AFRIROCK 2025

Abstract Book

21-23 JULY 2025

SUN CITY, RUSTENBURG, SOUTH AFRICA

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SOUTH AFRICAN NATIONAL INSTITUTE OF ROCK ENGINEERING

SAIMM
THE SOUTHERN AFRICAN INSTITUTE OF MINING AND METALLURGY

THE SOUTHERN AFRICAN INSTITUTE OF MINING AND METALLURGY JOHANNESBURG 2025

AFRIROCK 2025

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FOREWORD

PIONEERING PROGRESS: THE FUTURE OF ROCK ENGINEERING

It is our great pleasure to welcome you to the Afrirock 2025, themed *Pioneering Progress: The future of Rock Engineering*. This international conference brings together experts, practitioners, and academics from all over the world to share knowledge, exchange ideas, and advance the state of practice in rock engineering.

Two formal workshops are planned prior to the official commencement of formal proceedings of Afrirock 2025, one on pillar design and the other one stress measurements.

The first workshop will be hosted by Prof. Francois Malan, from the University of Pretoria. Presenters include Prof. Nielen van der Merwe, Prof. Bryan Watson, Mr. William Joughin and Dr. Rudi Kersten.

The second workshop will be hosted by representatives from Japanese and South African geoscientists. Since the 1990s, Japanese and South African geophysicists and geoengineers have collaborated to study the mechanisms of seismic events induced by mining activities, through geotechnologies including stress measurements. A Geotech Consortium has now been established based on this collaboration, to accelerate the transfer of the geotechnologies developed not only for deep mining, but potentially also to non-mining applications such as shale gas extraction. The outline, basic theory and practice of stress measurement methods and techniques will be presented by their inventors. Presenters include Prof. Ito Takatoshi, Prof. Yusuke Mukuhira, Prof. Kiyotoshi Sakaguchi, Prof. Yasuo Yabe, Prof. Ray Durrheim, Dr. Dave Roberts, Mr. Willem Meintjies and Mr. Gerhard Hofmann.

We are honoured to host distinguished keynote speakers, each bringing unique expertise and insight:

- Prof. Francois Malan, from the University of Pretoria.
- Dr. John Hadjigeorgiou, from the University of Toronto.
- Mr. Frans Basson, from Newmont Corporation.
- Mr. Brad Simser from Glencore Sudbury Operations.
- Associate Professor Bryan Watson, from the University of the Witwatersrand.
- Dr. Dave Roberts, from Sibanye Stillwater.

These keynote presentations promise to deliver rich and valuable insights that will stimulate discussion and inform best practices in our field. In addition to the keynotes, the symposium features a robust programme of technical papers from industry professionals, consultants, and researchers. These sessions offer attendees an opportunity to learn from the practical experiences of others, explore innovative solutions, and contribute to ongoing dialogue and development within the rock engineering community.

FOREWORD *(CONTINUED)*

Five technical visits to gold, platinum, diamond and copper mines have been organised, which will take place after the closing of the official proceedings. These technical visits, together with the social events planned at the end of each day, provide conference attendees with further opportunities to network freely in an informal setting.

We extend our sincere gratitude to all those who have contributed to making this conference possible—our keynote speakers, paper authors, reviewers, exhibitors, and sponsors. Your dedication, time, and expertise are the foundation of this event's success. A special note of appreciation goes to the Technical Paper Review Committee and the Organising Committee, comprising members from Sanire and the Southern African Institute of Mining and Metallurgy (SAIMM), for their dedication and hard work in delivering this international conference.

We look forward to a productive and inspiring event and encourage all participants to engage fully, share openly, and collaborate broadly.

On behalf of the Organising Committee,

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Conference Chairperson

Kevin Le Bron

Principal Consultant
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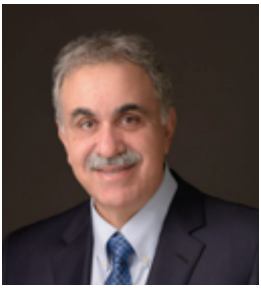
Kevin has spent more than 30 years working in the mining industry in various operational, research and consulting roles, after completing his B.Sc. Hons. degree in 1994. He obtained his SCO and Rock Mechanics Certificates in 1996, and the AREC in 1998. He holds a M.Sc. Eng. degree from Wits University (graduating in 2000). He obtained both the MDP (from Wits Business School) and PGCE (from Unisa) in 2005.

His experience includes numerous concept level, pre-feasibility and feasibility studies, which involved the design of mine layouts, support systems, mining strategies for both deep gold mines, shallow to intermediate mines within the BIC, massive mines (diamonds, copper, lead), underground coal and open pits (gold, coal, diamonds, heavy minerals), geotechnical instrumentation, siting and of decline and vertical shafts (geophysical and geotechnical evaluation), shaft pillar design and extraction. He is skilled in the use of various suites of numerical modelling.

Currently he is with MLB Consulting as the Principal Consultant in Rock Engineering.

Keynote Presenters



John Hadjigeorgiou

Ph.D., PEng. (Ont., Que., NT/NU), FCIM, ICD.D.

John Hadjigeorgiou holds the Pierre Lassonde Chair in Mining Engineering at the University of Toronto. Previously, he served as Head of the Department of Mining, Metallurgical and Materials Engineering at Université Laval in Quebec City. Dr. Hadjigeorgiou has degrees in Civil Engineering, Geological Sciences and Mining Engineering. A graduate of the Rotman School of Management at the University of Toronto and the Institute of Corporate Directors, he holds the ICD.D designation.

Professor Hadjigeorgiou has published more than 125 peer reviewed technical articles, co-authored two books on Ground Support, and has been co-editor of numerous conference proceedings on Deep and High Stress Mining. He is the recipient of multiple engineering awards and is a Fellow of the Canadian Institute of Mining and Metallurgy.

Dr. Hadjigeorgiou, P.Eng., possesses over 35 years of worldwide applied research and consulting experience in the areas of geotechnical and mining engineering, and currently participates in several Geotechnical Review Boards.

David Roberts

Sibanye-Stillwater

Dave studied mechanical engineering at the University of Natal before being tempted into the world of rock engineering by Tony Jager and Leszek Wojno. He joined CSIR Miningtek in 1993 as a bursar and completed his MSc in "Testing of Mining Tunnel Support Elements and Systems for Hard Rock Mines". He was then tempted into the world of modelling by Rob Eve and Ewan Sellers, and sent to Wales for four years to complete a PhD on Finite Element Modelling of Rockbolts and Reinforcing Elements. During this time he worked extensively on the Elfen finite element modelling code.

He was thereafter appointed as a researcher within CSIR Miningtek, and remained there for ten years, ultimately becoming a Principal Researcher and Research Group Leader for Rock Engineering. During that time he worked on many research projects for SIMRAC, Deepmine, Coaltech, Platmine and many private entities, usually providing modelling skills.

He then moved to Anglogold Ashanti as a Technical Assistant where he was involved with modelling for the Technology and Innovation Consortium Projects, including the bore-and-fill mining method. Here he was exposed to FLAC3D and Map3D. Six years later he moved back to the CSIR, this time as Principal Researcher for the Non-explosive Rock Breaking Project, which was run under the auspices of the Mandela Mining Precinct. Dr. Roberts is currently with Sibanye Stillwater as a Unit Manager for Modelling, performing modelling services and training as required, using ITASCA codes and Vantage. He is also involved in the management of research projects.

His main interest is modelling, but he also gets excited at the mention of instrumentation, stress analysis, and innovative rock breaking methods.

Bryan Philip Watson

Associate Professor
The University of the Witwatersrand

~40 years in the mining industry: Platinum, gold and coal.
A strong focus on hard rock pillar design and behaviour.
Rock engineering design of shallow and deep-level stopes.
Underground instrumentation and laboratory testing.

Francois Malan

Professor and Head of Department
University of Pretoria

Prof Malan started his geotechnical career in 1993 at the Chamber of Mines Research Organisation. This later became the CSIR Division of Mining Technology. His particular interest during this period was the time-dependent behaviour of hard rock and he used this as topic for his PhD thesis. For this work, the International Society of Rock Mechanics (ISRM) awarded him the Rocha medal in 2011 for the best PhD in the world. In 2011 he joined Groundwork Consulting and worked on pillar designs and layout problems in the South African platinum industry. In 2011, he joined the gold mining industry and was appointed as Senior Consultant Rock Engineering of Gold Fields South Africa. These mines were taken over by Sibanye Stillwater in 2013 and he remained with Sibanye Stillwater. In 2018, he joined the University of Pretoria as Associate Professor. In 2021, he was promoted to full Professor and is currently the Head of Department. He currently has an NRF rating of B2 has more than 1750 citations. His key research interest is numerical modelling and pillar and layout design for hard rock tabular mines. During the last 7 years, he built a vibrant research group in rock engineering in the Mining Department, focussing mostly on pillar design and numerical modelling aspects.

Over the years, he has received various awards for his contributions to rock engineering. These include six gold and silver medals from the South African Institute of Mining and Metallurgy and three Salamon awards from the South African National Institute of Rock Engineering for best publications. The ISRM awarded him the Rocha medal in 2011 for the best PhD in the world and in 2017 he presented the ISRM Franklin Lecture at the AfriRock Symposium in Cape Town. He also presented the 29th ISRM online lecture during March 2020. He has now been appointed as ISRM Fellow and was inducted in Saltzburg in October 2023. The position of ISRM Fellow was introduced in 2011 to recognise select individuals who have achieved outstanding accomplishments in rock mechanics and rock engineering and have contributed significantly to the work of the ISRM.

Between 2007-2011, Prof Malan served as ISRM Vice-President for Africa. Prior to this, he was also the President of the South African National Institute of Rock Engineering for the period from 2003 -2005. Prof Malan is a Fellow of the South African Institute of Mining and Metallurgy, a Fellow of the South African National Institute of Rock Engineering and a member of the Society of Mining Professors. He acts as a reviewer for several rock engineering journals and is a member of the Publications Committee of the Journal of the South African Institute of Mining and Metallurgy and a member of the Editorial Board of the International Journal of Rock Mechanics and Mining Sciences.

Brad Simser

Principal Ground Control Engineer
Glencore Sudbury Operations

Since graduating in 1988, most of my career has been in underground hard rock mines as a geotechnical/rock mechanics engineer. All the mines have been relatively deep and seismically active including stints in the South Africa Goldfields (Welkom 1990-95), lead-zinc in Northern New Brunswick (Brunswick Mine 1995-2001), and Glencores' Sudbury operations since 2003.

2001-2003 was spent at the Noranda Technology centre as a research engineer and inhouse consultant for several Noranda operations and included the running of a dynamic bolt testing rig. The Glencore Sudbury operations include narrow vein longhole/cut and fill mining, sub level open stoping, and a new mine project with ore reserves from 2300 to 2800m below surface. This project has completed a winze (sub shaft) to 2650m and is currently progressing towards full production ramp up.

Frans Roelof Petrus Basson

Director Geotechnical Engineering
Newmont Corporation

I started my career as a Secondary School Science Teacher, which I pursued for 6 years. I then joined Hartebeestfontein Gold Mine late 1995 and was transferred to Target Mine during 1998. Our family moved to Australia at the start of 2006 when I joined AMC Consultants in Perth, and I joined Newmont APAC at the start of December 2007.

Geotechnical engineering requires decision making by combining information from many data sources. The ability to spatially visualise the information from many sources provide another layer of context, which enhance decision making significantly. As visualisation tools that served my needs were not available in the late 1990's, I taught myself programming and started developing visualisation and analyses tools to enhance my problem-solving abilities. Others found the software useful, and I started making the solutions available on my website www.basrock.net for others to download and use since 2011.

The main software packages are GEM4D and Trajec3D, but smaller software solutions are also available. GEM4D is geotechnical software for three-dimensional visualisation and analysis from various data sources. The software applies existing technologies to geotechnical problems and supports many geotechnical and risk assessments. Trajec3D is a three-dimensional rigid body rock fall analysis program that can simulate the trajectories of volumetric bodies during free fall, bouncing, sliding and rolling.

I have been blessed with exceptional mentors during my geotechnical career, starting with Koos Bosman and Frans Weyers at Hartebeestfontein Gold Mine, Danie Ras at Target Mine, and Mike Sandy at AMC Consultants. As I spent many years at Target Mine, Danie Ras had the largest impact on my life, and I still often find myself quoting him today. My sincere hope is to have a similar positive impact in the life of young engineers that cross my path.

Outside working and programming hours, I love to read about history and the lessons that can be learned about human behaviour. As we are living through an exceptional time in world history, I spent a significant time researching and pondering the developments and the impacts on our future. Geotechnical Engineering equips as well for this task, as we develop effective skills to piece the bigger picture together with less than perfect information.

