy Processing, Lepidolite, Alternative Reagents

1 Introduction

Lepidolite is a mica with complex and variable composition and is used in the production of glasses and ceramics. Its Li content can vary significantly from 1.39% (3.0% Li2O) to 3.58% Li (7.7% Li2O) (Tadesse et al., 2019). Unlike spodumene, pre-treatment of lepidolite via decrepitation is unnecessary in most routes and one-step roasting of lepidolite and additives at high temperature is preferred (Tran & Luong, 2015). At present, the primary source of lithium commodities available in the market is derived from brine exploitation, predominantly in South America (Nogueira et al., 2104; Vera et al., 2023). Consequently, minerals rich in lithium such as spodumene, lepidolite, and petalite are extracted along with other silicates, primarily for ceramic uses, without significant beneficiation. However, due to the growing demand for lithium, these sources are being revisited to extract high-purity lithium compounds Fosu et al., 2020). The great similarity of chemical and physical properties between lithium minerals and the associated gangue minerals makes their valorization difficult. Thus, the most common hydrometallurgy of lithium ores typically involves a primary process of calcination followed by leaching and purification. Most of the techniques implemented nowadays, involve stages where the pre-concentrate is calcined with chemical additives at temperatures between 850 °C and 1100 °C (Mulwanda, 2021; Vieceli et al., 2017).

In recent years, there has been extensive research on the physical and thermodynamic aspects of lepidolite roasting. However, much of the existing literature lacks a comprehensive analysis using factorial experimental designs to evaluate the individual

effects of various factors. Additionally, most studies have only analyzed one variable at a time, neglecting the potential interactions between different variables. Therefore, the purpose of this study is to address these gaps and examine the impact of alternative reagents, specifically calcium carbonate and calcium sulfate, as additives in the roasting phase of lepidolite.

2 Experimental designs

The fractional factorial experiment was performed, with 6 factors at two levels. The objective of this methodology is to create designs that allow us to track a large number of factors, reducing the size of the experiment. The factors to be investigated include temperature, duration of roasting, concentration of additives, and the ratio of lepidolite to additives. These parameters have been identified as critical variables that can significantly impact the recovery of lithium. By studying their effects and interactions, the roasting conditions can be optimized an efficient and cost-effective method for extracting high-purity lithium compounds from lepidolite can be developed.

3 Materials and Methods

3.1 Sample characterization

The lepidolite ore sample used in this study comes from the Gonçalo mine, district of Guarda, Portugal. The sample used was pre-concentrated in optical separation in order to increase the Li content. The particle size distribution was characterized by a D50 of 52 µm and a D90 of 201 µm. The chemical analysis of the material showed the main elements was K, with 7,68%, Rb with 0,95% and Mn with 0,27%.

3.2 Equipment and reagents

The chemical composition of the ore, calcines, and residues after leaching was performed by X-ray spectrophotometry (XRF) XMDS2726 from Oxford Instrument. The elemental concentrations of leach liquors were measured by AAS using the equipment Analytik Jena, ZEENIT 700P. The reagents used were $CaSO_4$ from sigma Aldrich, purity 99 %. The $CaCO_3$ is from Thermo Scientific, also of purity over 99 %. For the acid digestion, 37 % HCL from VWR, 40 % HF from Fluka, and 65 % HNO3 from Fluka were used. All leaching tests used distilled water.

4 Results and discussion

4.1 Results of the fractional factorial study

The experimental conditions and the extraction yield for each assay are presented in Table 1. Among the conducted tests, the PBH test achieved the highest yield, with 82% of lithium extraction. To identify the key variables influencing the process, statistical analysis was performed using the Minitab software, with a confidence level of 1. The analysis (Figure 1a) confirmed that the data followed a normal random distribution, while Effect D is clearly away from the normal distribution line evidencing its deterministic quality. Further analysis using Pareto plot (Figure 1b) revealed that roasting time and Solid/Liquid ratio were the factors that followed roasting temperature in terms of their impact on the yield. In contrast, the leaching temperature did not exhibit significant effects on the efficiency of the process. In the main effects plot, the slope associated with roasting temperature was the only one that evidenced

deterministic characteristics capable of affecting the yield. Although the lines in the plot appeared nearly horizontal, indicating no statistical dependence on the efficiency, it can be inferred that specific conditions, such as a roasting time of 2 hours (or plus), a mass ratio of CaCO3/ore of 0.8:1, a mass ratio of CaSO4/ore of 0.4:1, a roasting temperature of 900 °C (or higher), and solid/liquid ratio of 1:1.5 (or bigger) , have the potential to increase the extraction efficiency.

Table 1: Conditions for each factor used in the experimental design and the yield of extraction obtained

Factor / Assay	Roasting time (h)	Mass of $CaSO_4$ (g)	Mass of $CaCO_3$ (g)	Roasting Temperature (°C)	L/S Ratio (W/V)	Leaching Temperature (°C)	Yield (%)
PBA	2	20	40	900	1	70	65
PBB	2	40	20	800	1	70	15
PBC	2	20	20	800	1,5	90	20
PBD	1	40	40	900	1	90	62
PBE	2	40	40	800	1,5	90	23
PBF	2	40	20	900	1	90	70
PBG	1	20	20	900	1,5	90	79
PBH	2	20	40	900	1,5	70	82
PBI	1	40	20	900	1,5	70	61
PBJ	1	40	40	800	1,5	70	17
PBK	1	20	40	800	1	90	19
PBL	1	20	20	800	1	70	16

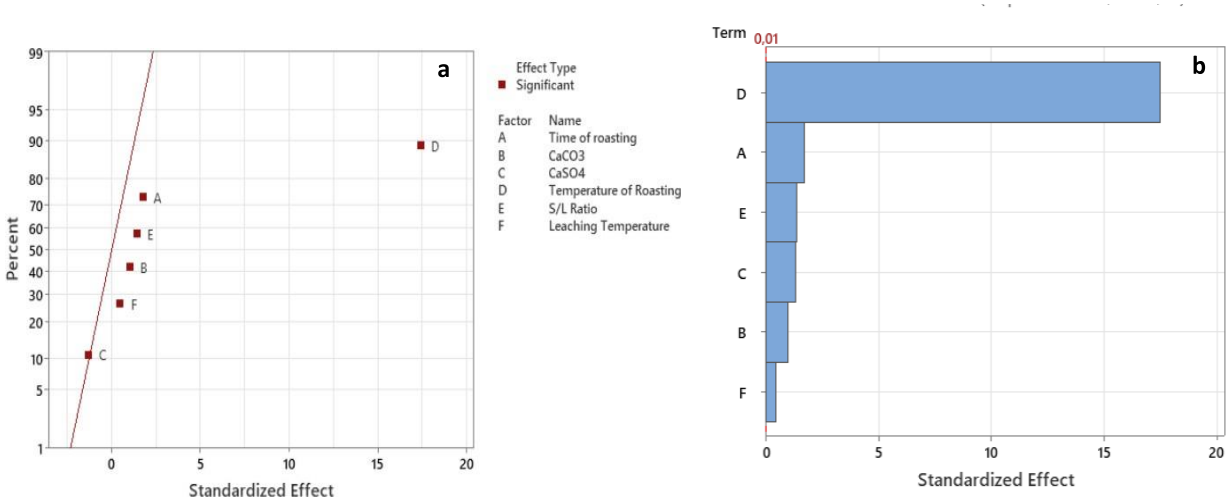

Figure 1: a) Normal plot of the standardized effects with a confidence level of 1; b) Pareto chart of the influence of each variable on the yield.

5 Conclusions

In conclusion, the findings of this study demonstrated that the PBH test exhibited the highest yield, reaching 82%. Utilizing the Minitab software for statistical analysis, it was revealed that the roasting temperature exerted the most significant influence on the process, followed by the roasting time and leaching temperature. Intriguingly, the leaching temperature appears to not impart a substantial effect on the process efficiency. However, it is important to note that these results are preliminary in nature, as further experimentation is required to optimize the outcomes and determine the

optimal conditions for the hydrometallurgical treatment of lepidolite. Moreover, additional variables with a diverse range of values should be explored. Nonetheless, these findings carry valuable implications for the advancement of more efficient and sustainable approaches for the recovery of lithium ores.

References

Fosu, A. Y., Kanari, N., Vaughan, J., & Chagnes, A. (2020). Literature review and thermodynamic modelling of roasting processes for lithium extraction from spodumene. In Metals (Vol. 10, Issue 10, pp. 1–18). MDPI AG. https://doi.org/10.3390/met10101312

Mulwanda, J. (2021). Extraction of Lithium from Lepidolite and Spodumene [Murdoch University College of Science, Health, Engineering and Education]. https://researchrepository.murdoch.edu.au/id/eprint/63573/1/Mulwanda2021.pdf

Nogueira, C. A., Margarido, F., Vieceli, N., Durão, F., & Guimarães, C. (2104). Comparison of Processes for Lithium Recovery from Lepidolite by H2SO4 Digestion or HCl Leaching. Proceedings of The International Conference on Mining, Material and Metallurgical Engineering.

Tadesse, B., Makuei, F., Albijanic, B., & Dyer, L. (2019). The beneficiation of lithium minerals from hard rock ores: A review. In Minerals Engineering (Vol. 131, pp. 170–184). Elsevier Ltd. https://doi.org/10.1016/j.mineng.2018.11.023.

Tran, T., & Luong, V. T. (2015). Lithium Production Processes. In Lithium Process Chemistry: Resources, Extraction, Batteries, and Recycling (pp. 81–124). Elsevier Inc. https://doi.org/10.1016/B978-0-12-801417-2.00003-7.

Vera, M. L., Torres, W. R., Galli, C. I., Chagnes, A., & Flexer, V. (2023). Environmental impact of direct lithium extraction from brines. Nature Reviews Earth & Environment, 4(3), 149–165. https://doi.org/10.1038/s43017-022-00387-5.

Vieceli, N., Nogueira, C. A., Pereira, M. F. C., Durão, F. O., Guimarães, C., & Margarido, F. (2017). Optimization of Lithium Extraction from Lepidolite by Roasting Using Sodium and Calcium Sulfates. In Mineral Processing and Extractive Metallurgy Review (Vol. 38, Issue 1, pp. 62–72). Taylor and Francis Inc. https://doi.org/10.1080/08827508.2016.1262858.