Keynote Address: Practical considerations in the selection of ground support

J. Hadjigeorgiou
University of Toronto, Canada

This paper discusses practical considerations in the selection of ground support for underground excavations in hard rock mines. Although the current focus appears to be on a distinction between conventional vs energy-absorbing elements, other factors can significantly influence the effectiveness and reliability of a ground support system.

It is recognised that there is a degree of uncertainty in all stages of the ground support cycle. This includes inadequate characterisation of ground and loading conditions, and challenges in defining the demand and capacity of the ground support equation. The focus of this paper is addressing a knowledge gap in the behaviour of different ground support elements within a range of ground conditions, and the compatibility between these units and installation equipment. In addition, this paper provides guidance in the selection of ground support under extreme ground conditions.

Rockbolts in shear

G Knox, J Hadjigeorgiou
University of Toronto, Canada

There is a considerable wealth of information on the behaviour of rockbolts under axial loading conditions both in situ and under controlled laboratory conditions. However, there are comparably less data on the behaviour of rockbolts in shear. Several authors have contributed to the understanding of the behaviour of conventional rockbolts performance under shear loading. Much of this data has been gathered through experimental programmes conducted on sections of the rockbolt. Considering the continuous coupling between the rockbolt and borehole interface, the approach is justified. Due to the design premise of energy-absorbing rockbolts with discrete couplings, full scale testing is required to quantify the behaviour of the rockbolts. This paper reviews published results obtained from the two testing facilities, the SINTEF Rockbolt pull test rig in Trondheim, Norway and the Epiroc combinations shear and tensile test rig in Johannesburg, South Africa, both capable of conducting full-scale testing of rockbolts. Based on this high-quality database it was possible to identify three distinct responses of rockbolts in shear. The behaviour under load is controlled by the presence or absence of an encapsulation medium (resin/cement grout), the reinforcement mechanism and whether the rockbolt is continuously or discretely captured. As a reference the results are compared to the performance in shear of conventional grouted rockbolts.

This paper will be published in the SAIMM Journal

Review of quality assurance methods for hydro-powered resin bolting

J.P. Gouvea[1], W. Geel[2]
[1]Glencore, South Africa
[2]Northam Platinum Holdings Ltd, South Africa

Resin bolting in South Africa was developed and refined in underground coal mines (i.e., soft rock) since the late 1940s. The extension of resin bolting to hard rock mines started in 2003 and has required significant adaptations, challenging the status quo from both a supplier and applicator perspective. As far as resin bolting is concerned, the most affected aspect between coal mining and hard rock mining environments is the rock drills or machinery used for installation. Hard rock mines mostly use hand-held airlegs with limited thrust, low torque, and rotation speed relative to coal mine mechanised bolters. Resin bolt development for hard rock mines was, and still is today, predominantly focussed on compensating for the 'shortfalls' of using hand-held airlegs. At face value, hydro-powered rock drills, which are more powerful than traditional hand-held equipment, provided hard rock mines with a means to attain more consistent and reliable resin bolt installations. This paper assesses the quality and performance of hydro-powered resin bolting at an intermediate to deep-level platinum mine in South Africa and its potential contribution to rock-related instabilities when applied erroneously. The findings of this paper necessitate a revision of current quality control and quality assurance measures related to resin bolting for underground support.

Keywords: hydro power, underground support, resin bolting, pull test, encapsulation, load transfer

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Controlling tailings backfill leakage through fractured pillars

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[2]South Deep Gold Mine, South Africa

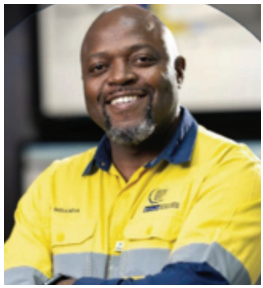
A deep level South African gold mine was experiencing leakage of tailings backfill through fractured pillars into the workings, where it created difficult operating conditions. The mine employs a long hole open stoping method, where the orebody is initially extracted using mechanised horizontal destress mining—similar to bord and pillar mining—creating a destress cut. This cut allows for long hole open stoping under reduced stress conditions, enabling the extraction of large mining targets above it. The mining takes place at depths nearing 3000 m, where the destress cut pillars are subject to high stress and are intensely fractured. During the subsequent backfilling operation the fractures provided pathways through the pillars for the highly fluid cemented tailings to migrate into the active workings. Accumulation of the hardening tailings disrupted vehicle and personnel movement, negatively impacting operations of the mine due to the need for rehandling the backfill in the active workings.

Solutions considered were coating the walls of the pillars with an impervious liner; sealing of the migration paths by injection into the pillars and modification of the tailings to increase viscosity. The first two were rejected as they were unlikely to achieve continuous sealing and they required additional crews and equipment to implement

.

Viscosity increase was achieved by adding a gelling agent to the tailings stream. This reacted with the cementitious binder in the tailings, to rapidly raise the viscosity to a level that the fill could not permeate through fractures. Setting of the binder then proceeded at its normal pace, over 4 – 6 weeks. The impact of the gelling agent was both significant and swift; migration of the backfill through the pillar fractures was drastically reduced shortly after its introduction and eliminated during the initial pour. Extensive laboratory testing was performed prior to underground trials. Issues investigated included: optimal dosage of the gelling agent; rate of viscosity increase and ultimate viscosity value; permeation rate of gelled tailings through simulated fractured rock and effect of the gelling agent on ultimate compressive strength of the backfill.

The system was then tested underground. Gelling agent was injected by a high-pressure dosing pump into the backfill pipelines, 10 – 30 m before the discharge points. Backfill leakage was significantly reduced or totally eliminated, contributing to a noteworthy increase in operational efficiencies.



Sifanekiso M Sibanda

Regional Geotechnical Engineer
Goldfields

Sifanekiso M. Sibanda is a geotechnical engineer currently serving as the Regional Geotechnical Engineer at Gold Fields South Deep Mine in Westonaria, where he oversees the entire Rock Engineering function of one of South Africa's most significant deep-level mining operations. With over two decades of expertise in underground hard rock mining across the Bushveld Complex and Witwatersrand Basin, Mr. Sibanda has established himself as a leader in geotechnical engineering, blending operational excellence with innovative research.

Mr. Sibanda holds a BSc in Mining Engineering from the University of Zimbabwe (2002), awarded cum laude with Distinction, and an MSc in Mining Engineering from the University of Exeter's Camborne School of Mines (2006), earned cum laude with Merit. Currently, he is pursuing a PhD in Rock Mechanics at the University of the Witwatersrand, further cementing his commitment to advancing the field of geotechnical engineering.

Mr. Sibanda's professional journey reflects a progressive ascent through South Africa's mining sector. He began his career in pivotal technical roles before rising to leadership positions at globally renowned firms. As Chief Rock Engineer at Anglo American Platinum's Bathopele Mine (2011–2016), he ensured geotechnical stability in challenging mining environments. His tenure as Manager Rock Engineering at Sibanye Platinum (2016–2023) showcased his ability to lead multidisciplinary teams, optimize safety protocols, and drive operational efficiency. In 2023, he joined Gold Fields, where he continues to shape best practices in rock engineering and risk management.

Committed to lifelong learning, Mr. Sibanda's PhD research at the University of the Witwatersrand focuses on advancing rock mechanics principles, aiming to address complex challenges in deep-level mining. His work underscores a dedication to both practical solutions and scholarly contribution.

The development of the fast cable anchor

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Mines across the many mining regions are increasingly reliant on both primary and secondary ground control systems. Secondary ground control systems mainly involve the use of deep anchored cable bolts. These cable bolts often require long wait times prior to mine operator re-entry into supported drives. In some current underground cable bolting operations, cable bolting crews must wait up to 12 hours for grout curing before re-entering the work area. This becomes particularly problematic for mine sites working with only one active heading. To reduce re-entry times, and to increase the safety of the work area, a Fast Cable Anchor (FCA) has been developed, which can also accelerate mining development. This FCA allows miners immediate re-entry to the supported work area by securing both the borehole and cable, which can be plated and tensioned immediately after complete insertion. Unlike prefabricated/pre-assembled cable bolts, the FCA device is compatible with bulk coiled cable, increasing the efficiency of the cable bolting process with the use of a Sandvik cable bolter. This paper presents the development of the FCA, and a case study performed at a gold mine in Australia and the Sandvik Test Mine in Finland.

Keywords: Ground support, cable bolting, immediate support, fast re-entry, mine safety, case study

Jamie Wang

Research and Development Engineer
Sandvik Mining & Rock Solutions, Australia

Jamie Wang is a dedicated and innovative Research and Development Engineer at Sandvik Mining & Rock Solutions, Australia. With a Bachelor of Engineering in Mechanical Engineering, Jamie has consistently demonstrated a strong commitment to advancing technology and improving operational efficiencies within the Ground Support division.

Jamie earned a Bachelor of Engineering in Mechanical Engineering from a respected institution, Tianjin University of Technology and Education, where she developed a robust foundation in mechanical systems, design, and engineering principles. This academic background has been instrumental in Jamie's ability to tackle complex challenges and contribute to cutting-edge research and development projects at Sandvik.

At Sandvik Mining & Rock Solutions, Jamie has played a role in several high-impact projects. Her expertise in mechanical engineering and innovative approach have led to the development of new products that enhance the efficiency and safety of mining operations.

Keynote Address: The implementation of hydraulic fracturing for pillar preconditioning in a deep gold mine

D. Roberts
Sibanye-Stillwater, South Africa

South Africa's gold mines leave up to 35% of the orebody in pillars. Mining these highly stressed pillars represents an unacceptable seismic risk. To ameliorate this risk, hydraulic fracturing has been suggested as a means of preconditioning pillars for safe extraction. Sibanye Stillwater undertook a series of trials to determine the feasibility of implementation. Trials showed that it was possible to drill NQ/BQ holes over lengths of up to 110 m with sufficient accuracy to intersect a pillar. Holes drilled in the direction of the major principal stress were of sufficient quality to enable the execution of hydraulic fracture tests. This work describes the successful implementation of mini-frack tests in holes under various stress conditions, including the target scenario: parallel to the major principal stress, up to the pillar horizon. Hydraulic tensile strengths were lower than anticipated, and all measurements indicated pressure requirements lower than the 80 MPa maximum capacity of the equipment. Numerical modelling indicated similar trends and value ranges to those measured. The current state of planning for growing hydraulic fractures over tens of metres is described, and observations of core fracturing and other significant findings are discussed.

Review of the stope support system at Impala Bafokeng North Shaft owing to stope closure at shallow mining depths

T. Walsh
University of the Witwatersrand, South Africa

Impala Bafokeng's North Shaft is a shallow platinum mine on the western limb of the Bushveld Igneous Complex. Shallow mines experience very little horizontal stress which leads to a support issue of the tensile zone. North Shaft relies heavily on mine pole support due to the requirements for a stiff support system. Elongate support failure in the deeper parts of the mine have occurred due to a change in the loading environment. The support failure has resulted in inadequate support resistance in the back areas and some large falls of ground (FOGs). In this research report the hybrid section stope closure rate was measured. The closure does not appear to be linked to a detachment of a hangingwall parting. The ground penetrating radar scans and borehole data correlate with the observations. The FOGs are structure related and occur in the back areas of the panel after the elongate support had failed. The footwall material is weaker than the hangingwall material and the pillar punches into the footwall. The footwall fractures and tensile cracks in the panel footwall indicate that the stresses are forced to move horizontally due to the Footwall 4 parting plane. The footwall thrusts into the panel causing the high closure observed. The combination of a shorter panel length and pencil sticks would provide adequate support for the high closure rates observed.

Keywords: closure, support failure, footwall thrust

Trevor Walsh

Shaft Rock Engineer
Impala Bafokeng Platinum

My career started with a bursary from Anglo American Platinum, I was a graduate at Northam in 2010 where I passed my Strata Control Ticket. I then moved to Rustenburg where I worked as an SCO at Bathopele mechanised mine before joining the team at Thembelani Mine. Whilst at Thembelani in 2012, I passed my Rock Engineering Certificate and was promoted to Shaft Rock Engineer. In 2015 I moved to Royal Bafokeng Platinum, I started my studies at Wits University in 2019 and achieved my Advanced Rock Engineering Certificate in 2022 and my Masters in Rock Engineering in 2024.

A proposed method of pre-mining rib pillars and replacing pillars using a cemented aggregate fill

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[1]Dayenu, South Africa
[2]Alphamin Resources, South Africa

The mine is progressing into deeper regions to access a high-grade tin deposit, unfortunately, due to the mining method, substantial ore remains locked in rib pillars required for stability. An investigation into the removal of the rib pillars was undertaken where replacing rib pillars with cemented backfill is considered. The study assessed 'jig tails' a tailings material, consisting of mica schist and amphibolite materials, as a backfill medium.