Acknowledgments

This work is a result of project CAVALI – CADEIA DE VALOR DO LITIO, with reference POCI- 01-0247-FEDER-047728, co-funded by the European Regional Development Fund (ERDF), through the Operational Programme for Competitiveness and Internationalization (COMPETE 2020), under the PORTUGAL 2020 Partnership Agreement.

Cavali Project: Lithium sorption by ion exchange

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Abstract

The high demand for lithium is increasing drastically due to its applications in electronic devices, electric vehicles, and other components. The present case study focuses on studying the sorption capacity of two resins - Dowex G26 and Dowex X8 – in capturing lithium from real solutions generated through lepidolite leaching and washing. So far, it was performed studies in artificial solutions in order to understand the behavior of the resins without the interference of competing ions. The results suggest that Dowex G26 exhibits the highest loading capacity among the two resins.

Authors keywords: lithium, hydrometallurgy processing, sorption, ion exchange

1 Introduction

The world's increasing dependence on lithium has created a high demand for this mineral, this highlights the need to study its supply and sources (Amalia, Perdana, and Purnomo 2021). In fact, theaverage concentration of lithium in the earth's crust is about 0.006%, therefore extracting it poses a significant current and future challenge (Güneysu 2020). In order to overcome this problem, the hydrometallurgy field is a preferred route for recovery metals such as lithium.

It is expectable that the Cavali project will supply technology that may be applicable in a company with lepidolite resources. To recover lithium from this mineral the ore concentrates, which may reacha grade of around 4% in Li_2O, are processed by calcination and alkaline leaching. The produced liquors, after solid-liquid separation, will be purified and enriched by cationic ion exchange. This technology allows us to eluate and regenerate the resin, and for this reason, it has low operating costs;it is also selective and efficient and easy to implement (Güneysu 2020).

The present research focuses on the sorption of lithium by acidic cationic resins. The loading capacityfor lithium of two resins, Dowex G26 and Dowex X8, was assessed. The resin loading capacity is thequantity of exchangeable ions, in this case Li^+, that can be exchanged by the resin, expressed by unitsof weight (generally mg/g).

The research consists of studying both artificial solutions and leaching liquors. The artificial solutionsrepresent the ideal behavior of the resins without interference from other competing cations. Until themoment, the impact of pH on the loading capacity was studied in artificial solutions to select the optimum pH for the resin with the highest loading capacity.

2 Materials and Methods

2.1 Materials

Dowex G26 resin (batch 573663) and Dowex 50 W X8 resin (batch 44519), are both strongly acidic resins having exchangeable cations of hydrogen ions in a matrix with sulfonic groups, as counter ions. Resins were purchased from Sigma Aldrich. Lithium chloride from the company VWR Chemicals (MW 42.39 g/mol). Nitric acid from Honeywell Lab Chemicals (batch M2210; density 20ºC 1400 – 1480 g/cm^3. Sodium hydroxide, tablets from Frilabo company (Batch B19450500). Sulfuric acid (Code: J/8400/PB15; density 98.08 g/mol) was purchased from Fisher Chemical.

2.2 Methods

2.2.1 pH adjustment

Initially, it was prepared 1.5 L of a solution with a concentration of 1 g/L lithium (Li) using lithium chloride (LiCl). Then, using 100 mL of the previous solution, the pH was adjusted to different values:4, 5, 6, 7 and 8. Sodium hydroxide (NaOH) at 0.1 M and sulfuric acid (H_2SO_4) at 0.1 M were the solutions added to adjust the pH. In total, 10 solutions were prepared, 5 of which contained 1 g of Dowex G26 resin and the remaining with 50 W X8 resin. They were placed on a low-speed orbital shaker for 3 hours. After this time, the liquid phase was analyzed, and the loading capacity was calculated using Equation 1.

$$q\left(\frac{mg}{g}\right) = \frac{V(C_0 - C_f)}{w} \quad (1)$$

where q is the resin loading capacity (mg/g), V is the volume of solution used (L), C_0 and C_f are the initial and final concentrations of the solution (mg/L), and W is the mass of resin (g).

2.2.2 Adjustment of experimental values to the Langmuir isotherm

To determine the isotherms, the contact scheme in a pyramid shape was performed as illustrated in Figure 1. A solution with a concentration of 1.5 g/L Li was prepared using lithium chloride. Small volumes (50 mL) were measured, and the pH was adjusted to 12 using NaOH (0.5 M). 1 g of DowexG26 resin was added. The solutions were placed on a low-speed orbital shaker for 3 hours. The liquidphases of the four final solutions were analyzed.

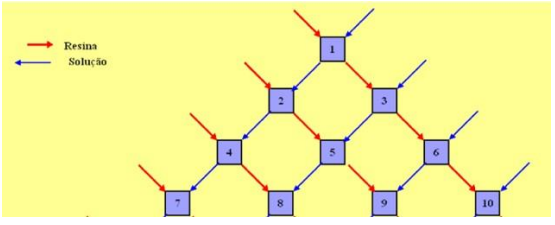

Figure 1: The pyramid contact scheme performed (adapted from: (Fiúza, n.d.)).

3 Discussion

3.1 pH influence

The experiments were carried out in triplicate. In Figure 2 is possible to observe that the Dowex 50 W X8 resin has a lower loading capacity compared to Dowex G26 resin. Therefore, G26 resin was chosen to proceed with the subsequent tests. Also, it is possible to visualize that pH 7 is the optimum,presenting a loading capacity of 34 mg/g.

The leaching liquors, having a pH of 12.5, were then tested using the same procedure mentioned above. It was obtained the highest loading capacity, 39 mg/g. This experiment was executed in duplicate.

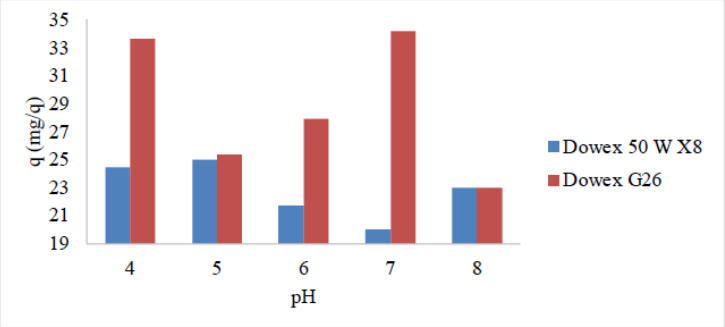

Figure 2: Loading capacity of Dowex X8 and Dowex G26 resin.

3.2 Adjustment of experimental values to the Langmuir isotherm

The Langmuir isotherm was performed using triplicate data. Based on the values obtained in Figure 3, it is possible to conclude that the experimental values adjust to the Langmuir isotherm. According to the literature, the capacity of this resin ranges from 4.5 to 5.5 meq/g (Chen, Lee, and Ho, 2018). Therefore, it was considered that there is 5.5 meq of the sulfonic acid group per gram of resin (under optimal conditions), as it is through this group that the ion exchange with Li+ occurs. Taking into account the molecular weight of lithium (6.941 g/mol), a capacity of 38 mg/g was obtained. Hence on the previous results, is possible to conclude that the maximum loading capacity of the resin Dowex G26 was achieved.

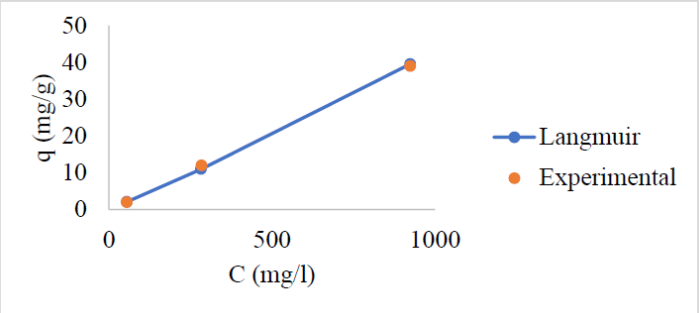

Figure 3: Adjustment of experimental values to the Langmuir isotherm.

4 Conclusions

The tests performed in artificial solutions allowed us to compare the behavior of different resins and identify the ideal operating pH. Therefore, it was concluded that the resin Dowex G26 possesses the highest loading capacity using artificial solutions

for alkaline pH. Hence, its application using real complex solutions resulting from lepidolite leaching and washing is under study. Additionally, the operating conditions, such as contact time will be optimized.

References

Amalia, Dwi, Indra Perdana, and Chandra W. Purnomo. 2021. “Adsorption of Lithium and Calcium Using Cationic Resin for Separation Application.” In *AIP Conference Proceedings*. Vol. 2349. American Institute of Physics Inc.

Chen, Wei Sheng, Cheng Han Lee, and Hsing Jung Ho. 2018. “Purification of Lithium Carbonate from Sulphate Solutions through Hydrogenation Using the Dowex G26 Resin.” *Applied Sciences (Switzerland)* 8 (11).

Fiúza, António. n.d. “PROCESSOS DE CONCENTRAÇÃO E PURIFICAÇÃO.” Güneysu, S. 2020. “Lithium Sorption from Aqueous Solution with Cationic Resins.” *Desalination and Water Treatment* 177 (February): 102–8.

Acknowledgments

This work is a result of project CAVALI – CADEIA DE VALOR DO LITIO, with reference POCI- 01-0247-FEDER-047728, co-funded by the European Regional Development Fund (ERDF), through the Operational Programme for Competitiveness and Internationalization (COMPETE 2020), under the PORTUGAL 2020 Partnership Agreement.

Assessment of Antarctic vegetation classification as a function of the spatial resolution and application to historical images of Barton Peninsula, King George

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Abstract

Climatic conditions strongly affect the growth/decline of vegetation in Antarctica. Therefore, their mapping and monitoring can be used as an indicator of climate change. The main objective of this work is to contribute to a broader understanding of how vegetation growth/decline is affected by climate change through remotely sensed imagery in the Antarctic Peninsula (AP) where changes have been more rapid. The main focus concerns the development of an automated methodology to classify vegetation, discriminating the dominant species (lichens and mosses), by encompassing data from different sensors throughout AP's monitoring history since 1980s. To that end, multitemporal satellite images from different sensors are being integrated with new images acquired with Unoccupied Aerial Vehicles (UAV) to better perceive the spatial distribution of the vegetation.