Initial testing demonstrated high strengths (12.65 MPa to 27.4 MPa) but revealed that cement content exceeding 20% would be economically unviable. Modified mix ratios (1:3:6, 1:2.25:9 and 1:3:8) with reduced cement content (8%–10%) targeted UCS values between 3 MPa and 10 MPa, aligning with operations of similar approaches. Empirical design methods were used to estimate the backfill strength. A conservative design strength of 32 MPa, was eventually suggested.

Trial mining is planned where it is suggested that cored samples of the backfill from the trial mining site be taken. These samples will undergo further testing, and results will inform discrete element or finite different codes to validate design parameters for deeper mining areas.

Ronny Martin Arlow

Rock Engineering Manager
Dayenu Mining Consultants

My mining career began in 2006 when I joined Anglo American as a Learner Miner. During this time, I obtained my blasting certificate and developed foundational mining skills, progressing from PTV to Stope Drilling Operator. In 2008, I enrolled as a Learner Official and gained exposure to all technical departments. My Rock Engineering career commenced in the same year when I took on the role of Strata Control Observer, eventually advancing to Rock Engineer. I continued as an Operations Rock Engineer until 2013 when I transitioned into consulting.

I was appointed as a Consulting Rock Engineer, where I honed my expertise in project management, geotechnical engineering, geotechnical logging, feasibility studies, numerical modeling, and geotechnical reviews. I was subsequently promoted to Senior Rock Engineer and then to Rock Engineering Manager. My career has spanned 18 years, with 7 years in mining and 11 years in consulting, during which I have gained experience in both local South African mining operations and international massive and surface mining methods.

Performance and mechanical properties of a styrene-free polyester resin produced with water-based catalyst and a new generation catalyst

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Due to increased knowledge about styrene safety, health, and its environmental impact (especially its effects on humans) a new generation of styrene-free resin cartridges has been recently created. It has been shown that the new styrene-free resin cartridges produced with the so-called oil-based catalyst have superb mechanical parameters. Their compressive strength, stiffness and low creep strain are superior in comparison with standard polyester resin capsules.

As the majority of the resin capsules used in hard rock mines worldwide use the so-called water-based catalyst, the next step in the creation of the new generation of the styrene-free resin cartridges has been made by using a water-based catalyst in their production as well as the development of a novel, new-generation type catalyst.

In this paper we discuss characteristics and performance of these new types of a styrene-free resin. Not only the standard testing results (uniaxial compressive strength, Young's modulus, creep and shear strength) are presented but the procedure of a special push-out test to confirm the effectiveness of the anchoring along the bolt is described. The results of pushing ca. 15 cm cut sections of the bolt embedded in a high strength concrete in a steel pipe are presented as well. The first results of impact (dynamic) loading of Versa bolts embedded in the steel pipes with the styrene-free resin conclude the paper.

Grzegorz Smolnik

Dr., Chemicals R&D Manager Global Products, SANDVIK Ground Support Division and Lecturer, Silesian University of Technology, Poland
SANDVIK Ground Support Division and Silesian University of Technology, Poland

Grzegorz has been involved with rock and strata mechanics research and rock mass and ground support modelling for mining applications for more than twenty years. He serves as Chemicals R&D Manager Global products in SANDVIK Ground Support Division. He is also a lecturer of Rock Mechanics and Ground Control at Silesian University of Technology in Gliwice, Poland. Grzegorz has extensive domestic and overseas industrial and research experience.

Blast-on-Mesh: Transforming deep-level gold mining – success stories from Kusasalethu

R. van Heerden[1], M. Phathu[2]
[1]Harmony Gold Mining Company Limited, South Africa
[2]Geobrugg Southern Africa

This case study examines the successful implementation of permanent blast-on-mesh (BOM) at Harmony Gold's Kusasalethu Mine and its positive impact on mine safety. The adoption of netting and bolting as a ground support practice began in 2013 as part of the Mine industry Occupational Safety and Health (MOSH) initiative, which aimed to reduce fall-of-ground incidents and enhance safety standards. In 2020, Kusasalethu pioneered the introduction of permanent blast-on-mesh, marking a significant shift in ground support practices. The initiative was met with favorable feedback from underground crew members, who noted the improvement in safety in their working environment.

The introduction of permanent BOM resulted in a marked reduction in gravity-induced fall-of-ground injuries and a significant decrease in overall fall-of-ground incidents. This study highlights the effectiveness of permanent areal support in providing long-term stability to underground workings, with the transition to permanent areal cover support becoming a leading practice by 2023. However, the success was not without its challenges. Issues related to the installation quality of the mesh, as well as damage during routine cleaning and maintenance, were identified as areas for improvement. Despite these challenges, the implementation of netting and BOM proved effective in reducing the severity of fall-of-ground incidents, thus enhancing the overall safety and operational efficiency of the mine.

This case study underscores the critical role of innovative ground support technologies and safety practices in improving mine safety, and it serves as a model for the continued evolution of ground support systems in the mining industry. By detailing both the successes and challenges encountered at Kusasalethu, the study provides valuable insights into the practical application of permanent BOM and its potential to reduce ground-related hazards in deep-level mining operations

Do underground excavations mined by non-explosive mining techniques require less support than when mined by blasting? A challenge to rock engineers to review support design practice

R.G.B. Pickering, D. Arnold, J. Porter
Rock Eater (Pty) Ltd, South Africa

In a paper by Olsson et al, from the Swedish Rock Engineering Research Unit and entitled 'What Causes Cracks in Rock Blasting', presented at EXPLO 2001 they concluded that:

- Shock waves are mainly responsible for crack lengths in the remaining rock walls.
- Gases are responsible for moving the rock.

It is a given that explosives, by definition, create shock waves, non-explosive mining does not create shock waves. In this paper the authors will:

- Consider the current support design methodology for hard rock underground excavations.
- Investigate the work done to quantify the extent of rock fracturing caused by blasting.
- Provide visual evidence of how excavations mined non-explosively have weathered the ravages of time.
- Identify possible benefits of non-explosive rock breaking to mining (and other) operations.
- Raise the question of how to design support in non-explosively mined excavations

Rodney GB Pickering

Director
Rock Eater Pty (Ltd)

Since 1977 I have worked in the field of developing and implementing new technology into the mining industry. From 1977 to 1997 I was at Chamber of Mines Research Organization as the Director of Stoping Technology. From 1998 to 2017 I was a consultant to Sandvik and very involved in LP and XLP mining together with the development of a hard rock cutting machine. Most recently my time has been spent on the commercialization of Controlled Foam Injection to facilitate the development of practical non-explosive hard rock mining.

I was very involved in the development of the Centre for Mechanized Mining at Wits and as a lecturer. I am a past president of SAIMM.

The role of stress and geology on the design of block cave mining sequences and layouts - a case study

T. Mtshali[1], N.M Chiloane[2], N.M.B. Makgate[1], T. Chauke[2], F.K. Mulenga[2], V.C. Madanda[2], T. Moyane[1], R.B. Khumalo[1]
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[2]University of South Africa, South Africa

While high production rates are important for the profitability of a mine, the influence of geotechnical engineering cannot be ignored. In block caving, a high-stress level is required for cave propagation; this is one of the core elements for ore recovery. Therefore, stress distribution and geological structures play a major role in the planning and layout design of the mine. This paper explores the influence of stress and geological features on the design of the mine from the feasibility study phase. The geology and stress measurement of the mine were determined through logging and overcoring, respectively. This study found that while production rate is the primary operational consideration, the long-term layout design of the undercut face advance, face angle, drawpoint spacing, and undercutting sequence is mainly governed by the stress orientation and major geological structures. Moreover, widely spaced drawpoints result in isolated draw zones, consequently, resulting in ore loss and early dilution; whereas closely spaced drawpoints affect the stability of the major apex pillar. This paper also provides insight into how operations can leverage stress distribution to optimise mine layout and safety in massive mining methods.

Keywords: block caving, advanced undercut, drawpoint spacing, leads and lags, isolated draw zones

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Thokozani Sidwell Mtshali
Chief Rock Engineer
Palabora Copper

Mr Mtshali Thokozani Sidwell is a highly passionate mining professional with experience in variety of mining methods from underground deep level gold mining, trackless operations, underground conventional gold mining, open pit and block caving (undercutting and draw bell development) at a copper mine. He is currently employed at Palabora Mining Company (PMC) as a Chief Rock Engineer tasked with the responsibility of the rock engineering duties for the whole mine starting from surface to underground mine.

Application of Flac3D to analyse the effects of mining- induced stresses on the behaviour of drawpoint pillars: A case study of a long-hole open stoping mine in Zimbabwe

A. Velempini
Gwanda State University, Zimbabwe

The shift from shallow depth to medium depth operations at mine A resulted in geotechnical challenges. The stability of underground excavations is now more stress control. On 30L, which is 1092 m below surface, the stability of drawpoint pillars is a cause for concern due to pillar size with respect to the depth of operation. The drawpoint pillar width is 7 m, which may be too small to withstand the overburden and mining-induced stresses. Sidewall scaling of drawpoint pillars is observed after every blast in the cone level. This challenge indicates the progressive degradation of the pillar strength, imposing a threat to the safety, stability and overall effectiveness of mining operations. In this paper, the author utilises the Itasca software to analyse the stability of the drawpoint pillars and to compute the average pillar stress for the expected maximum loading. Empirical approaches will be used in conjunction with numerical modelling in order to get the best results. The main purpose of this paper is to confirm the viability of the current pillar size at lower mining depths. The design factor of safety was used to judge the stability of several drawpoint pillar sizes, and to decide upon an optimum size for different mining depths.

Keywords: numerical modelling, drawpoint pillar, factor of safety, spalling, induced stresses, pillar stability

Ama Velempini
Student
Gwanda State University, Zimbabwe

Ama is an aspiring rock engineer holding a National Diploma in Mining from the Zimbabwe School of Mines, and a pass in Strata Control theory. He is currently pursuing a BSc (Hons) degree in mining engineering at the Gwanda State University. He is a very ambitious young man who is eager to begin his career in rock engineering and get the rock rolling. Through persistent practise and autonomous learning, he has become an advanced beginner in numerical modelling and is on the right path to becoming an advanced Flac3D user. He is looking forward to gaining valuable experience in the rock engineering field.

Rectifying, conforming and extracting value from existing geotechnical data sets – the importance of good data management for optimal value extraction

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[1]Independent Consultant - Data Governance, South Africa
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Extracting value from existing geotechnical data sets involves collecting, collating, synthesising, standardising, verifying and presenting the primary data which originates from field and laboratory investigations. These programs produce core logging, outcrop and face mapping descriptions, sampling and resultant tests. Mining method selections, regional and local geological, structural, rock mass and hydrogeological challenges dictate geotechnical programme objectives. The value extraction from the database must inform known and unknown risks. This paper focuses on interactions between source data and state-of-art good data capture and management practice. Traditionally, logged data accumulates on paper and photographs. Data issues include vast quantities of recaptured, missing and duplicated data, and inconsistent logging standards. Solutions must produce usable data and information. Computerised logging was applied to geotechnical investigations by Iscor Mining during the 90s, before developing and proving a methodology across large iron ore (de Beer, 2000) and platinum operations (Little, 20062). Portable database software technology supplied multi-user editing capabilities and data security. Initial implementations ran successfully at Sishen and Thabazimbi Iron Ore mines by 1998 (SABLE®, 1997). Real time validations promoted correction of captured data within its relational context in the field before posting to the final database. The 'hard coded' system rules were subsequently improved to become a configurable software module interfacing directly to the database. Customisable Data Standards allowed geotechnical and rock engineers to define classification systems for individual projects, leading to a standardised methodology for geotechnical data capture and management. This methodology provides a proven approach for optimal value extraction from geotechnical data in general, via sound data capture and data management practices.

Marcia Hilary van Aswegen

Independent Contractor - Data Governance

Marcia joined Anglovaal Limited in 1979 to develop and implement software applications across micro, mini and mainframe computers to capture and process data for mineral target generation and estimated resources and reserves. She then contracted as a software analyst / programmer in the fields of geostatistics, geochemistry, geological exploration, ore grade estimation and ore resource reconciliation in the South African mining industry. This spawned seven generations of software products and the trademarked methodology SABLE®; which has enforced data standards for over 40 years. Marcia is a life fellow and past president of the GSSA and retired member of SAIMM.

Influence of saturation fluids on the elasto-plastic deformation behaviour of shale

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China University of Petroleum, China

As a critical component of unconventional reservoirs, shale's mechanical characterisation is essential for hydrocarbon extraction efficiency. Existing research predominantly examines dry or water-saturated conditions, failing to replicate in situ reservoir environments adequately. This paper evaluates three characteristic saturation states (dry, oil-saturated, water-saturated) through multiscale compression testing (uniaxial, triaxial) under variable confining pressures. Experimental results reveal that pore fluids reduce the in situ Young's modulus significantly (about 20% for water, 5% for oil), compressive strength relative to dry specimens, and amplifying plastic deformation capacity. Oil saturation predominantly affects post-yield characteristics through hardening rate reductions, whereas water saturation induces a stronger influence on both elastic and plastic behaviours due to water-rock interactions. During plastic deformation, fluid saturation reduces plastic hardening rate by 46 - 100%, with water demonstrating superior influence. This paper provides practical insights into the role of fluid saturation in controlling shale's mechanical properties and offers guidance for optimising hydraulic fracturing and enhancing wellbore stability in shale gas and oil reservoirs.

Keywords: shale, oil/water saturation, elasto-plasticity, failure

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Linghao Chen is a Ph.D. student at the School of Safety and Marine Engineering, China University of Petroleum, majoring in rock mechanics. He earned his master's degree from the University of Texas at Dallas. He has worked as a geological engineer at the Oil and Gas Exploration Institute of the Sichuan Provincial Geological Exploration Bureau, participating in geological drilling and unconventional oil and gas extraction projects.His current research focuses on rock mechanics related to hydraulic fracturing in unconventional oil and gas, such as shale gas and shale oil. He is particularly interested in the effects of different saturation fluids, pore pressures, and multi-field coupling and multi-scale aspects of rock mechanics. His research integrates nuclear magnetic resonance, digital image technology (LD-DIC), and mechanical experiments to analyze the changes in the elastic-plastic mechanical properties of unconventional reservoir rocks like shale under various geological conditions and the main control mechanisms.

Unravelling the past for a safer future: How historic rock mass classification data compare with slope performance monitoring data

M. Pretorius
Vedanta – Gamsberg, South Africa

In this paper the author investigates the correlation between empirically derived deformation threshold values and actual slope monitoring deformation data in open-pit mining, focusing on the Gamsberg mine in South Africa. Two slope failure events within a schist layer were analysed.

Rock mass classification data from borehole logs were analysed and empirical calculations were done to derive predicted deformation values. This data was then compared with real-time deformation measurements from slope stability radar; in particular, where the two failures occurred.

The study revealed a significant alignment between empirical predictions and actual measurements, with both events falling within one standard deviation of the empirical dataset's mean. This validates the utilisation of empirical methods for initial deformation threshold estimations in slope stability monitoring.

This study provides valuable insights into the practical application of empirical deformation thresholds in open-pit mining, offering a foundation for more accurate and reliable slope stability assessments. The findings have implications for enhancing safety protocols, optimising resource extraction, and improving overall operational efficiency in the mining industry.

Keywords: Open-pit mining, Slope deformation, Rock mass classification, Slope stability.

Mornè Pretorius
Chief Rock Engineer
Vedanta Zinc International

Mornè is a registered professional scientist (SACNASP, Earth Science) and holds a Chamber of Mines Certificate in Rock Mechanics (Open Pit) amongst other qualifications. He spent 15 years in the consulting space as a Strata Control Officer and later Rock Engineer, gaining valuable experience in various different commodities and mining methods. He is currently the Chief Rock Engineer for the Gamsberg Open Pit.

Stabilisation of highwall instability using numerical modelling and statistical analysis for open pit mining

N.I. Umeh, S. Darries, N.E. Baloyi, T. Rangasamy
Middindi Consulting (Pty) Ltd, South Africa

This study focuses on the geotechnical evaluation of a highwall that experienced a significant slope failure. The primary objective was to thoroughly assess the extent of the failure, identify and evaluate potential trigger mechanisms, and evaluate the risk it posed to a public road situated approximately 100 m from the highwall. Aerial photography and fracture propagation analysis, conducted using QGIS, tracked fracture development over several months. Numerical modelling using Rocscience RS3 and RS2 software enabled a comprehensive stability analysis of the highwall. The results showed that the failed sections had factors of safety below unity (0.82 and 0.81), signalling instability, whereas stable sections maintained sufficient safety margins. The combination of fracture intensity and propagation data coupled with numerical back analyses was able to predict both time to failure and progressive instability. Predictive numerical simulations were subsequently used to derive buttress designs to stabilise the highwall. The study further assessed the potential impact on the public road, which indicated no significant displacement effects.

Keywords: Highwall stability, Fracture propagation, Numerical modelling, Stability analysis, Buttress design

Nicolas Ikenna Umeh
Geohydrologist (Mining Geotechnical).
Middindi Consulting (Pty) Ltd.

I am a Geohydrologist with a focus on Mining Geotechnical applications, blending a solid academic foundation in Geology, Chemistry, and Hydrology from North-West University with practical experience in rock engineering. Over two years at Middindi Consulting, I have refined my expertise in geotechnical analysis, data interpretation, and technical reporting. Skilled in tools like Rocscience, Map3D, QGIS, and GEM4D, I thrive on solving complex challenges in the mining sector. Driven by a passion for innovation, I aim to deliver impactful solutions that advance industry standards and project outcomes.

Integrating monitoring technologies to understand slope deformation in open-pit mines: A case study from Swakop uranium mine

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[1]CGNPC Swakop Uranium, Namibia
[2]SRK Consulting, South Africa
[3]The University of the Witwatersrand, South Africa

This study investigates the slope deformation characteristics and failure mechanisms on the Western slope of the Zone 1 open pit at the Swakop Uranium Husab mine, Namibia. Slope failures at the Husab Mine are primarily influenced by persistent foliation, sub-vertical joint sets, and intrusive contacts, which collectively define structurally constrained failure zones. Monitoring data obtained from automated prisms and ground-based radar revealed progressive deformation patterns, including rebound effects and stick-slip movement indicative of pre-failure conditions. The observed deformation followed the classic three-stage process consistent with established slope failure models in slope stability research. Two dominant failure modes were identified: rapid wedge failures and slower-moving planar failures, both triggered by excavation-related unloading and blasting-induced vibrations. The blast vibrations contributed significantly to crack propagation and deformation along existing discontinuities. Continuous monitoring enabled early warning and targeted interventions – installation of 10 m catch benches and batter-angle reduction – that effectively mitigated progressive deformation. These findings highlight the critical importance of integrating detailed geological and structural analyses into mine planning and slope design. Overall, the results contribute to the development of predictive models and site-specific stabilisation strategies essential for improving the safety and efficiency of large-scale mining operations. This research contributes to the refinement of slope stability models in highly anisotropic geological settings, with direct implications for mine design and operational safety.

Grantham Ockhuizen

Superintendent: Geotechnical
CGNPC Swakop Uranium

Grantham Ockhuizen is a highly experienced Engineering Geologist with 17 years in the mining industry. He is professionally registered with SACNASP and serves as the Superintendent - Geotechnical at Husab Mine, Namibia, where he leads the geotechnical team and overseeing operational risks, slope design and the execution of monitoring programmes in line with medium and long term mine plans. This includes continual improvement of Department systems to optimise both efficiency and effectiveness in order to maximise production. Support operations and projects with the implementation of best-practise geotechnical standards in mapping, logging, analysis, groundwater conditions and slope stability interpretation

His leadership extends beyond his operational role, having served as the Namibian branch Chairman for the Southern African Institute for Mining & Metallurgy (SAIMM) from 2013 to 2017 and remains an active affiliate member. His extensive expertise and leadership highlight his ongoing commitment to the industry.

Rock fall hazard analysis of a natural slope at the Sungun Copper Mine

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The Sungun Copper Mine is in the mountainous terrain of East Azerbaijan Province in the Islamic Republic of Iran. Following a rockfall incident from a natural cliff, the exposure of the exposed section of a conveyor belt was identified as a potential risk to continued safe operations. A comprehensive rockfall hazard analysis was required to quantify the potential risks to the exposed conveyor belt area. The study aimed to quantify the risk to the belt infrastructure and propose protective measures to prevent damage. Using high-resolution photogrammetry, LiDAR scanning and back analysis, the study determined key input parameters for rockfall simulations.

The photogrammetry approach involved particle size distribution analyses of the natural cliff which enabled the estimation of the size of falling rock blocks. The size, shape, and mass of the falling bodies are essential for creating realistic 3D models used in rockfall trajectory simulations. The LiDAR scan of an actual boulder that had fallen onto the conveyor belt provided critical data on block size and shape. A wireframe model, representing the boulder, was constructed to simulate its movement and impact along the slope. In addition, the topography of the slope was carefully considered, to be used for trajectory simulations, using the Trajec3D software.

Back analysis of an observed rockfall proved valuable in refining simulation input parameters such as the coefficient of restitution, static and dynamic friction angles, and block size. The analysis revealed that the existing fence, on a portion of the slope, provides 93% effectiveness in mitigating rockfall risk. The study concludes with recommendations for the most effective protective measures and providing a robust risk assessment for the exposed conveyor belt infrastructure.

Keywords: Rockfall, conveyor belt, photogrammetry, LiDAR scanning, risk assessment.

Jacobus Delarey (Koos) Bosman

Managing Director
Open House Management Solutions Pty Ltd

Koos started his mining career as a learner official in January 1987, at the Hartebeestfontein Gold Mine. In 1990, he joined the Rock Engineering Department at Harties, where he obtained relevant industry certificates. He was appointed as the head of Rock Engineering at Harties in 1996. In February 2000, co-founded Open House Management solution, and has spent the last 25 years building the company. Koos currently consults on a wide variety of rock engineering topics to clients in the global mining industry.

Mitigating pit floor instability above a confined aquifer: Assessing mining block dimensions and sequencing strategies

L. Bruyns, M. Rangasamy, T. Rangasamy
Middindi Consulting (Pty) Ltd, South Africa

This study investigated the potential for clay aquitard failure within the floor of an open-pit mine overlying a confined aquifer system. Excavation activities above the clay layer can disrupt the equilibrium between the weight of the overlying material and the upward pressure exerted by the confined aquifer. This can lead to ground movement and, in extreme cases, failure of the pit floor. This paper sought to mitigate the impact of mining activities on the pit floor through establishing an acceptable area of clay aquitard exposure by defining optimal mining block dimensions (width and length) and excavation sequences. Two (2D)- and three- dimensional (3D) numerical models were simulated and analysed to extract vertical displacement data for various geological and mining conditions. Optimal mining block widths (E-W) were determined through 2D modelling. Furthermore, 3D modelling, which included backfilling of excavated areas, provided critical insights into the optimal length (N-S) and sequencing of mining blocks. Strip-mining and checkerboard mining sequences were evaluated through a comparative analysis to identify the sequence that minimises the amount of permanent disturbance to the clay aquitard and mitigates the overall risk of subterranean blowouts. Results indicated that limiting mining blocks to 70 m (E-W) in width and 170 m (N-S) in length, in conjunction with a checkerboard mining sequence, effectively abates pit floor disturbance. This research establishes a robust methodology for ensuring minimal pit floor disturbance in open-pit mines with underlying confined aquifers.

Keywords: clay aquitard, area, numerical models, vertical displacement, mining sequence, pit floor disturbance

Leandi Bruyns

Engineering Geologist
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Leandi Bruyns is an Engineering Geologist at Middindi Consulting Pty Ltd, specializing in geotechnical investigations and engineering geology assessments. She completed her undergraduate and postgraduate studies in Engineering Geology at the University of Pretoria, gaining a strong foundation in geological and geotechnical principles.

During her studies, Leandi worked as a demonstrator (Demi) for 1st- and 3rd-year students at the University of Pretoria from 2021 to 2022. This role allowed her to develop mentoring and instructional skills while assisting students in understanding fundamental geological concepts, field techniques, and laboratory analyses.

In 2023, she joined Middindi Consulting as a Junior Engineering Geologist and has since progressed to the role of Engineering Geologist. She is actively involved in a range of geotechnical and engineering geology projects, including site investigations, rock mass characterization, stability assessments, and technical reporting for mining and infrastructure developments. She collaborates with multidisciplinary teams to provide geotechnical recommendations that contribute to safe and efficient design solutions. Leandi has developed proficiency in various RocScience software programs, including Dips, Slide, RS2, RS3, SWedge, and RocPlane, allowing her to conduct advanced stability modeling and rock mechanics analyses. Her expertise extends to data analysis, report writing, and the interpretation of geotechnical data to support engineering decision-making.

Her experience at Middindi Consulting has provided exposure to real-world geotechnical challenges, including slope stability, and underground support design. She continues to expand her knowledge and technical skills in engineering geology, striving to deliver high-quality geotechnical solutions for diverse projects.

Leandi is passionate about applying her geological expertise to practical engineering challenges and contributing to the advancement of geotechnical engineering in mining projects.