Authors keywords. Remote sensing; Vegetation; Antarctic Peninsula; Change detection.

1 Introduction

The monitoring of vegetation in Antarctica is crucial as it serves as an indicator of climate change (Robinson et al., 2003; Sancho et al., 2019). The only practical way of extensively mapping the vegetation is using satellite imagery, but its occurrence in relatively sparse and small patches makes this identification difficult and challenging (Pina et al., 2016). While previous studies have used satellite imagery and vegetation indices for mapping (Fretwell et al., 2011), these methods lack precision in detecting changes in vegetation covers at a subpixel scale. To improve vegetation identification and study the impact of climate on the ecosystem, a methodology was developed and tested in Barton Peninsula, King George Island. This area was chosen due to the availability of highly detailed orthomosaics from recent UAV surveys, as well as multispectral satellite images from high to very high resolution. A range of machine learning approaches, including support vector machines and deep learning, were employed in sequence for accurate vegetation mapping. The classifiers were selected and calibrated based on the size of the vegetation patches.

2 Fields sites, data and pre-processing

The study area is Barton Peninsula (62°14'S, 58°46'W), an ice-free area of King George Island, in the South Shetlands, with about 10 km^2. The six remotely sensed datasets used are listed in Table 1. During February 2019, several aerial surveys were developed in different locations of the peninsula with a DJI Phantom quadcopter with a RGB camera, also collecting ground control points with a D-GPS. The respective orthorectified mosaics and digital elevation models (DEM) were built using Agisoft Metashape. Satellite optical images from three different platforms were gathered for the closest date available with acceptable quality (low

cloud covers), being all orthorectified and atmospherically corrected using FLAASH method. The co-registration of all datasets was next performed. Subsequently, two Landsat images were acquired to evaluate the application of the methodology in a previous and future date, with respect to the year when the methodology was developed (2019/2020).

Table 1: Image datasets

Platform	Date	Resolution (m)
Landsat 4	28 January 1989	30
UAV	February 2019	0.02
WorldView 2	17 March 2019	2
Sentinel 2	19 January 2020	10
Landsat 8	19 January 2020	30
Landsat 8	25 February 2023	30

3 Methodology and Discussion

The proposed methodology (Figure 1) aims to classify vegetation in remotely sensed images of varying spatial resolutions and to determine the feasibility of downscaling for each pixel size. The fluxogram in Figure 1 illustrates that the classification method differs for each pixel scale based on the average size of vegetation patches. For UAV images, which have a pixel size (2cm) much smaller than the average vegetation patch size, an object-based classifier is employed. For WorldView 2 images, with a pixel size (2m) similar to the average vegetation patch size, a pixel-based classifier is utilized. For Sentinel 2 and Landsat 8 images, which have pixel sizes (10m and 30m) larger than the average vegetation patch size, a spectral unmixing approach is deemed most suitable. Masks were created for water and shadows in each satellite image, and their union was used in each classification. Four classes were defined: lichens, mosses, bare (soils and rocks), and snow. The classification performance of each thematic map (Figure 2) was evaluated using 1600 randomly sampled points from the UAV orthomosaics, which served as the ground-truth for the development of the methodology.

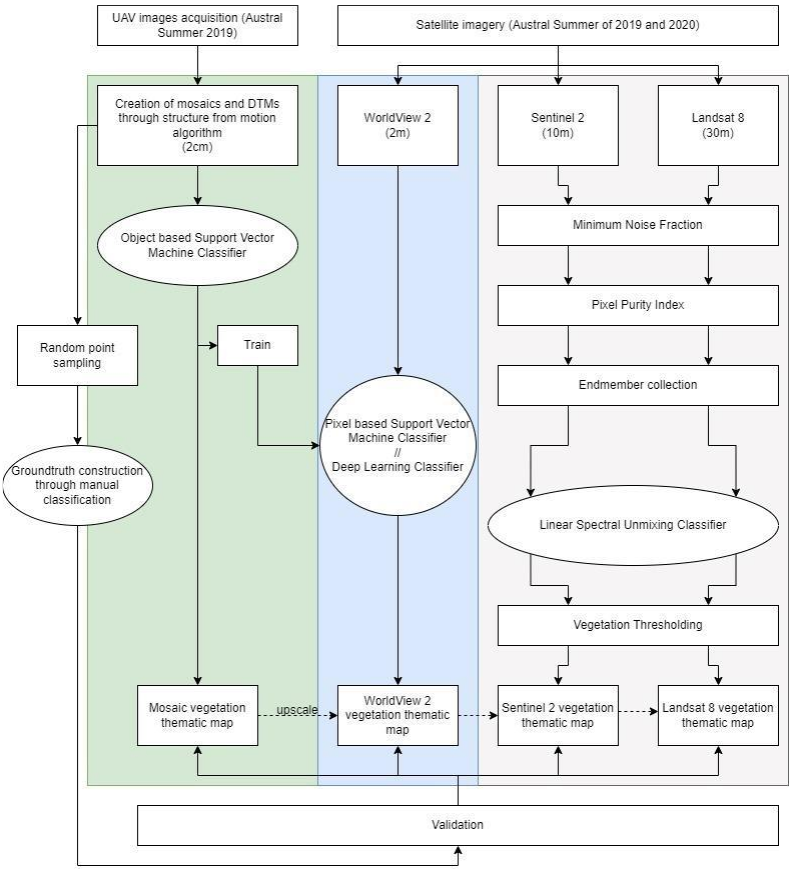

Figure 1: Methodology flowchart.

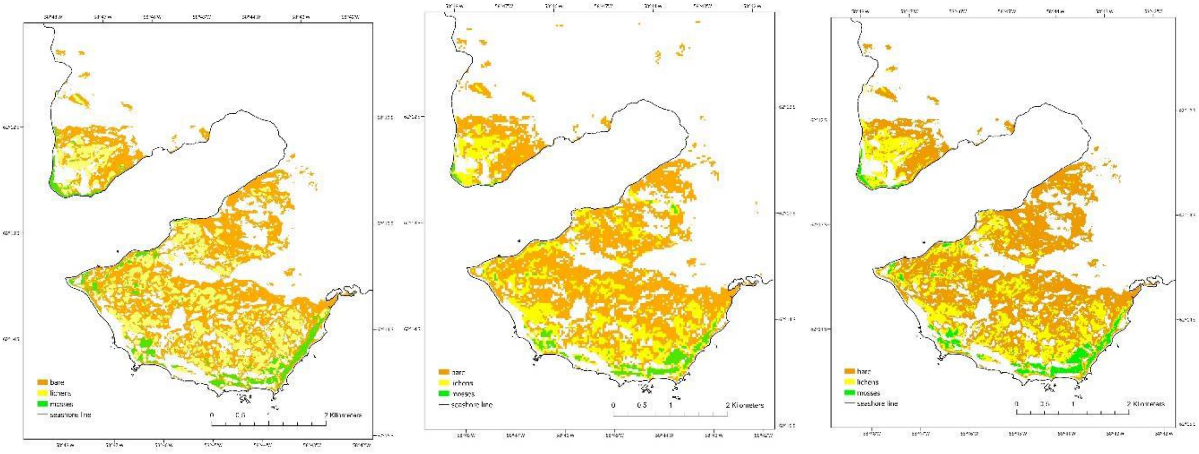

Figure 2: Classification in Barton Peninsula: WorldView2(left), Sentinel 2 (middle), Landsat 8 (right).

Using this classification methodology for the three scales for the same period, it was possible to assess the expected loss of vegetation detection throughout the downscale, shown on table 2.

Table 2: Vegetation areas classified by satellite

Vegetation	Area (m^2)		
	WorldView 2	**Sentinel 2**	**Landsat 8**
Lichens	2,114,992	1,825,100	1,820,700
Mosses	483,252	394,100	356,400
Total	2,598,244	2219200	2,177,100

Finally, the methodology was applied to two other Landsat 8 images (1989 and 2023), one previous and the other after the date where the methodology was developed. The results shown in Figure 3 show that vegetation detected in the three dates preserves the proportions between lichens and mosses, showing an increase trend over the years.

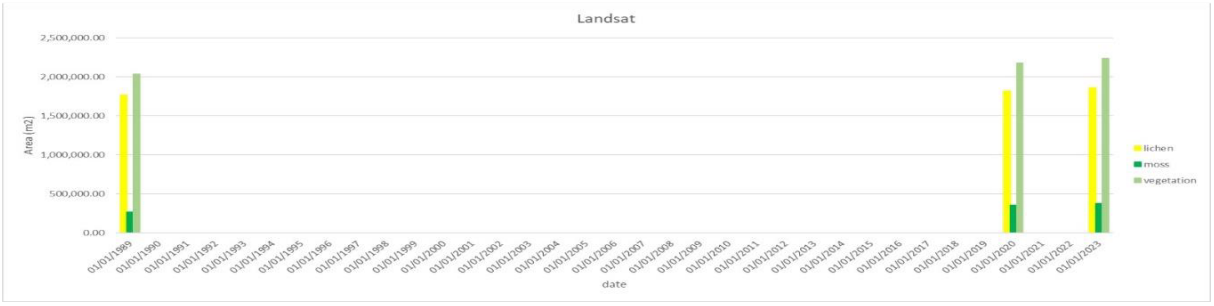

Figure 3: Vegetation cover in 3 Landsat images (1989, 2020 and 2023).

4 Conclusions

These are very preliminary results from a work in progress. The classification methodology shows promise in accurately detect and discriminate vegetation in two groups (lichens and mosses) throughout the increasing pixel sizes. Applied to two other images on different dates, the vegetation detected shows an area expansion trend through the years, which is expected with the warming of the peninsula. In the latest Antarctic campaign (2023), UAV surveys with a multispectral camera were performed, and are expected to greatly improve the quantification of the degree of pixel purity of lichen patches. Also, since this year's field campaign was developed in other ice-free regions in the South Shetlands and Western AP, it is also expected that the greatly expanded UAV datasets will allow the validation of the methodology in a wider area of the AP and better relate the effect of climate change in their vegetation distribution.