Mayuri Rangasamy

Geotechnician
Middindi Consulting (Pty) Ltd

As a Geotechnician specialising in Mining Geotechnics at Middindi Consulting (Pty) Ltd., I have cultivated significant expertise over the past two years. My tenure has been marked by rapid professional development and a commitment to continuous improvement. I am highly adaptable and thrive in challenging environments. My academic background, encompassing a General BSc in Biology and Honours in Human Biology from the University of Witwatersrand, has provided me with a robust analytical foundation. While my initial academic pursuits differed from my current field, I am deeply passionate about Mining Geotechnics and am grateful for the opportunity to contribute to this industry. My immediate goals include enhancing my rock mechanics knowledge through specialised courses at the University of Witwatersrand, obtaining my SCO certification, and pursuing a Master's degree in the discipline. Ultimately, I am dedicated to achieving the Qualified Person (QP) designation in Rock Engineering. I am driven by a belief in the importance of perseverance, as encapsulated by Winston Churchill's sentiment: 'Success is not final, failure is not fatal, it is the courage to continue that matters.'

Stability design of slopes in carbonatite complexes characterised by brecciation

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Carbonatites are generally competent rock masses with rock mass rating class II rating 60-74. In spite of their competency, they tend to be affected by weak features like Mn-Fe veins and/or in situ rock damage due to brecciation associated with carbonatite complexes. Rock slope failure in such hard rocks is complex since such structures within the rock mass form weak links that could potentially control slope instability. In this paper, a numerical simulation using phase2 v 7.0 was carried out to investigate the influence of in situ rock damage on the stability of mine pit walls. The outcome reveals that the existence of breccia in the competent rock mass has the capability to reduce the slope stability performance, particularly at gentle dipping angles of emplacement in close range to the slope toe. However, as the emplacement position of breccia moves away from the pit wall, the stability performance increases at gentle dipping angle < 50°. On the contrary, at the dipping angle of 50° the performance of slope reduced, and at steeper angles >50° the impact becomes negligible. Thus, from a series of analyses of mine design in brecciated rock masses, the ratio of 1:5 between the breccia distance from slope toe and pit depth should be implemented to counter its impact, and if the breccia is within or close to the pit limit, a deliberate effort must be made to mine it out.

Keywords: Songwe Hill, carbonatite, finite element method, in situ rock damage, breccia

This paper will be published in the SAIMM Journal

Slope stability evaluation of gneiss rock slopes using SMR and Qslope

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One of the biggest problems in open pit mining is slope stability. The avoidance of slope stability problems depends on a comprehensive assessment of environmental and operational factors such as geology, climate and mining activities. In the light of these considerations, slope geometries should be determined in accordance with engineering principles. In this paper, the slope stability of rock slopes in a mine opened in a gneiss geological unit was studied. Production activities were stopped in 2019 due to the slope movements in the eastern part of the quarry. In order to continue the production safely, mainly fieldwork has been carried out. To assess slope stability, detailed discontinuity surveys were carried out on bench faces. Subsequently, kinematic and numerical analyses were employed to identify geometries that are expected to maintain stability under the prevailing geological structures and environmental constraints. Engineering geological studies such as scanline measurements in steps and investigation of potential failure mechanisms by kinematic analysis technique were carried out. Slope mass rating and Qslope rock mass classification systems were used to evaluate slope stability. Based on these classification systems potential unstable rock slopes were determined and thematic maps were created using a geographic information system. The most suitable slope geometries are suggested for these slopes. In addition, the improvement methods suggested by the rock mass classification systems were proposed for these slopes.

Keywords: Gneiss, QSlope, Slope Mass Rating (SMR), Rock Mass Classification Systems, Slope Stability, Open Pit Mine

This paper will be published in the SAIMM Journal

Enes Kalhan

Dokuz Eylul University

Enes Kalhan, born in Izmir, Turkey, in 1996, graduated from the Bachelor's degree program in Geological Engineering at Dokuz Eylül University in 2019, and then completed his Master's Degree in Applied Geology at the same university in 2021. His master's thesis focused on the "Monitoring and Numerical Analysis of Open Pit Mine slopes". He is currently pursuing his PhD program in Applied Geology at Dokuz Eylül University and is in the thesis phase.

In 2023, he conducted doctoral-level academic research at the University of Silesia in Katowice, Poland, under the Erasmus+ program. Kalhan, who has attracted attention with his academic achievements, is progressing in his doctoral education with a GPA of 3.94/4.00.

Kalhan began his professional career in 2021 at Koza Gold Companies, working on underground gold mining, where he gained experience in tunnel mining, production planning, data processing, and 3D modeling. In the same year, he started working at HD Energy, where he was involved in both field and office-based work in the field of Engineering Geology. He has specialized in remote sensing techniques for mineral exploration, structural geology analysis, ArcGIS-based data processing, and 3D modeling with SURPAC and Datamine.

He has published articles at the national and international levels as part of his scientific work. He has conducted research on topics such as slope stability in open pits, the application of classification systems such as SMR and Q-slope, data collection using UAVs, and comparisons with traditional methods.

Kalhan possesses advanced technical knowledge and effectively uses various geology and modeling software such as ArcGIS, Surpac, Datamine, Rocscience, and AutoCAD. He also has extensive experience in engineering geology applications such as photogrammetry, remote sensing (ENVI, ERDAS), laboratory testing, geotechnical logging, structural analysis, and numerical modeling. He is proficient in English (B2) and has a basic knowledge of Polish (A2).

Enes Kalhan continues to create value in the fields of mining geology, engineering geology, and geotechnical engineering with his scientific expertise, field experience, and multidisciplinary approach. His goal is to combine his academic and sectoral knowledge to establish his own consulting office and provide qualified engineering solutions.

Risk-based slope design: Insights from the Thabazimbi failure

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Certain degrees of safety, economic and financial risk are implicit in any mining operation. At Thabazimbi mine slope stability was one of the major sources of risk, largely due to data uncertainties. Consequently, a risk-based approach in slope design was followed. On the 6 June 2015, a slope failure occurred in Thabazimbi mine's Kumba pit, involving approximately 65 million tonnes of rock falling into the pit and the valley below. Although the failed mass moved rapidly and resulted in a run-out distance of approximately 900 m, controls had been put in place to successfully evacuate all personnel. Risk assessment during the onset of failure supported the decision to not compromise the safety of personnel in any way, leading to unavoidable equipment loss. This contribution presents the failure as a case study in the context of a risk-based approach to slope design as well as the importance of implementing geotechnical controls to effectively manage slope instability risk. Furthermore, a comprehensive back-analysis was performed, on a fully-constrained 3D model, utilising 3DEC, to gain insights into the failure mechanism. In conclusion, lessons from the Thabazimbi slope failure are valuable as they demonstrate the importance of following a risk-based approach in slope design to effectively manage safety and financial risk in open pit mines.

Keywords: slope failure, geotechnical risk management, geotechnical controls

This paper will be published in the SAIMM Journal

Calibratable rock mass shear strength for open pit slopes

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Open pit slope stability analyses for large scale instabilities are often carried out using Limit Equilibrium, Finite Element or Finite Difference computer programs. All of these require empirical estimates of rock mass shear strength when calibrated values are not available, which is a common occurrence. A common method of estimating rock mass shear strength is the Hoek-Brown failure criteria; however this method often over- or underestimates rock mass shear strength when used in Limit Equilibrium or Elastic Linearly Plastic slope stability analyses, resulting in published alternative estimates for the coefficients of the Hoek-Brown failure criteria. This paper investigates the differences between Limit Equilibrium and Elastic Linearly Plastic slope stability analysis based on the Hoek-Brown failure criteria. The investigation consisted of a comparison of 3840 RS2 Finite Element analysis models completed with strain softening, and 216 Slide2 Limit Equilibrium models. The models were used to evaluate a methodology to determine equivalent Limit Equilibrium and Elastic Linearly Plastic shear strength parameters that provide the same stable slope angles and instability back break distances as the more representative Strain Softening stress analysis methods. This paper presents the methodology, and compiles the results into design charts and equations for equivalent Limit Equilibrium Mohr-Coulomb shear strength parameters, simplifying calibration against actual case studies. The results compare well with older empirical shear strength estimates; however a detailed calibration of the results against case studies will need to be carried out.

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Development of a filtered inverse velocity method analyser: A comparative study of smoothing filters in surface mines for optimisation of slope failure predictions

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The inverse velocity method (IVM) has proven to be an effective approach for predicting slope failures in surface mines by analysing displacement monitoring data. However, the accuracy of IVM predictions is significantly affected by instrumental noise and natural environmental variations, which influence the identification of different deformation stages. To enhance predictive accuracy, this paper applies and evaluates three filtering techniques to velocity time series data: exponential smoothing filter, short-term smoothing filter, long-term smoothing filter, and also compares it to raw data (no filtering). A refined prediction framework (filtered inverse velocity method analyser) is proposed to improve slope failure forecasting in surface mining operations. The results demonstrate that filter selection plays a crucial role in optimising failure time predictions, offering valuable insights for geotechnical monitoring and early warning systems in surface mines.

Keywords: Slope Monitoring; Slope Stability Radar; Surface Mines; Early Warning Systems; Inverse Velocity Method.

This paper will be published in the SAIMM Journal

Mohd Maneeb Masood

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Dr. Mohd Maneeb Masood is a researcher, educator, and technologist specializing in smart mine safety systems, predictive analytics, and sustainable mining practices. Currently serving as a faculty member in the Department of Mining Engineering at the National Institute of Technology (NIT) Raipur, Dr. Masood has made significant contributions to the advancement of geotechnical monitoring, early warning systems, and data-driven approaches in mining engineering.

Driven by a commitment to operational safety and environmental sustainability, Dr. Masood's PhD work centers on the development and deployment of advanced monitoring solutions for slope stability and failure prediction in surface mines. His research focuses on the integration of real-time sensor data, computational modeling, and filtering techniques to enhance slope deformation assessment and provide robust, actionable early warning indicators. As the author of "Development of a Filtered Inverse Velocity Method Analyzer: A Comparative Study of Smoothing Filters in Surface Mines for Optimization of Slope Failure Predictions," Dr. Masood introduced the FIVM-Analyzer, a novel methodological framework that optimizes prediction accuracy by mitigating sensor noise and environmental uncertainty through the use of advanced smoothing filters such as Exponential Smoothing Filter (ESF), Short-Term Smoothing Filter (SSF), and Long-Term Smoothing Filter (LSF).

Learnings from development of an underground sub-level open stope mine below an open pit

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This paper presents the lessons learnt during the transition from an open pit method to a sub-level open stoping method within the same Koidu Limited kimberlite pipe. These learnings may assist other mines with planning, both from a practical implementation perspective (layout, charging up challenges), a method for estimating potential dilution and stability challenges associated with the interaction between the surface and underground excavations. Predictive geotechnical stability modelling was successfully applied to highlight potential failure zones, which allowed modification and enhancement of the mining layouts and quantification of the potential dilution of the kimberlite from indicative instabilities.

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Guide to using gravity in the detection of underground voids

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The gravity method is often applied in mining-related scenarios such as geological and mineral exploration, detecting subsurface cavities and voids ('receptacles') that may become sinkholes, siting of surface structures, fault-mapping, and more. It is also widely applied in geotechnical engineering to map subsurface karst profiles and to detect subsurface cavities, such as can occur in open pit mines. While it is widely acknowledged that, compared with other available geophysical methods, this method is the most applicable to the karst profiling problem, survey geometries applied in the field are often far from optimal. The gravity surveying specifications given in SANS 1936 (2012) Part 2 omit some key requirements for optimal survey outcomes, and this paper is intended to fill those gaps. The authors have seen scopes of work that require only a few measurements over the footprint of a proposed structure, indicating a lack of understanding of the nature of the gravitational field. A single gravity measurement is subject to the camouflaging effects of several influences, many of which can be larger than the anomaly caused by the subsurface density variation itself. Papers in the body of literature show an awareness of the need to map the regional field so it can be subtracted to unmask the residual gravity anomaly, but rarely do they examine how instrument sensitivity governs the size of detectable anomalies, or discuss how a detailed terrain correction can be instrumental for isolating faint targets.

This paper will be published in the SAIMM Journal

Lindsay Linzer

Corporate Consultant (Geophysics) | Partner
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Lindsay has 27 years of combined experience in mining seismology, reflection seismics and engineering geophysics. Lindsay's experience ranges from: acoustic emissions recorded in the laboratory; seismic surveys for geotechnical purposes; seismicity induced by shallow and deep level mining; and, seismic reflection data. She has applied state-of-the-art seismic interpretation technology to extract information vital to shaft-sinking, optimal borehole siting, and mine-planning. Lindsay has specialist skills in determining seismic source mechanisms (laboratory tests in rock and concrete and mining seismology) through moment tensor inversion using her own code and expertise in dynamic numerical modelling (2D and 3D) of seismic waves for AE/NDT laboratory tests; mine-seismology problems; geotechnical problems; shaft-sinking, and reflection seismology. Lindsay is an expert user and programmer in mXrap, a geotechnical data analysis and monitoring platform within which data analysis tools have been developed under the ACG's Mine Seismicity and Rockburst Risk Management project. Current interests are applying machine learning techniques to geophysical wireline and hyperspectral data.