References

Robinson, Sharon A., Jane Wasley, and Alyson K. Tobin. "Living on the Edge - Plants and Global Change in Continental and Maritime Antarctica." Global Change Biology 9, no. 12 (November 7, 2003): 1681–1717. https://doi.org/10.1046/j.1365-2486.2003.00693.x.

Sancho, Leopoldo G., Ana Pintado, and T. G. Allan Green. "Antarctic Studies Show Lichens to Be Excellent Biomonitors of Climate Change." MDPI, March 19, 2019. https://doi.org/10.3390/d11030042.

Pina, Pedro, Gonçalo Vieira, Lourenço Bandeira, and Carla Mora. "Accurate Determination of Surface Reference Data in Digital Photographs in Ice-Free Surfaces of Maritime Antarctica."

Science of The Total Environment 573 (December 2016): 290–302. https://doi.org/10.1016/j.scitotenv.2016.08.104.

Fretwell, P. T., P. Convey, A. H. Fleming, H. J. Peat, and K. A. Hughes. “Detecting and Mapping Vegetation Distribution on the Antarctic Peninsula from Remote Sensing Data.” Polar Biology 34, no.2 (October 10, 2010): 273–81. https://doi.org/10.1007/s00300-010-0880-2.

Acknowledgments

This research has been supported by Fundação para a Ciência e a Tecnologia (FCT) through the following grants: PTDC/EAM-REM/30475/2017 (project ALTITUD3), UIDB-P/04028/2020 (CERENA), UIDB-P/04434/2020 (IA) and UIDB-P/00295/2020 (CEG). VM also acknowledges FCT the support for his PhD fellowship (SFRH/BD/148538/2019). The logistical and field support by the Portuguese Polar Program (PROPOLAR) and the Korean Polar Research Institute (South Korea) are also warmly thanked.

Geostatistical joint inversion of FDEM and ERT data for modelling near-surface deposits

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Abstract

The near-surface is a heterogeneous, complex and highly dynamic region of the Earth's surface, impacted from natural and anthropogenic processes. Due to its importance in different activities, an accurate characterization of the spatial distribution of the near-surface geological properties is essential but often challenging. Geophysical methods, mainly electrical and electromagnetic methods, have been progressively and successfully applied in near-surface characterization of complex and heterogeneous subsurface environments, but requires solving an inverse problem. The most common geophysical inversion methods are still based on deterministic approaches with limited capabilities of modelling such complex systems. This work presents an iterative geostatistical joint inversion technique for FDEM and ERT data. A geostatistical framework is used to couple both data domains in a consistent spatial model, capturing the spatial continuity and assess the uncertainty of the modelling procedure. The method is illustrated with an application to both a synthetic and a real data set.

Author keywords. Near Surface Modelling, Geostatistical simulation, Joint inversion.

1 Introduction

The near surface of the Earth supports most of human activities and yields much of the water and mineral resources. Therefore, it is essential to characterize the physical, chemical, and biological near-surface properties. Geophysical surveys have been proven powerful tools for the collection of virtually spatially continuous high-resolution data sets that can be translated in detailed images of subsurface physical properties (Moorkamp, 2017). Modelling the subsurface through geophysical data involves solving an inverse problem: predicting the spatial distribution of the relevant subsurface properties from the observed geophysical data (Tarantola 2005). Within geophysical methods, frequency-domain electromagnetic (FDEM) induction and electrical resistivity tomography (ERT) methods have demonstrated their efficiency to characterize heterogeneous and complex subsurface systems. The FDEM and ERT data are often interpreted and modelled separately. Nevertheless, inverting both data sets in a joint inversion methodology is generally a preferable approach due to the complementary information, different spatial resolutions, and sensitivity to distinctive physical properties. However, handling the differences in the resolution and nature of both methods is not straightforward and prone to uncertainties.

In this work, we present an iterative geostatistical joint inversion technique for FDEM and ERT, based on a previously established iterative geostatistical FDEM inversion technique (Narciso et al., 2020), that is able to provide a small-scale characterization of the spatial distribution of the subsurface electrical conductivity (EC) and magnetic susceptibility (MS) and assess the uncertainty about the predictions. A geostatistical framework is used to couple both data domains in a consistent spatial model and assess the uncertainty of the modelling procedure.

The method is illustrated with an application to both a synthetic and a real data set, where the benefits of the joint approach are discussed against the individual inversions.

2 Methodology

The proposed iterative geostatistical joint FDEM and ERT inversion technique is based on global geostatistical seismic inversion method (Azevedo and Soares, 2017) and an iterative geostatistical FDEM inversion technique (Narciso et al., 2020). It relies on two key main ideas: (1) the perturbation of the model parameter space with direct sequential simulation (DSS) and co-simulation (Soares, 2001), and (2) the convergence is ensured by a global stochastic optimizer driven simultaneously by the misfit between true and synthetic FDEM and ERT data. The proposed iterative geostatistical joint inversion methodology may be summarized in the following sequence of steps (Figure 1):

1) Stochastic sequential simulation of two ensembles of Ns models for EC and MS given borehole data and a calibrated variogram model from the borehole data (Soares, 2001);
2) Calculation of the Ns synthetic FDEM data and apparent EC (ECa) from each pair of models simulated in 1) using Hanssens et al. (2019) and Pidlisecky and Knight (2008);
3) Computation of the local similarity between true and synthetic geophysical data;
4) Combination of both similarity coefficients (step 3) in a multi-objective function and selection of the highest coefficients along with the corresponding EC and MS models;
5) Generation of a new ensemble of EC and MS models using co-DSS (Soares, 2001) from the EC and MS models that ensure the best local matches and the similarity values from 4).
6) Iteration and repetition of steps 2-5, while the global convergence of the method reaches a pre-defined threshold.

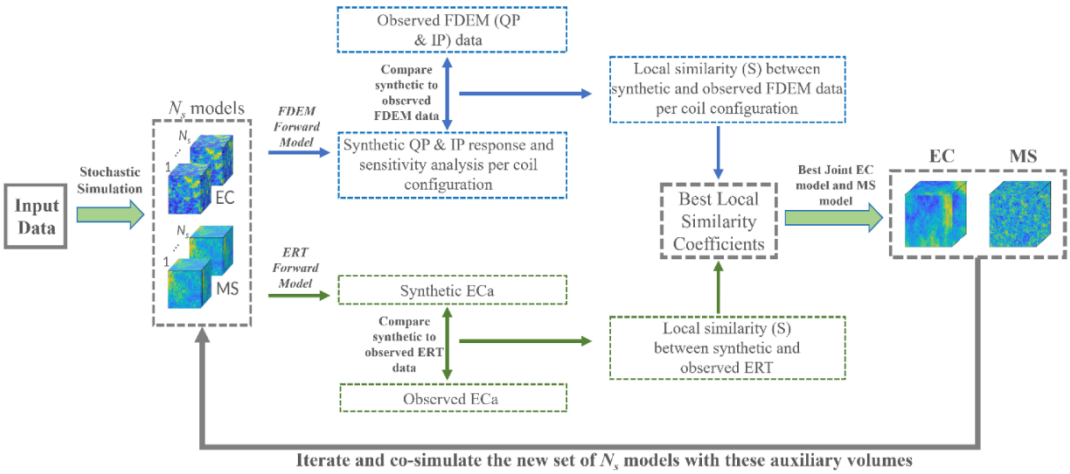

Figure 1: Schematic representation of the iterative geostatistical joint inversion workflow.

3 Application and Results

The proposed iterative geostatistical joint inversion methodology was applied to a 3-D benchmark landfill data set, developed based on real data collected at a mine tailing disposal.

The corresponding observed FDEM data were obtained using a 1-D forward model (Hanssens et al., 2019) and replicating a DUALEM-421S sensor, including two loop-loop coil orientations, a horizontal coplanar (HCP) and a perpendicular one (PRP), and 3 offsets per coil orientation, 1, 2 and 4 meters for HCP and 1.1, 2.1 and 4.1 meters for PRP. The observed electrical resistivity data was calculated using a 2.5-D forward model (Pidlisecky & Knight, 2008), with a Wenner-Schlumberger configuration, starting with 1 meter spacing between electrodes.

Applying the iterative geostatistical joint inversion technique to the same realistic 3-D synthetic data set used in Narciso et al. (2020) with an iterative geostatistical FDEM inversion technique, we could obtain improvements in the modelling procedure and in the reproduction of the spatial structure of the electrical conductivity (Figure 2c), and reducing the uncertainty of the modelling procedure, showing lower residuals in the last iteration (Figure 2, e).

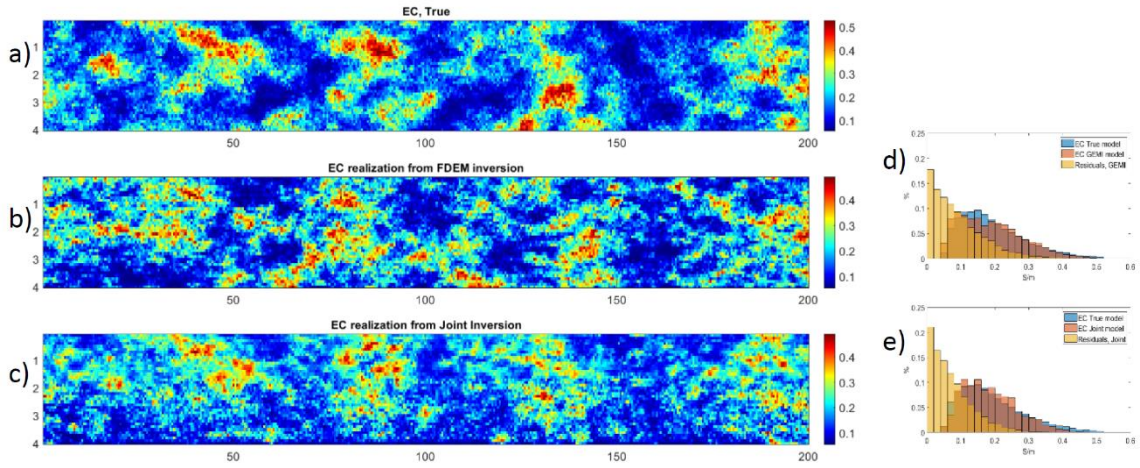

Figure 2: Left: Cross sections extracted from the 3-D models of: a) EC true model; b) EC model from FDEM inversion; and c) EC model from joint inversion. Right: Residuals between the EC true model and: d) the EC model from the FDEM inversion; e) the EC model from the joint inversion.