3D elastodynamic modelling applied in the design of technical blasts in open pit mines

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[3]Independent
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Complex blast patterns are both time-consuming and costly to implement in terms of their planning, drilling, charging, stemming, and execution. Moreover, testing different combinations of charge length, blast timing, and sequencing is infeasible for full production blasts, but calibrated models can assist with investigating such variations for the purpose of optimising blasting parameters. 3D elastodynamic blast modelling for large blasting patterns in open pits is a recent innovation that has arisen due to the increasing need for properly designed technical blasts in which the peak particle velocities are carefully controlled so as not to damage critical infrastructure. Since the original modelling code was designed to simulate rockbursts and wave propagation in deep South African gold mines, several adaptations were necessary to apply the code to surface blasting problems. These adaptations are the focus of this paper.

Lindsay Linzer

Corporate Consultant (Geophysics) | Partner
SRK Consulting

Lindsay has 27 years of combined experience in mining seismology, reflection seismics and engineering geophysics. Lindsay's experience ranges from: acoustic emissions recorded in the laboratory; seismic surveys for geotechnical purposes; seismicity induced by shallow and deep level mining; and, seismic reflection data. She has applied state-of-the-art seismic interpretation technology to extract information vital to shaft-sinking, optimal borehole siting, and mine-planning. Lindsay has specialist skills in determining seismic source mechanisms (laboratory tests in rock and concrete and mining seismology) through moment tensor inversion using her own code and expertise in dynamic numerical modelling (2D and 3D) of seismic waves for AE/NDT laboratory tests; mine-seismology problems; geotechnical problems; shaft-sinking, and reflection seismology. Lindsay is an expert user and programmer in mXrap, a geotechnical data analysis and monitoring platform within which data analysis tools have been developed under the ACG's Mine Seismicity and Rockburst Risk Management project. Current interests are applying machine learning techniques to geophysical wireline and hyperspectral data.

Key block theory for the miner: A novel simplified method for determining block removability

C. van Rooyen
University of the Witwatersrand, South Africa

Gravity-driven rock falls cause the most injuries and deaths in the South African underground mines when compared to other agencies. Blocks are primarily defined by the intersection of discontinuities such as joints. Key block theory describes a methodology to determine whether such a rock can move into an excavated space. The complex calculations and multiple iterations required to execute key block analysis, however, restrict its routine use. Although several methods address some of the shortcomings of key block theory, none address the complexity of its underlying calculations. The main drive of this paper was to find a method to judge rock block removability that is simple enough to encourage the routine application of key block theory in daily mining. The novel gravitational removability theorem satisfied the need for simplicity. A comparison between the gravitational removability method and the edge vector method on a large set of synthetic blocks yielded a fair correlation in terms of removability, but less so in terms of non-removability. The definition and application of a set of calibrating geometric conditions in conjunction with the gravitational removability method resulted in a perfect accounting of all the synthetic blocks. The gravitational removability method proved effective in identifying rotational removability as well. The gravitational removability theorem allows for the judgement of the removability of a block with minimal or no calculation.

Christiaan van Rooyen

Rock Engineering Manager
Glencore

I started my mining career at Lonmin Platinum in 2001 and became a miner by 2003. I joined the Rock Engineering team in 2008 and achieved the Strata Control certificate in the same year. I obtained the Rock Mechanics certificate in 2012 and was appointed as a Rock Engineer shortly after. The advanced Rock Engineering certificate came along in 2018. I joined Marula Platinum as Rock Engineering Manager in 2022. I graduated from the University of the Witwatersrand in 2024 with an MSc in mining engineering, specializing in Rock Engineering. I joined Glencore early in 2025 as Rock Engineering Manager.

Application of large-scale finite element method simulations to determine geomechanical hazard during room-and-pillar mining under a tectonic fault

K. Fulawka[1], L. Stolecki[1], R. Kolodziej[2]
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The issue of geomechanical hazards manifested by roof falls, rock bursts and induced seismicity has been one of the main aspects accompanying the exploitation of copper deposits in the Legnica Glogow Copper Basin region, Poland, in recent years. With the constantly increasing depth of deposits, the scale of hazards increases, negatively affecting the safety and continuity of mining operations. The problem becomes even more pressing in the case of the necessity to conduct exploitation under tectonic faults. Disturbance of the equilibrium state in such areas can often result in the release of high-energy tremors and serious rock bursts. It is therefore important to design exploitation in the safest and most effective way possible, based on the data collected in continuous manner in an underground site. One of the tools enabling the data-driven prediction of the impact of mining operations on the stability of excavations and their tendency to failure as a result of conducted operations are large-scale 3D numerical simulations with the finite element method. This paper presents the results of 3D non-linear finite element method-based numerical simulations of exploitation conducted under a tectonic fault in one of the Polish underground copper mines. The computational assumptions and the method of model validation are described and discussed. Finally, the applicability of the proposed approach in regular exploitation of the room-pillar system at great depths has been defined.

Krzysztof Fuławka

Assistant Professor in Rock Engineering Department
KGHM CUPRUM Ltd. Research & Development Centre

PhD Krzysztof Fuławka works as Assistant Professor in Rock Engineering Department of KGHM Cuprum Ltd Research and Development Centre. He received his doctoral degree in Mining Engineering at Wroclaw University of Science and Technology, Poland. He also obtained a postgraduate diploma in Applied Geophysics at AGH University of Science and Technology, Cracow, Poland. In last few years, Krzysztof has participated in numerous international research and scientific projects financed by Interreg BSR, Polish National Centre for Research and Development, Horizon 2020, Horizon Europe and EIT Raw Materials. He is an author and co-author of numerous research reports, scientific papers and pre-feasibility studies. His background is rock mechanics and numerical modelling as well as risk assessment and blasting technology. Krzysztof Fuławka is also a vice-chair of European Underground Laboratories Association (EUL).

Keynote Address: Design of crush pillars and their use in high-stress mining

B.P. Watson
University of the Witwatersrand, South Africa

The concept of crush pillars was discovered by accident in 1978. One of the deeper-level platinum mines in South Africa was experiencing regular stope collapses when spans reached 30 m on either side of the centre gully. The mine manager ordered small chain-pillars to be cut on strike, at a dip spacing of 30 m. The problem was resolved, and a paper was submitted to the Mine Managers Association. Experts in the field of rock engineering visited the mine and realised that the pillars had failed. Since that time, a significant amount of work has been done on these so-called 'crush pillars', including the conditions for safe pillar failure and the relationship between residual strength and pillar size. Pillars must be designed to fail near the advancing face under stiff loading conditions. A similar loading stiffness requirement was observed for both pyroxenite and quartzite pillars. The safe distance from the face for failure, therefore, depends on the available stress and deformation that will take place at failure. More recently, crush pillars have been trialled in deep-level mines. One of the challenges in high-stress conditions is a high closure rate, resulting in crush pillar disintegration. The disintegration problem was resolved using support. Fibre-reinforced shotcrete was applied and covered by mesh and yielding tendon support near the advancing face. At one gold mine 6 m high crush pillars are being successfully used. They have been found to absorb seismic events

Applications of Fibre Optic Distributed Sensing (DAS) for mining industry

S. Dande[1], E. Forbes[2], T. Butler[2], A. Senso[2]
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Fibre optic sensing technologies, particularly distributed acoustic sensing (DAS), show potential as a complementary tool for monitoring seismicity and stress in underground mining environments, as well as for perimeter monitoring and assessing the integrity of tailings dams. While distributed fibre optic sensing is widely applied in the oil and gas industry, its use in mining remains in the early stages. This paper presents results from two case studies: one focusing on seismicity monitoring during mining operations, and the other on a small-scale tailings dam and perimeter monitoring experiment.

The first case study, conducted at Glencore's Onaping Depth Project in Sudbury, Ontario, Canada, involved installing an engineered fibre optic cable grouted into a 200 m-deep borehole to monitor seismicity and strain. DAS strain rate data were analyzed across two frequency bands: high-frequency signals (above 10 Hz) for microseismic event characterization and low-frequency signals (1–10 Hz) for observing broader strain behaviour. The results indicated that DAS could co-locate seismic events detected by conventional geophones and accelerometers, offering additional data for refining event locations. Furthermore, in the low-frequency range, a potential relationship between strain energy and raisebore activities was observed, hinting at the possibility of using DAS data for monitoring stress changes during specific operations. This case study suggests that DAS has the potential to complement existing seismic systems by providing additional perspectives on stress and strain monitoring 1.

In the second study, a lab-scale tailings dam model was built to test the ability of DAS to monitor stress buildup before a dam collapse. In the same experiment, DAS was tested for perimeter monitoring. DAS was able to detect people walking along the fibre, rain events, sledgehammer shots, and monitor equipment noise. Strain signals were also detected during the dam model collapse

Suresh Dande
Fiber Optic SME
ESG Solutions

Suresh Dande is a geophysicist with over 12 years of experience specializing in seismicity monitoring using Distributed Acoustic Sensing (DAS) and geophones. He currently serves as Fiber Optics Subject Matter Expert at ESG Solutions, where he leads and develops advanced data processing and integration workflows for fiber-based strain and seismic monitoring in Mining, Energy and Energy Transition projects.

He holds a Ph.D. in Geophysics from the University of Houston, where he studied the geomechanics of propped fractures using laboratory experiments and 3D-printed models. His research has been published in several peer-reviewed journals, and he is an active reviewer for Geophysics, Interpretation, and Journal of Petroleum Science and Engineering.

Determining the applicability of muon tomography for monitoring hazards in deep underground mines - a case study from a Polish copper mine

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The development of methods for continuous and reliable monitoring of geomechanical hazards is one of the key challenges facing modern rock mechanics. Current knowledge of the distribution of cracks or stress accumulation areas would potentially be the basis for taking preventive and corrective actions well in advance. Unfortunately, commonly-used methods of rock mass imaging are expensive and laborious, which is why the measurement is periodic. A breakthrough may be muography technology, which, based on the measurement of muon flow per unit of time, allows determining changes in the rock mass density. As it results from the analyses conducted so far, the number of muons observed in an area of 1 m^2, at a depth of 800-1200 m below the surface, oscillates between several dozen and several hundred thousand per year. Such a number should be sufficient to monitor density changes at great depths. This paper presents the results of pilot muon tomography measurements lasting several months in the Lubin underground mine. The principles of the system operation, assumptions and measurement results are described in terms of the possibility of identifying hazards accompanying underground exploitation of deposits. Finally, the scope of application of muography in the conditions of copper deposits in the LSCB area was determined.

Roman Kolodziej

Chief Foreman in the Ground Control Department
KGHM Polska Miedź S.A.

As Chief Foreman in the Ground Control Department at the Lubin mine, Roman Kolodziej is responsible for overseeing and evaluating geological and mining conditions in areas exposed to seismic risk. His core duties include implementing and supervising preventive and protective measures, conducting tremor analysis, and monitoring rock mass deformation using specialized instrumentation.

He holds a degree in underground mineral extraction from the AGH University of Science and Technology in Kraków. Throughout his career at KGHM, he has served as a project manager for various initiatives related to ground control and monitoring, including the deployment of measurement systems, data acquisition, and technical maintenance of installed infrastructure.

While his professional focus lies in mining geotechnics and seismic hazard mitigation, he also has a strong personal interest in automotive diagnostics and mechanical engineering. International collaboration within his role has broadened his professional horizons, enabling him to gain valuable insights into diverse mining practices and to engage with experts from various cultural and technical backgrounds.

Advancing geotechnical risk management and seismicity mitigation through interactive guidelines and industry collaboration

H. Greeff, J. Hanekom
Council for Scientific and Industrial Research, South Africa

Effective geotechnical risk management and seismicity mitigation are essential for ensuring safety and productivity in underground mining operations. This paper introduces an innovative approach to developing interactive industry guidelines that address these challenges by combining structured decision-making frameworks with industry specific insights. At the core of this approach is an interactive flowchart tool, designed to assist practitioners in selecting and optimising risk mitigation strategies. The flowchart is dynamically powered by a document miner, connected to a centralised repository of validated case studies, research findings, and operational data contributed by industry stakeholders. This ensures that the guidelines are driven by real-world, and near real-time, best practices and remain under the control of the industry itself.

This interactive guideline marks a significant departure from static, prescriptive documents, evolving instead into a living framework that adapts to advancements in technology, data, and practices. By fostering collaboration and continuous updates, the repository ensures the guidelines remain relevant and flexible, catering to diverse geological and operational conditions. Key aspects of this initiative include the emphasis on customisation in geotechnical risk management, leveraging advanced tools to address seismic risks, and promoting ongoing knowledge sharing to stay aligned with industry developments.