4 Conclusions

This work introduces an iterative geostatistical joint inversion method that represents an advancement in probabilistic joint inversion of DC resistivity data and FDEM data, coupling both geophysical data with sensitivity analysis in the modeling procedure. It allows a better modelling and characterization of complex and heterogeneous subsurface environments, predict the spatial distribution of the properties of interest and assessing the spatial uncertainty associated with the inverted properties from the Ns equal probabilistic realizations in each iteration. Due to the lack of space, this abstract is dedicated to present the methodology. A more developed presentation of the results will be made at the meeting.

References

Azevedo, L., and A. Soares. 2017. “Geostatistical Methods for Reservoir Geophysics”. *Advances in Oil and Gas Exploration & Production*, Springer.

Hanssens, D., S. Delefortrie, J. De Pue, M. Van Meirvenne, and P. De Smedt. 2019. "Frequency-Domain Electromagnetic Forward and Sensitivity Modeling: Practical Aspects of modeling

a Magnetic Dipole in a Multilayered Half-Space". *IEEE Geoscience and Remote Sensing Magazine*, 7(1), 74-85.

Moorkamp, M. 2017. “Integrating electromagnetic data with other geophysical observations for enhanced imaging of the earth: a tutorial and review”. *Surveys in Geophysics*, 38, 935–962.

Narciso, J., Azevedo, L., Van De Vijver, E. and Van Meirvenne, M. 2020. “Geostatistical Electromagnetic Inversion for Landfill Characterization”. *NSG2020 26th European Meeting of Environmental and Engineering Geophysics*, Conference Proceedings.

Pidlisecky, A. and Knight, M. 2008. “FW2_5D: A MATLAB 2.5-D electrical resistivity modeling code”. *Computers & Geosciences*, 34, 1645–1654.

Soares, A. 2001. “Direct Sequential Simulation and Cosimulation”. *Mathematical Geoscience*, vol. 33, no. 1, pp. 911–926.

Tarantola, A. 2005. “Inverse Problem Theory and Methods for Model Parameter Estimation”. *Philadelphia: Society for Industrial and Applied Mathematics*. 358 pp.

Acknowledgments

This work was supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project SFRH/BD/139577/2018. The gratefully acknowledge the support of the CERENA (strategic project FCT-UIDB/04028/2020). We also thank Schlumberger for the donation of the academic licenses of Petrel.

Intergenerational Knowledge Transmission in Mining Engineering Using New Technologies (Virtual Reality and Augmented Reality)

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Abstract

The transfer of knowledge from experienced professionals to younger generations is crucial for the sustainability of various industries in which mining is included. However, traditional methods of knowledge transmission may need to be more effective in meeting the demands of today's rapidly changing industries. New technologies, such as Virtual Reality (VR) and Augmented Reality (AR), offer a unique opportunity to enhance intergenerational knowledge transmission by providing an engaging and immersive learning experience. This article aims to identify the feasibility and effectiveness of new technologies already in use in several areas of education within the framework of intergenerational knowledge transfer.

Author keywords. Virtual reality, Augmented Reality, Mining, Feasibility, Effectiveness, Knowledge Transfer.

1 Introduction

Virtual Reality is a technology that allows for an immersive experience of two different realities, with a helmet with stereoscopic screens, achieving the interaction of the user with a virtual environment through the multiple devices available, ranging from a keyboard to suits, which seek to deceive our brain into stimulating the senses and perceive that environment as accurately as possible (Sánchez et al., 2022. 7858-7859). Augmented reality (AR) is a process of enhancing the real world with computer-generated information (typically a graphical overlay) to improve the interaction of the user with the natural world (Kalawsky et al., 2000. I-507). VR can provide a safe and controlled environment for students or employees to practice new skills or procedures in education and training. An excellent example is using VR to simulate medical procedures or emergency response scenarios, allowing medical professionals or first responders to practice in a realistic and safe environment before facing real-world situations. VR technology can revolutionize how we interact with and experience the world, creating new opportunities for entertainment, education, training, and the military (Boyles, 2017. 7-9).

In education, AR can create interactive and engaging learning experiences. For example, AR can create 3D models of historical sites or scientific concepts, allowing students to interact more effectively with the material. There are also potential uses for this technology in healthcare, which can be used to visualize and understand complex medical procedures and anatomy. AR has the potential to enhance our experience of the world and create new opportunities for entertainment, education, marketing, and healthcare. As technology advances, it is expected to see even more innovations. This review aims to identify opportunities for future research in this area through a comprehensive analysis of the existing literature.

2 Materials and Methods

A literature review of academic articles was conducted in several online databases to understand the potential of VR and AR in higher education, including Web of Science and Scopus, to identify relevant peer-reviewed articles published in English until 2022—the search strategy aimed to include all relevant studies while excluding irrelevant or duplicate studies.

After conducting the initial search, duplicate articles were removed, and titles and abstracts of the remaining articles were screened to determine their relevance to the topic. Inclusion criteria were based on knowledge from different areas, mining engineering, and new technologies such as VR and AR. Exclusion criteria were based on the publication language, publication date, and relevance to the research topic.

3 Discussion

In addition to the tools and technology trends established and present in recent decades, such as the rise of mobile computing, high-speed networks, and social media, the new use of the increasing power and capabilities of the rapidly evolving modern computer is developing rapidly. No better example is the rapid evolution of Virtual Reality and Augmented Reality (VR/AR), which has recently moved away from dedicated training labs and apps. From the past to the mainstream, advances in VR/AR have opened opportunities for digital internships, virtual labs, and new collaborative and experiential learning forms. The scale and impact of these emerging technologies are also evident in the strong interest in their application and use in various business, professional, and industrial environments. Examples include but are not limited to the entertainment industry, specialized training, corporate conferences, demonstrations, and prototyping and modelling in engineering. As universities play an essential role in nurturing the talent of tomorrow, integrating these technologies can help them by supporting teaching and learning, contributing to relevant research, and improving the learning technology framework (D. Xanthidis, 2020.206-210). In recent years, virtual reality (VR) simulation has received much attention as an innovative health education strategy. While few studies evaluate VR simulation for knowledge, motivation, and satisfaction, more evidence is needed to evaluate the effectiveness, acceptability, and usefulness of immersive VR simulation for nursing students (Adhikari et al. 2021. 1-6).

Many surgical trainers and simulators use virtual reality, including temporal bone surgery (Fang et al., 2014. 675-680) and dental training (Mirghani, I et al., 2018. 67-70). Some of these VR apps offer haptic feedback, allowing students to practice their skills in a safe environment without the expense of human practice. VR provides basic medical training, simulation of surgical procedures, medical forces and disaster medicine, and virtual prototyping of medical devices (Satava, 1995. 1).

Training of residents is an essential but time-consuming and costly task in the surgical disciplines. During the coronavirus pandemic, surgical education became even more challenging due to the increased shift to corona care caused by the reduced caseload. In this context, augmented 360° 3D virtual reality (VR) videos of surgical procedures enable practical

off-site training through virtual participation in the surgery. This study aimed to establish and evaluate 360° 3D VR operative videos for neurosurgical training (Bruening et al., 2022. 2-7).

Computer-assisted learning effectively teaches anatomy, with 3-D visualization technology improving participants' factual and spatial knowledge more successfully than traditional methods.

At the United States Military Academy at West Point, military history research can take on a new dimension through virtual staff tours of historic battlefields using virtual or augmented reality. A staff visit is a historical study of a campaign that combines the academic study of the campaign with visits to actual battlefields to understand better the terrain and conditions that shaped the campaign. A virtual reality staff ride allows cadets to view the battlefield in three dimensions from the perspective of the various units and commanders involved in the battle and a bird's-eye view of how the battle is unfolding (Boyles, 2017. 7-8).

Behavioral studies have also been performed using virtual reality to reproduce scenarios in fire escape studies, using virtual reality simulations to record people's reactions to fires and yield more accurate results than traditional methods (S. Arias et al., 2021. 462-470). While it is essential to study emergency management, real-life disaster scenarios are challenging to construct, and it is illegal and unethical to force subjects to experience natural disasters. To solve this problem, new technologies in emergency research are essential. Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) are especially important because they can provide researchers with virtual emergencies without endangering reality, which is essential for emergency management studies (Y. Zhu and N. Li, 2021. 1-7).

Integrating augmented reality and virtual reality (AR/VR) elements into academic mining education is part of the EU-funded project MiReBooks (Mixed Reality Books) pedagogical approach. The project aims to develop interactive AR and VR-based mining manuals as a new digital standard for higher education in engineering education across Europe. The combination of AR and VR technologies makes it possible to innovatively address current challenges in mining education. These virtual applications are designed to expose students to otherwise impossible and dangerous situations. Classic paper-based teaching materials are enriched with AR content and translated into instructional and teaching-coherent manuals for extensive use in the classroom (Daling et al., 2020. 185-188).

4 Conclusions

By using traditional paper-based teaching materials and enriching them with AR and VR-based experiences, professors and teachers can now teach more complex subjects in the classroom or lecture hall. Students can be a part of those experiences that are generally not readily accessible in the real world. Mining engineering is a dynamic field that requires significant knowledge and skills to master. Many experienced mining engineers are approaching retirement age with the current demographic trends, leaving a considerable knowledge gap. Virtual Reality (VR) and augmented reality (AR) can be utilized to preserve and transfer this valuable knowledge to the next generation by adopting and following the experience from other areas, such as medicine. Research in this field intends to ensure that complex mining

questions are manageable for learning progress. Students can complete their studies with a better understanding of their discipline. Through thoughtful didactical integration into lesson plans, students will be able to use new forms of participation appropriate to the needs of their generation (Daling et al., 2020.191-193).