This paper details the development process of these guidelines, demonstrates the functionality of the flowchart and document miner, and examines their potential to enhance safety, operational efficiency, and collaboration within the rock engineering community. By bridging practical tools with new research, the initiative aims to establish a new standard for managing geotechnical risks and mitigating seismicity. Unlike prescriptive frameworks, these guidelines are designed to be educational, empowering practitioners to train upcoming professionals, validate evolving practices, and confidently adapt standards to their specific operations.

Heinrich Greeff

Principal Rock Engineer
Council for Scientific and Industrial Research

Heinrich launched his mining career in 2010 post university studies in physics, mathematics, and applied mathematics. Certified in rock engineering in South Africa, he specialised in ultra-deep-level gold mines before designing ground control systems in Canada, enhancing safety. Back in South Africa, Heinrich simplified ground-penetrating radar workflows for wider adoption. As CSIR's Principal Rock Engineer, he now leads the Geotechnical Sciences department, promoting innovative mining practices and technologies.

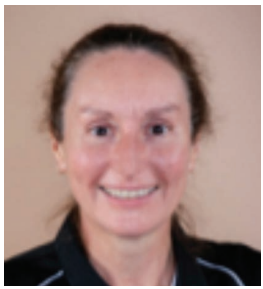
Geotechnical and operational risk review for an ultra-long ore pass in a caving operation

J. Walls
AMC Consultants (Pty) Ltd, South Africa

For orebodies suited to caving type extraction, the orebody shape (subvertical emplacement) may lend itself to include the design of ultra-long ore pass systems, to transfer ore and waste muck quickly from top to bottom infrastructure. In a case of interest, the emplacement of an ultra-long (>300 m) ore pass arrangement forms part of the materials handling system. The design provides an opportunity to utilise a simple vertical geometry which can significantly limit materials handling complexity and improve efficiency by creating a direct transfer for broken rock from the upper mine workings to the bottom of mine, from where the material will be removed to surface via conveyor and shaft system.

The broken rock handling system is critical to ensure continuous productive throughput, and must therefore ensure effective ore pass functionality, be reliably stable for a duration in line with the mine plan, and safely operated. However, while it is known that cases exist within the broader mining industry where ultra-long ore passes have been designed and executed, references pertaining to the conditions under which these passes were operated, and the nature of successes or failures, remain limited. Consequently, de-risking this critical infrastructure is an imperative.

This paper describes the process and outcomes of a risk management assessment that was carried out with multidisciplinary input to conclude a go-forward case for the operation. Consideration was given to benchmarking across similarly arranged operations, with similar ore muck properties, with reference to available data for ultra-long ore pass systems. This was combined with an assessment of the local geotechnical conditions affecting ore flow and ore pass stability, contexted to limiting factors defined by the underground infrastructure, planned and already locked-in (executed). Finally, the minimum required operational controls to sufficiently limit the residual risks for safe and effective ore pass utilisation were built into the case.



Jeanne Walls

Principal Geotechnical Engineer
AMC Consultants (Pty) Ltd

Jeanne's professional service to the mining industry includes a wide range of experience. She started out at deep level gold mining operations in Carletonville while completing an honours degree in geophysics, then migrated through exploration geophysics where she worked in various locations including South America, Africa and Australia, on into mining seismology, and thereafter transitioning in 2005 into rock mechanics. Variably applied to site-based assignments, and consulting projects, Jeanne has carried out work in several commodities in a range of mining methods, specialising mostly in underground applications. She is known for her analysis of pillar stability using probabilistic analysis, shaft sinking feasibility assessment, and interactive mining methods particularly in the transitioning from open pit to underground.

Jeanne continues to serve as an active contributor to industry through SAIMM, SANIRE and SANCOT, is a registered professional, and maintains a passion for development of young professionals through mentorship and examinations programmes.

Stabilisation of open pit wall movements detected by InSAR

J. Pretorius[1], J. du Toit[2], P. Narshai[1]
[1]SkyGeo, Netherlands
[2]First Quantum Minerals, Zambia

The M15 west slope of the Main Pit at First Quantum Minerals' Kansanshi copper mine in Zambia is an actively-mined eastward facing wall. This paper highlights the early warning provided by an InSAR based monitoring service. Displacements were detected along the slope face, prompting an intervention using horizontal drains.

To monitor the west slope of the pit, visual inspections, Ground Based Radars (GBR), Robotic Total Stations (RTS) as well as imagery from the radar satellite constellation TerraSAR-X were used. The early warning alert was issued in July 2022 on InSAR displacements, estimated using three months of imagery acquired at 11-day intervals. Surface movement was detected on several benches with the displacement beginning at the base of the wall and spreading radially and laterally, resulting in a circular subsidence pattern. This was suspected to be a precursor to a failure along the slope face. There was no alert of anomalous displacements from the GBR and RTS.

In response to the observed displacements, a mitigation plan was drawn up on site. It was hypothesised that the movements were due to increased pore water pressure. Using horizontal drains and boreholes, the area was to be dewatered. The depressurisation drilling began in November 2022 and continued until December 2022 when it was observed that the rate of movement slowed from 15.1 mm/year to 5.9 mm/year before the onset of the wet season.

Controlling the risk and prevention of the failure allowed for the smooth and continued operation of the trolley lines that were installed to reduce diesel usage. Furthermore, other costs associated with the failure - an increase in the tramming distance, for example - were successfully avoided. Using InSAR as a monitoring tool, timely intervention was possible; saving time, operational efficiency as well as quantifiable monetary resources.

Priyanka Narshai

Project Consultant
SkyGeo

Priyanka Narshai is a project manager in the mining technology industry, specialising in satellite-based ground deformation monitoring using InSAR. At SkyGeo, she leads monitoring projects across Africa and India, supporting mining clients with actionable insights on ground movement around tailings dams, pit slopes, and other high-risk infrastructure. She began her career working with Ground-Based Radar systems during slope failures, blasting events, and routine monitoring. This hands-on work deepened her interest in remote sensing and geotechnical risk reduction.

She holds a BSc in Geomatics from the University of Cape Town, with majors in Engineering Land Surveying and Environmental Geographical Sciences. Priyanka is registered with SACNASP and is an active sub committee member of Women in Mine Stability (WIMS).

Priyanka is passionate about the role of geospatial technology in driving safe and responsible mining practices. Priyanka believes in continuous learning and collaboration, and values opportunities to contribute and learn from knowledge sharing in the mining and geospatial communities.

When she's not working, you'll likely find her spending time with family or stretching things out in a yoga class.

HelloMac – Intelligent engineering revolutionising underground mine monitoring

W. Greyling
Maccaferri, South Africa

Since 2020, Maccaferri has been advancing its journey into Internet of Things innovation. HELLOMAC is a cutting-edge solution designed to transform traditional rockfall protection systems into intelligent safeguards. Our entire suite of technologies is built to enhance both safety and operational efficiency across civil engineering projects. By integrating smart early warning mechanisms, we raise the standard of resilience and responsiveness—empowering communities and promoting well-being. At the core of HELLOMAC is our unwavering commitment to smart innovation, driving elevated safety across a wide range of applications.

Wynand Willem Greyling

Rockfall Specialist
Maccaferri

With a career spanning over three decades, Wynand Greyling is a Rockfall Specialist at Maccaferri Africa. Starting as a Geotechnical Engineer in 1989, he has honed his expertise in rockfall mitigation and slope stability solutions across Africa's diverse terrains. Wynand's adeptness in navigating geological complexities has made him a trusted leader in the field. At Maccaferri, he spearheads innovative strategies, safeguarding critical mining and infrastructure projects from rockfall hazards. Wynand's collaborative approach and commitment to excellence ensure seamless project execution and client satisfaction. Passionate about engineering excellence and sustainability, he continues to push the boundaries of innovation, solidifying Maccaferri's reputation as a premier provider of rockfall protection solutions in Africa.

Application of MEMS accelerometers for continuous near-field monitoring of mining-induced seismicity

L. Stolecki, K. Fuławka, P. Mertuszka
KGHM CUPRUM Ltd. Poland

Disturbance of the equilibrium state in rock mass resulting from underground mining often leads to excessive stress accumulation, ultimately leading to seismic activity. Monitoring seismicity in terms of tremor energy, its location and induced vibration parameters is therefore crucial to constructively plan mining operations and manage seismic hazards. However, the problem with most mines is the high cost of building a seismic network. High costs associated with purchasing equipment and installing stations lead to a situation in which the number of measurement stations in networks is often reduced to the necessary minimum. Depending on the layout, the costs of measurement equipment and recorders cover 60-80% of the total network construction costs. These cost constraints can be overcome by using low-cost seismic devices based on micro-electromechanical system (MEMS) technology. This paper presents multi-month measurements of seismic activity generated by mining activities in underground mines in the Legnica Glogow Copper Basin region in Poland. An analysis of the effectiveness of the MEMS-based devices in relation to the results of recording with standard piezoelectric, piezoresistive and force balance accelerometers has been achieved. The results of pilot measurements of the velocity of seismic wave propagation using an underground seismic monitoring network based on MEMS technology are presented. According to preliminary analyses, despite certain limitations, MEMS technology can be successfully used to build a mine seismic network.

Lech Stolecki

Deputy Department Manager
KGHM CUPRUM Ltd. Research & Development Centre

Lech Stolecki, PhD, is a research worker in KGHM Cuprum Research & Development Centre. He received his M.Sc. at Wroclaw University of Science and Technology in 2000. In 2006 he obtained his Ph.D in mining and environmental protection. His research interests cover protection of land surface and rock mechanics. He is interested mainly in natural hazards accompanying the underground exploitation of copper ores. The research, that he conducted on this subject, enabled to development of a new inclinometer measurement method for assessing the stability of underground workings. This method is based on the measurement of the excavation roof's inclination. The wide and long-term research resulted in the development of the dynamic criterion of assessing the stability of roof layers, where for the first time it was possible to create a quantitative criterion describing the process of the roof fall. This method was patented by its authors and widely published in scientific articles. Measurement system based on this method is applied on an ongoing basis in copper mines belonging to KGHM Polska Miedź S.A. Dr Lech Stolecki is also a co-author of the verification of the seismic intensity scale for mining tremors about the land Surface impact. The research, carried out under his supervision, allowed the development and implementation of a modified GSI-2004/18 scale, which is currently used to assess the impact of mining-induced seismic events on buildings, people's perception and the nuisance of using buildings and apartments in LGOM mining area. One of the appendices to the scale is the standard operation procedure for conducting surface seismic measurements, interpreting the results for the assessment and forecasting of ground vibration parameters caused by mining tremors on the surface of the LGOM area based on the GSI-2004/18 scale, containing guidelines for the implementation of seismic measurements, their interpretation and assessment, and principles of forecasting seismic activity.

Seismic-based live tracking of underground fires and cooling period response

M. Wiggins[1], L. Scheepers[1], J. Gerber[2]
[1]Sibanye Stillwater, South Africa
[2]IMS – Institute of Mine Seismology, South Africa

This paper outlines the monitoring and analysis of an underground fire incident at Hlanganani Shaft, Driefontein Operations, Sibanye Stillwater, Gold Division in 2023. Through the utilisation of Institute of Mine Seismology software and live feed monitoring of seismic responses, the thermal dynamic trend of the fire was tracked from ignition to cooling. This approach facilitated early detection and response, enhancing safety for deployed proto teams (mine rescue brigades men). Although not universally applicable, similar systems could enhance fire containment efforts and enable early interventions through trend analysis of peak particle velocity in high-risk areas.

Keywords: Fire, seismicity, PPV, withdrawal, tracking

Mitch William Wiggins

Unit Manager Rock Engineering
Sibanye-Stillwater

Mitch Wiggins is an appointed Rock Engineering Practitioner at Kloof Operations, where he applies a blend of practical experience, analytical expertise, and evolving technical knowledge to support safer and more efficient mining practices. His journey into rock engineering began in seismic processing, where he built a solid foundation in rock mass behavior and data interpretation—skills that continue to inform his decisions in high-risk underground environments.

Raised in a mining family, Mitch was immersed from an early age in stories of falls of ground and near misses. These early experiences instilled a deep respect for the earth's complexities and a lifelong passion for understanding its dynamic behavior. For him, rock engineering is not just a profession but a vocation—one rooted in purpose and driven by the goal of protecting lives through the responsible application of geotechnical science.

Mitch's career reflects a hands-on, progressive path through the rock engineering discipline. He has consistently embraced both the lessons of the field and the insights of academic study. Currently in progress of completing his Advanced Rock Engineering Certificate, Mitch views formal accreditation as a natural extension of his commitment to continuous learning and professional development. He is particularly interested in bridging the gap between theoretical models and real-world mining conditions, advocating for solutions that are both technically sound and practically implementable.