References

Adhikari, R., C. Kydonaki, J. Lawrie, M. O'Reilly, B. Ballantyne, J. Whitehorn, and R. Pater-son. 2021. "A mixed-methods feasibility study to assess the acceptability and applicability of immersive virtual reality sepsis game as an adjunct to nursing education". Nurse Education Today 103. Article 104944. DOI: 10.1016/j.nedt.2021.104944.

Arias, S., J. Wahlqvist, D. Nilsson, E. Ronchi, and H. Frantzich. 2021. "Pursuing behavioural realism in Virtual Reality for fire evacuation research". Fire and Materials 45, no. 4: 462-72. DOI: 10.1002/fam.2922.

Boyles, Brian. 2017. Virtual Reality and Augmented Reality in Education. Master Teacher Program. Center for Teaching Excellence: United States Military Academy, West Point. https://www.westpoint.edu/sites/default/files/inline-imag-es/centers_research/center_for_teching_excellence/PDFs/mtp_project_papers/Boyles_17.pdf

Bruening, D. M., P. Truckenmueller, C. Stein, J. Fuellhase, P. Vajkoczy, T. Picht, and G. Acker. 2022. "360° 3D virtual reality operative video for the training of residents in neurosurgery". Neurosurgical Focus 53, no. 2. DOI: 10.3171/2022.5.FOCUS2261.

Daling, L., C. Kommetter, A. Abdelrazeq, M. Ebner, and M. Ebner. 2020. "Mixed Reality Books: Applying Augmented and Virtual Reality in Mining Engineering Education". In Springer Series on Cultural Computing, 185-95. Springer. DOI: 10.1007/978-3-030-42156-4_10.

Fang, T. Y., P. C. Wang, C. H. Liu, M. C. Su, and S. C. Yeh. 2014. "Evaluation of a haptics-based virtual reality temporal bone simulator for anatomy and surgery training". Computer Methods and Programs in Biomedicine 113, no. 2: DOI: 10.1016/j.cmpb.2013.11.005.

Kalawsky, R. S., A. W. Stedmon, K. Hill, and C. A. Cook. 2000. "A taxonomy of technology: Defining augmented reality". Paper presented in Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Association, 'Ergonomics for the New Millennium'. DOI: 10.1177/154193120004400506.

Mirghani, I., F. Mushtaq, M. J. Allsop, L. M. Al-Saud, N. Tickhill, C. Potter, A. Keeling, M. A. Mon-Williams, and M. Manogue. 2018. "Capturing differences in dental training using a virtual reality simulator". European Journal of Dental Education 22, no. 1. DOI: 10.1111/eje.12245.

Palos Sánchez, P. R., J. A. Folgado-Fernández, and M. A. R. Sánchez. 2022. "Virtual Reality Technology: Analysis based on text and opinion mining". Mathematical Biosciences and Engineering 19, no. 8: 7856-85. DOI: 10.3934/mbe.2022367.

Satava, Richard M. M. D. 1995. "Telemanipulation, telepresence, and virtual reality for surgery in the year 2000", Bellingham, WA, United States. DOI: 10.1117/12.197307.

Xanthidis, D., C. Manolas, S. Paul, and O. K. Xanthidou. 2020. "Virtual and Augmented Reality: Enhancing the learning experience in higher education in the U.A.E. Current standing research directions". Paper presented in 2020 7th International Conference on Information Technology Trends, ITT 2020. DOI: 10.1109/ITT51279.2020.9320882.

Zhu, Y., and N. Li. 2021. "Virtual and augmented reality technologies for emergency management in the built environments: A state-of-the-art review". Journal of Safety Science and Resilience 2, no. 1: 1-10. DOI: 10.1016/j.jnlssr.2020.11.004.Cardoso, Henrique Daniel de Avelar Lopes and Eugénio da Costa Oliveira. 2005. "Virtual enterprise normative framework within electronic institutions". In *Engineering Societies in the Agents World V*, 14-32. Heidelberg: Springer.

Acknowledgements

I want to express my sincere gratitude and appreciation to my PhD mentors for their invaluable guidance, support, and expertise since the start of my doctoral journey. Additionally, I would like to acknowledge the resources and the financing provided by the Doctoral Program in Mining and Geo-Resources Engineering.

Evaluation of Impacts of Geology Structures on Underground Mine Production Tunnels' Stability in an Iron ore Mine

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Abstract

Deep underground mining presents unique challenges particularly regarding stability of excavations at great depths. The study evaluated impacts of geology structures on underground mine production tunnels of an Iron-ore mine. Underground structural data were analyzed using numerical analyses software Dips program to define orientation of major structures within the various tunnels. The structures orientation results were further analyzed using Rocscience modeling software Unwedge. The tunnels stability was investigated by numerical evaluation of state of the formed wedges. A design factor of safety (FoS) of 1.5 was used as stability benchmark criterion for the wedges. Wedges with factor of safety below the benchmark FoS criterion were considered unsafe. The results showed that geology structures have significant impacts on wedges formation within the underground mine production tunnels, and thus negatively influence the stability of the tunnels.

Author Keywords. underground mine, production tunnel, Rocscience, Dips, Unwedge, wedges, modeling.

1 Introduction

Stability of underground excavations such as tunnels, stopes, pillars, ore-passes, and drifts is partly controlled by the quality of structural data collected and utilized for rock mass geomechanical properties analysis, and excavations stability modeling. Accurate modeling of stability of mine tunnels is largely dependent on knowledge of interaction of geology structures such as joints, fault planes: zones of weakness within the rockmass and tunnels. Of huge significance are the orientations of the structures and their interaction with one another and with the tunnels: whether they daylight in the excavations' openings (Hoek et al., 2013). Inadequate knowledge due to insufficient data on rock mass geology structures is a major cause of structural induced instability in underground mines (Brady and Brown, 2004).

Quality geology structures data provides the building block upon which structurally controlled excavations stability evaluations are based (Mohebbi et al., 2017). The study utilized structural data sets from underground mapping in Iron ore mine in Northern Sweden. Rocscience numerical analyses software 'Dips' was used to process the geology structures data sets and to define their orientations. Joint sets orientations data was further analyzed to determine formation of wedges within the underground tunnels that may induce instability, with the aid of underground excavations stability analyses and modeling software 'Unwedge' by Rocscience (Rocscience, 2019). Each production tunnel was evaluated for wedges formation and the factors of safety of the wedges.

2 Materials and Methods

Structural geology mapping data sets of production tunnels were extracted from Leapfrog program database of the mine. The data set was filtered to eliminate overlapping data of adjacent tunnels, which includes haulage drift. The resulting filtered data sets of were plotted in the Dips software to define number of joint-sets and mean joint-set plane. The joint sets orientation was defined for each tunnel based on the mine coordinate system. Results of dips joint-sets orientation were used for wedges analyses and modeling for each production tunnel.

Table 1: Geology structure data set samples used for joint orientation modeling (Ca = calcite; Chl = chlorite; Hem = hematite/magnetite)

Location Coordinates			Structure	Strike	Dip	Dip Direction	Number of Joint	Spacing (m)	Joint width (mm)	Fill Material
Easting	Northing	Elevation								
6839.4	5661.6	-436	joint	344	60	74	15	0.2		Ca
6842.4	5657.8	-436	joint	346	75	76	1		30	Chl
6848.9	5656.2	-436	joint	346	75	76	5	0.4		Ca
6870.6	5653.4	-436	joint	353	70	83	2	1		Hem

3 Results

3.1 Joint sets orientation Plots

Figures 1 and 2 are the results of joints data plotting in Dips software for tunnels 542 at level 436.

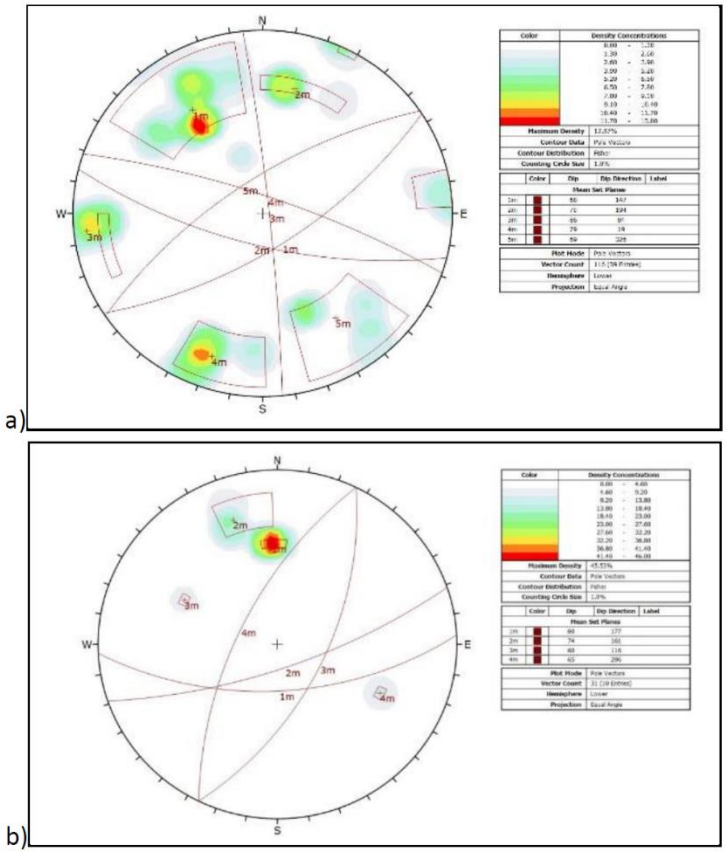

Figure 1: Mean joint-sets and their orientation for a) level 436 tunnel 542 and b) level 486 tunnel 562.

3.2 Wedges modeling

Wedges formed within tunnel 542, level 436 were modeled using the tunnel's joint sets orientation data within UnWedge software. The results are presented in figures 2 and 3.

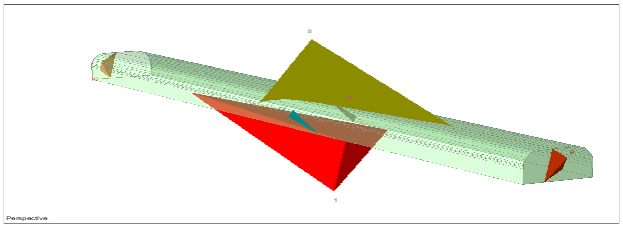

Figure 2: Modeled wedges formed in tunnel 542 level 436.

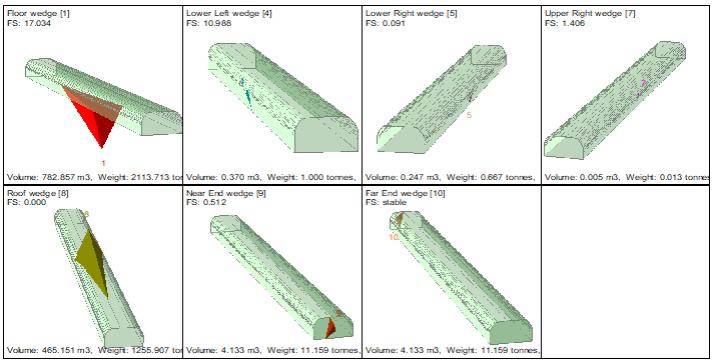

Figure 3: Modeled factors of safety of the wedges formed in tunnel 542 level 436.

3.3 Wedges Factors of safety (FS)

Table 2 is an overview of wedges formed in tunnels 542 level 436 and tunnel 562 level 486, and their factors of safety after the following unit operations: blasting, shotcrete application, and rock bolts implementation.

Table 2: Results of wedges factor of safety values in the production in two different working levels

Mine Level (below ground)	Tunnel №	Wedge Location Description	Factor of Safety after blasting (FoS)	Factor of Safety after shotcrete (FoS)	Factor of Safety after bolting (FoS)
436	542	535-Upper left (4)	10.988	19.85	22.758
		535-Lower left (3)	1.406	105.694	105.694
		535-Lower right (6)	0.091	9.048	11.597
		535-Roof (8)	0	0.041	0.125
		535-Far end (10)	stable	stable	stable
486	562	562-Lower left (4)	13.288	16.434	17.307
		562-Upper right (6)	5.171	162.827	162.827
		562-Lower right (5)	2.66	13.986	18.453
		562-Roof (8)	0	0.147	0.513

4 Discussion

Based on the results of joints analyses and wedges formation modelling results in section 3, it was observed that the geology structures created formation of wedges in the production tunnels. Analyses results of the factor of safety of the wedges formed showed that there are numbers of wedges with factor of safety below the benchmark 1.5 before ground management interventions were implemented. More concerning is the fact that some of the wedges still has factors of safety which are unsafe, according the safety criterion set by the

author, even after ground stability strategies had been completely implemented. The production tunnels comprising the unsafe wedges constitute hazards to safety of personnel and equipment.

5 Conclusions

According the results of the study it was concluded that geology structures have significant impacts on stability of the production tunnels of the mine. Therefore, it is crucial to collect qualitative and reliable geology structures data of production tunnels, to enhance analyses and modeling of their impacts on underground mines' safety, especially at mines get deeper. This will promote better knowledge of the ground conditions and facilitate the design and deployment of robust ground control strategies to forestall ground fall and other undesirable consequences.

References

Brady, B.H.G. and Brown, E.T. (2004). *Excavation design in stratified rock*, Rock Mechanics for underground mining, pp. 224–241.

Hoek, E. Carter, T. G. Diederichs, M. S. (2013). *Quantification of the Geology Strength Index Chart*. Geomechanics Symposium held in San Francisco, CA, USA.

Mohebbi, M. Bafghi, A. R. Y. Marji, M. F. and Gholamnejad, J. (2017). Rock mass structural data analysis using image processing techniques - Case study of Choghart iron ore mine northern slopes. *Mining and Environment,* vol. 8 (1), pp. 61-74.

Rocscience (2019). Unwedge User's manual: *3D visualization of potentially unstable wedges in the rock surrounding underground excavations and calculation of factors of safety and support requirement for these wedges*. Toronto, Canada: Rocscience Inc.

Acknowledgements

Doctoral Program in Mining and Geo-Resources Engineering for the resources and the financing provided to participate in DCE23.

Posters displayed in the Symposium

- **Ana Silva** and Maria de Lurdes Dinis. Occupational Exposure to Radon in the ACES Tâmega II - Vale do Sousa Sul (#108).
- **Andrés Cardenas**, Rosa Marques, Maria I. Dias, Dulce Russo, Catarina Diamantino and Edgar Carvalho. Weather influence on the REE behavior in soils and sediments from an old uranium mine, Portugal (#118).
- **Zaid Al-Shomali**, Maria De Lurdes Dinis, Alcides Pereira and Ana Clara Marques. Removal of Naturally-Occurring Radioactive Materials (NORM) at water treatment plant with innovative approaches based on porous microspheres with immobilized catalysts (#122).
- **Lobarinhas R.**, Paneiro G. and Dionísio A.. The influence of high temperatures in stones capillarity behavior – Portuguese limestones (#150).
- **Inês Amaral**, Ana Filipa Duarte, Leonardo Azevedo and Luís Matias. Seismic data processing to image the water column in Northwest Portugal (#344).
- **Miguel Gomes**, Ana Meira Castro and Amílcar Soares. Precipitation indices - A tool for studying the drought phenomenon (#375).
- **Tiago da Costa Silva**, Carlos Magno Muniz and Silva. Monitoring and Control of Ground Vibrations in Construction Area of Arena Pernambuco Stadium (#377).
- **Assane Luís Pena**, Mitoxe Osseias Munhembye and Amílcar de Oliveira Soares. Bottom Surface, Easy Sediments and Depositional Models from the Beira Port Region to the Pungwe River Estuary, Part of the Mozambique Basin, Sofala (#382).
- **Pietro Merandino**, Rui Sousa, Maria de Lurdes Dinis, António Fiúza and Cristina Ribeiro. Re-utilization of mining waste – the case of a lithium-bearing ore processing (#410).

Occupational Exposure to Radon in the ACES Tâmega II - Vale do Sousa Sul

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Abstract

The legal regime for protection against the dangers arising from exposure to ionizing radiation established by Directive 2013/59/Euratom was transposed by Decree-Law No. 108/2018, December 3, which determines the preparation of the National Radon Plan (PNRn), which was approved by the Resolution of Councils of Ministers No. 150-A/2022 of December 29, 2022. In Portugal, the National Radon Plan was approved by the Resolution of Councils of Ministers No. 150-A/2022 of December 29, 2022. According to WHO, radon is the second leading cause of death from lung cancer (WHO 2009; IAEA 2011).

The aim of this study is to characterize the occupational exposure to radon of health professionals from the ACES Tâmega II - Vale do Sousa Sul, namely to evaluate the radon concentrations and to assess the effective dose rates to which the workers are exposed. For this study all workplaces where health care is provided to users in the demographic area of the ACES Tâmega II - Vale do Sousa Sul, encompassing the municipalities of Paredes, Penafiel and Castelo de Paiva will be evaluated. A total of 20 buildings will be measured. The concentration of radon in indoor air will be evaluated in several workplaces of health professionals (medical office, nursing room, meeting room, among others) of the ACES Tâmega II - Vale do Sousa Sul, using Radon eye. The measurement of gamma radiation dose rate will be performed in two distinct periods autumn/winter and spring/summer. For the radiometric survey in the health units, the GAMMA SCOUT® (GS3) equipment will be used.

Author Keywords. Radon, Radon Action Plan, Occupational exposure, Workplaces.

References

EPA (2013). United States Environmental Protection Agency, Consumer´s Guide to Radon Reduction, How to fix your home. URL: http://www.epa.gov/radon, EPA 402/K-10/005 | March 2013.

IAEA (2011). Safety Standards Radiation for protecting people and the environment. Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards Interim edition Nº GSR Part 3 (Interim), Vienna. URL:http://www-pub.iaea.org/MTCD/publications/PDF/p1531interim_web.pdf

WHO (2009). WHO handbook on Indoor Radon, A Public Health Perspective, ISBN 978 92 4 154767 3. URL: http://whqlibdoc.who.int/publications/2009/9789241547673_eng.pdf.

Acknowledgments

This work was financially supported also by Base Funding - UIDB/04028/2020 and Programmatic Funding - UIDP/04028/2020 of the Research Center for Natural Resources and Environment - CERENA - funded by national funds through the FCT/MCTES (PIDDAC).

Doctoral Program in Mining and Geo-Resources Engineering for the resources and the financing provided to participate in DCE23.

Weather influence on the REE behavior in soils and sediments from an old uranium mine, Portugal

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Abstract

Rare earth elements (REE) comprise a group of elements from lanthanide series (La-Lu), and have several applications (Liu et al., 2022). There are still many gaps in the knowledge of their behavior, fractionation, and extraction in diverse environments, namely in uranium where it has aroused a huge interest (Dushyantha et al., 2020). Aiming to study the weather influence on REE behavior, two sampling campaigns were done during dry and wet seasons in an old uranium mine. Soils and sediments were collected inside/outside the mine area (Quinta do Bispo). Samples were characterized by ICP-MS, INAA, XRD and SEM. Preliminary results showed slight variations on REE behavior in samples collected inside the mine, which might be controlled by the mineral phases, as secondary REE minerals and REE-containing Fe-Mn-oxyhydroxide compounds. Samples collected outside the mine have lower REE concentrations in the dry season, which can be related to soil moisture, water logging, and desiccation.

Author keywords. REE, old uranium mine, weather influence, center-north Portugal

References

Dushyantha, Nimila, Batapola, Nadeera, Ilankoon, I.M.S.K., Rohitha, Sudath, Premasiri, Ranjith, Abeysinghe, Bandara, Ratnayake, Nalin, and Kithsiri Dissanayake. 2020 "The story of rare earth elements (REEs): Occurrences, global distribution, genesis, geology, mineralogy and global production. In *Ore Geology Reviews*. Accessed March 29, 2023. https://doi.org/10.1016/j.oregeorev.2020.103521.

Liu, Yongxue, Wu, Qixin, Jia, Huipeng, Wang, Zhuhong, Gao, Shilin, and Jie Zeng. 2022 "Anthropogenic rare earth elements in urban lakes: Their spatial distributions and tracing application." In *Chemosphere*. Accessed April 3, 2023. https://doi.org/10.1016/j.chemosphere.2022.134534.

Removal of Naturally-Occurring Radioactive Materials (NORM) at water treatment plant with innovative approaches based on porous microspheres with immobilized catalysts

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Abstract

The abundant natural radionuclides found in water sources are radium, radon, and uranium. Specific water regulations limit the amount of radioactivity allowed in drinking water. Water treatment processes purify drinking water by removing naturally occurring radioactive materials (NORM) present in raw water. As large quantities of water are treated, the NORMs (mostly uranium and radium) become concentrated in various filtration media, and in wastes streams as well, which require management and disposal.

The objective of this work is to understand the nature and potential of the impact of the residual radioactivity associated with NORM in the water supply cycle. The experimental work focuses on the removal of the radionuclides (radium and its progeny) from water using photocatalytic catalytic microspheres. These microspheres consist of TiO2 nanoparticles loaded with SiO2 microspheres. Different designs of experiments with solar irradiation are being tested varying the duration in ranges between 3 hours up to 72 hours and testing at the same time the effect of the presence of the microspheres. At the end, a predictive model should be developed for the concentrations of radionuclide in residues and filters at the water treatment system to perform a dose assessment at all stages of the water treatment cycle.

Author Keywords. NORM, water treatment, residual radioactivity, radium, sludge, microspheres, photocatalysis, porous silica, solar light

References

Dinis, M.L., Alshomali, Z. (2022). Impact of residual radioactivity associated with NORM in the water supply cycle. NORM X conference, Utrecht, The Netherlands, May 9 – 13, 2022.

Marques, A.C., Vale, M., Vicente D., Schreck, M., Tervoort, E., Niederberger, M. (2021). Porous Silica Microspheres with Immobilized Titania Nanoparticles for In-Flow Solar-Driven Purification of Wastewater, Global Challenges 2021, 2000116, DOI: 10.1002/gch2.202000116.

Acknowledgments

This work is being developed under the FCT scholarship UI/BD/152300/2021 of the Research Centre for Natural Resources and Environment – CERENA; supported also by Base Funding - UIDB/04028/2020 and Programmatic Funding - UIDP/04028/2020 of the Research Center for Natural Resources and Environment - CERENA - funded by national funds through the FCT/MCTES (PIDDAC) and by the Doctoral Program in Mining and Geo-Resources Engineering of FEUP through the resources and financing provided to participate in DCE23.

The influence of high temperatures in stones capillarity behavior – Portuguese limestones

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Abstract

Future projections in temperature extremes as consequence of climate change will lead to an increasing number, duration, and intensity of heat waves. This phenomenon is associated with droughts and devastating wildfires. In the Mediterranean this alarming trend is also confirmed, being projected a future increase in fire danger and fire season length in southern Europe, particularly in the countries of the northern arch.

Portugal as a country inserted in this context should be concern about the influence of high temperatures in their stone resources, since they represent a very important part of their past, as a heritage material and their future, as economic resource.

This study assesses the impact of high temperatures on different Portuguese limestones. Although the mineralogical composition is approximately the same the results observed are distinct. Showing that other petrographic properties can significantly influence capillarity lithotypes behavior like grain size, relic structures and fossils characteristics.

Author keywords. Climate change, Ornamental Stones, High Temperatures, Capillarity, Portuguese limestones.

Seismic data processing to image the water column in Northwest Portugal

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Abstract

The North Atlantic Ocean is a complex structure with currents that play an important role in regulating the Earth's climate (Azevedo 2021), carrying warmer waters away from the Equator. Distinct water layers with contrasting temperature and salinity values, known as thermohaline structures, provide evidence of the ocean's mixing processes (Holbrook 2003). The processing of seismic data consists in applying filters and processes that enhance the signal to noise ratio and improve the image quality. Processes such as removing direct arrival and applying the normal moveout correction, through a coherent velocity model, are challenging but necessary. Finally, stacking and migrating the seismic data, by combining multiple traces, allows imaging oceanic fronts, which can relate to Mediterranean water intrusions (Song 2012). Overall, these processes and techniques enables to better understand the complex dynamics of the North Atlantic Ocean and its impact on the Earth's climate.

Authors keywords. Seismic oceanography, seismic data processing, imaging thermohaline structures.

References

Azevedo, Leonardo, Luís Matias, Francesco Turco, Renan Tromm, and Álvaro Peliz. "Geostatistical Seismic Inversion for Temperature and Salinity in the Madeira Abyssal Plain." Frontiers in Marine Science 8 (August 12, 2021). https://doi.org/10.3389/fmars.2021.685007.

Holbrook, W. Steven, Pedro Páramo, Scott Pearse, and Raymond W. Schmitt. "Thermohaline Fine Structure in an Oceanographic Front from Seismic Reflection Profiling." Science 301, no. 5634 (August 8, 2003): 821–24. https://doi.org/10.1126/science.1085116.

Song, Haibin, Luis M., Barry Ruddick, and Xinghui Huang. "Seismic Oceanography: A New Geophysical Tool to Investigate the Thermohaline Structure of the Oceans." Oceanography, March 23, 2012. https://doi.org/10.5772/29178.

Precipitation indices - A tool for studying the drought phenomenon

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Abstract

Drought has severe impacts on various domains, from water resources to socio-economic systems, at regional and global scales, and is expected to become more frequent and severe due to climate change. Indices are important decision-making tools for monitoring and preventing water scarcity in a given region.

Based on a systematic literature review, this work presents a synthesis of the main drought indices, their advantages, and limitations. Forty-five indices were identified, most based on precipitation and/or temperature data. The SPI and SPEI indices were found the most used globally, although no index was identified as more relevant than others.

Careful consideration is required in choosing an index due to the unpredictability of precipitation and data availability. This study identifies drought indices with a direct relationship to physical phenomena such as precipitation, which at later stage, make their spatiotemporal modelling, fundamental instruments for the management of extreme events of the phenomenon.

Author Keywords. Precipitation index, Drought index, Drought risk, Climate change

Monitoring and Control of Ground Vibrations in Construction Area of Arena Pernambuco Stadium

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Abstract

Ground vibrations are a side effect present in the use of explosives in mining activities (open pit or underground mining) and in some construction works as the foundation structures of buildings, subway tunnels and galleries, etc. To avoid the damages caused by these vibrations to the building structures nearby, there are some specific norms indicating the permissible limit levels.

The objective of this work was to apply an attenuation law to predict and assist the control of the ground vibration generated by the blasting activities executed in the site of construction of the Arena Pernambuco Stadium, in 2011, in the Municipality of São Lourenço da Mata, Metropolitan Region of Recife, Pernambuco, Brazil, to reduce the structure damage risk.

It was performed a seismographic monitoring at the structure sites and analyzed the blasting designs to adjust the parameters to the attenuation law and calculate the correlation to the experimental values observed.

Author Keywords. Ground vibration, Seismographic monitoring, Environmental mining impact, Blast design

Bottom Surface, Easy Sediments and Depositional Models from the Beira Port Region to the Pungwe River Estuary, Part of the Mozambique Basin, Sofala

Assane Luís Pena [1,2], Mitoxe Osseias Munhembye [1], Amílcar de Oliveira Soares [2]

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Abstract

This work describes part of the results of research carried out on sedimentology and stratigraphy between the region of the port of Beira and the Pungwe River estuary, and corresponds to part of the chapter characterizing the study area of the thesis under development entitled "Numerical modeling of oil reservoirs and gas based on seismic and geostatistics – application to the mozambique basin, sofala province". The objective of this work is to characterize the bottom surface sediments, easy sediments and depositional models of the sediments. To characterize and qualify the sediments, 4 sediment samples were collected and analyzed. For faciological and stratigraphic analysis data from geotechnical tests (SPT) of seven holes were used. The granulometric results of the sediments indicate that they are mostly sandy with a very fine texture. The facies and stratigraphic analysis allowed the recognition of five associations of facies related to a deltaic and shallow marine system.

Authors keywords. Characterization of sediments, facies and positional models, Beira port and Pungwe River estuary, Mozambique Basin, Sofala

References

Pena, Assane Luis, Miranda, Paulo, Terroso, Denise, Martins, Maria Virginia Alves. Sediment's quality and potential uses of dredged material: a cases tudy (Portugal). Journal of Sedimentary Environments 1(4). Published by Universidade do Estado do Rio de Janeiro, 2(2):1-81-4April-June, 2017.

Pomerol, C., Lagabrielle, Y., Renard, M., &Guillot, S. Principles of Geology: techniques, models and theories. (M. L. Lelarge, P. F. C. Lelarge, & R. Menegat, Eds.) (14th ed.). Porto Alegre: Bookman, 2013.

Tucher, M. E. Rochas Sedimentares: guia geológico de campo (4ª edição ed.). (T. R. Menegat, Trad.) Porto Alegre: Bookman Editora LTDA, 2004.

Re-utilization of mining waste – the case of a lithium-bearing ore processing

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Abstract

This work was carried out in the scope of the CAVALI project and involves the study of the potential reutilization of materials currently designated as waste, which are generated during lithium extraction from lithium-bearing minerals, such as lepidolite. These waste materials are mainly generated during the froth flotation and leaching stages. Each process yields distinct types of residues, with the flotation stage producing a coarser material and the leaching process producing a finer one. The primary objective of this research work is to identify potential collaborations with companies operating in various industries, such as construction, in order to adopt a more sustainable approach towards addressing the reutilization of mining wastes. Therefore, at as an initial stage, these residues were characterized for physical and chemical features to evaluate if they accomplish the required properties to be used in industrial applications.

Author keywords. Mining waste; Lithium; Sustainable Raw-Materials; Waste Management.

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ISBN: 978-972-752-305-4

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