Beyond his operational role, Mitch is an active contributor to the broader rock engineering community. He serves on the council of the South African National Institute of Rock Engineering (SANIRE) and is the current Chair of the Free–Vaal Branch. He is also a member of the International Society for Rock Mechanics (ISRM) and the Southern African Institute of Mining and Metallurgy (SAIMM).

Mitch approaches rock engineering with humility and purpose, recognizing both the potential and limitations of current practice. He is committed to collaborative problem-solving, applying modern tools, and sharing experience in service of safer mining. Grounded in the realities of deep-level operations yet inspired by the possibilities of innovation, he continues to strive in shaping the future of rock engineering in South Africa.

Modern satellite data provide new insights into surface movements above coal longwall mining

A. Vervoort
KU Leuven, Belgium

Apart from theoretical considerations and mathematical calculations, most basic concepts of subsidence over coal longwall mining are based on conventional levelling techniques. At the end of the last century, satellite data images became freely available for research. Although this remote sensing technique has its limitations, it offers many advantages over conventional levelling. The datasets are not limited to specific survey lines above the mined area and its immediate surroundings, and the frequency is relatively high (i.e., once a month or, for the more recent datasets, every six days). Furthermore, there is no time limit on the observation period. Analysis of more than 30 years of satellite observations above the Belgian Campine coal district shows that (i) in old mined sub-areas, subsidence continued for several decades after the last longwall panel in that sub-area had been mined, (ii) 12 to 15 years after mine closure, the direction of surface movements reversed and an uplift of the surface above the mined areas was observed, which is still ongoing in 2025, (iii) the horizontal extension of the impact of mining on surface movements is larger than is generally assumed.

Keywords: surface movements, subsidence, uplift, longwall mining, remote sensing

Andre Vervoort

Professor
University of Leuven

Prof. Andre Vervoort is a mining engineer and obtained his Ph.D. in 1987 at FPMs, Belgium for a study of roof behaviour in coal longwalls. From 1988 to 1992 he was a researcher at COMRO, South Africa and was mainly involved in ground control studies for the South African coal mines. Since 1992 he is a professor at the University of Leuven, Belgium. His academic teaching duties include courses in rock mechanics, geostatistics, mining methods and aspects of sustainable development. The emphasis of his research is on rock mechanics. He has published about 250 technical papers.

Keynote Address: The art of rock engineering design and the need for research

D.F. Malan
University of Pretoria, South Africa

This paper highlights the difficulty of rock engineering design owing to the very limited rock mass data available to rock engineering practitioners. The design tools readily available are based on many simplifications and assumptions. This aspect is highlighted in the paper based on two practical examples, namely simulating the time-dependent rock mass behaviour of deep tabular excavations and the design of shallow bord and pillar layouts. For the deep layouts, a new displacement discontinuity model combining a face fracturing model and a bulking model to simulate the time-dependent deformation is presented. This circumvents the problem of adopting a modulus reduction strategy to simulate the measured stope closure. The large number of modelling parameters required and the difficulty in calibrating these nevertheless highlight the art of rock engineering design. A simple elastic rock mass model and sound engineering judgement may still possibly be a better alternative. Similarly, in the shallow hard rock bord and pillar mines, the strength of pillars is still largely unknown. The application of an empirical pillar strength formula not applicable to the rock mass behaviour may lead to spectacular collapses. A limit equilibrium model in a displacement discontinuity code seems like a useful alternative to simulate pillar spalling, but again, a large number of parameters need to be calibrated. This also applies to pillar modelling done using finite difference codes. Sound rock engineering judgement is therefore always required. A key lesson is that major advances in rock mechanics will not be possible without extensive research projects, and ongoing monitoring of the rock mass behaviour in experimental sites will always be required for sound rock engineering designs.

Machine learning as a catalyst to enhance collaboration across generations and disciplines in South African Rock Engineering

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[1]University of KwaZulu-Natal, South Africa.
[2]Gauteng Department of Education, South Africa

Mining in South Africa presents complex rock engineering challenges, including geological intricacies, high-stress environments, and rockburst risks. Traditional design methods have long been essential to the field, but machine learning (ML) offers new opportunities to enhance accuracy, efficiency, and predictive capabilities. However, integrating ML into rock engineering is impeded by generational divides that hinder knowledge transfer. Overcoming this barrier requires fostering effective knowledge-sharing practices to accelerate artificial intelligence (AI) adoption. Collaboration is vital in merging traditional expertise with AI-driven advancements. A significant challenge arises when essential knowledge remains undocumented or unshared. Older generations, particularly Baby Boomers (1946-1964), have often neglected to impart their wisdom, resulting in lost solutions and repetitive problem-solving by younger professionals. This delay stifles innovation and hinders progress.

To investigate this dynamic, a qualitative study was conducted involving semi-structured interviews with rock engineers and early-career professionals. The interviews, even though designed to be conversational and informal in tone, followed a structured format with guided discussion focused on challenges in knowledge-sharing, perceptions of ML, and collaboration preferences. The responses were thematically analysed to identify barriers and enablers in generational collaboration.

This paper advocates for inter- and multi-generational collaboration, pairing experienced Baby Boomers with technologically proficient Generation Z professionals. This synergy can bridge the gap between legacy methods and modern computational tools, leading to transformative advancements in rock engineering. By strategically aligning the strengths of different generations with their unique training, the sector can improve operational efficiency and resilience. A framework is proposed to implement collaborative strategies, addressing key challenges and opportunities. This approach ensures sustainability and innovation in South Africa's mining sector, positioning it to navigate future challenges effectively. References highlight the role of inter-generational knowledge-sharing in driving progress and securing the industry's future.

Keywords: Machine Learning, ML, Artificial Intelligence, Inter-generation, Multi-generation, Hazard, Risk, Monitoring, Seismic event, Platinum

Dr Richard Masethe

Senior Lecturer (Rock Mechanics and Engineering)
University of KwaZulu-Natal

Dr. Richard Masethe is a seasoned professional in the field of Rock Engineering and Mine Seismology, with a career spanning nearly two decades. He has been actively involved in overseeing seismic systems and executing a variety of rock engineering projects across complex underground environments. His academic journey, from undergraduate to doctoral studies, all completed at the University of the Witwatersrand, has provided him with a comprehensive and interdisciplinary foundation that continues to inform his research and teaching practice.

Dr. Masethe holds a BSc in Economic Science, a BSc Honours in Geophysics, a Graduate Diploma in Engineering (Rock Engineering), an MScEng in Rock Engineering, and a PhD in Geophysics and Rock Engineering. This progression through the earth and engineering sciences reflects both depth and breadth in his academic preparation, positioning him uniquely at the intersection of geophysics, rock mechanics, and engineering seismology.

His professional career began in 2007 as a graduate rock engineering trainee at Gold Fields, after which he joined Sibanye-Stillwater, working in the Rock Engineering and Seismology Department. With 19 years of operational experience (Gold and Platinum), he transitioned into academia, where he currently serves as a Senior Lecturer. In this role, he teaches, leads research, and supervises postgraduate students, including those at the Master's and PhD levels at both the University of Cape Town and the University of KwaZulu-Natal. He has also contributed to academic programs as a guest lecturer and visiting academic at the University of Johannesburg and the University of the Witwatersrand.

Dr. Masethe's research interests are grounded in addressing critical challenges within deep-level mining. His expertise spans rockburst phenomena, the application of artificial intelligence in rock engineering, underground support design, geophysics, and the study and control of mine-induced seismicity. He is particularly interested in applying probabilistic and risk-based methods to enhance the reliability and safety of rock engineering designs in seismically active mining environments.
An accomplished researcher, Dr. Masethe has published more than 24 peer-reviewed papers in accredited journals and international conference proceedings. His work is recognized for its practical relevance and scientific contribution to the field. In 2023, he was awarded the prestigious SANIRE Salamon Award for the best rock engineering paper an acknowledgement of his impact in advancing the discipline.

He is an active member of several professional bodies, including the International Society for Rock Mechanics (ISRM), the Southern African Institute of Rock Engineering (SANIRE), EUROCK, and the American Rock Mechanics Association (ARMA). His career continues to bridge academic scholarship with real-world industry application, making him a valuable contributor to both education and the broader rock engineering community.

Transforming geotechnical monitoring data acquisition, 3D visualisation and analytics for modern mining

J.J. Meiring, P.S. Piper
Groundwork Consulting, South Africa

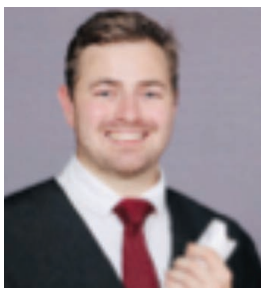
As the deepening of an underground mine occurs, dynamic events (rockbursts) or high In the evolving landscape of rock engineering, the transition from traditional data collection methods to advanced digital solutions is imperative for enhancing safety, planning and design. Historically, reliance on manual data gathering, fixed sensors, and localised storage systems – which often rely on basic tools such as Excel – has led to fragmented information silos and limited analytical capabilities. Such approaches are increasingly inadequate for addressing the complex demands of modern geotechnical projects and for enabling key patterns and relationships to be identified in datasets.

This paper explores the transformative potential of contemporary technologies, notably the integration of Industrial Internet of Things (IIoT) sensors and mobile applications, which facilitate real-time, accurate data collection. These innovations enable seamless transmission of information to cloud-based storage systems, ensuring data integrity and accessibility across various platforms for downstream analytics.

The paper outlines the key advantages of structured, cloud-based data repositories that support sophisticated analytics, including machine learning and artificial intelligence applications. Furthermore, the paper proposes that mobile applications can effectively complement IIoT sensors by providing flexible monitoring solutions in critical locations without requiring extensive infrastructure investment in networks.

Advancements in visualisation software are also discussed, with emphasis on the importance of distilling actionable insights from complex datasets that facilitate data-driven decision-making. Case studies demonstrate that by adopting these cutting-edge technologies, the rock engineering sector can significantly improve safety protocols and optimise design processes.

This comprehensive technological analysis, supplemented with mining examples and case studies, aims to provide rock engineers, mining engineers, safety personnel, and geotechnical professionals with a nuanced understanding of the current state of the technological landscape in this field. Furthermore, it offers practical insights into leveraging these tools to drive the industry towards a safer, more efficient and secure future.



Johannes Jacobus Meiring
Project Engineer
Groundwork Consulting

Jaco Meiring graduated with a Bachelor's Degree in Electrical Engineering from the University of Pretoria. Since 2020, he has been a valuable team member at Groundwork Consulting, actively contributing to over 30 mining operations, including underground projects and tailings storage facilities.

Soft computing techniques for predicting mode-ii fracture toughness: A cost-effective approach to advancing rock mechanics' design and sustainability

N.O. Ogunsola[1,2], H. Grobler[1]
[1]University of Johannesburg, South Africa
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The pure Mode-II fracture toughness (K_{IIc}) of rocks plays a critical role in understanding shear-dominated failure mechanisms in engineering applications; including tunnelling, slope stability, hydraulic fracturing, and rock mass design. However, experimental determination of K_{IIc} is often complex, expensive, and time-consuming due to the intricate testing procedures involved. This paper examines the application of soft computing techniques, including Levenberg-Marquardt trained artificial neural networks (ANN-LM), adaptive neuro-fuzzy inference system (ANFIS), and multilinear regression (MLR) to predict K_{IIc} of the International Society for Rock Mechanics and Rock Engineering -recommended Punch-Through Shear with Confining Pressure Test using test specimen geometrical and rock geomechanical properties. An experimental database comprising six predictor parameters: inner notch diameter, intact rock portion, specimen height, upper notch depth (a), compressive strength (σC), and confining pressure were used to develop and validate the predictive models. The predictive accuracy of the models was assessed using statistical error metrics, including the coefficient of determination (R^2), variance accounted for, and mean absolute error. The results of the predictive performance assessment showed that ANN-LM 6-8-1 model provides a superior predictive accuracy compared to ANFIS and MLR models. The ANN-LM model was later transformed into a user-oriented mathematical formula for easier computation of K_{IIc}. Finally, a sensitivity analysis technique was employed to evaluate the effect of each input parameter on K_{IIc} predictions. This research demonstrates the efficiency of soft computing techniques in predicting K_{IIc}, providing a cost-effective alternative to experiments while advancing rock mechanics design and sustainable practices.

Keywords: Fracture toughness, Soft computing, Punch-Through Shear with Confining Pressure Test, artificial neural network, adaptive neuro-fuzzy inference system

Nafiu Olanrewaju Ogunsola

Researcher
University of Johannesburg

Nafiu Olanrewaju Ogunsola is a postdoctoral research fellow at the Sibanye-Stillwater Centre for Sustainable Mining within the Department of Mining Engineering and Mine Surveying, University of Johannesburg, South Africa. Before joining the University of Johannesburg, Nafiu was awarded the Global Korea Scholarship (GKS) by the Korean Government in 2019. He earned his PhD in Mineral Resources and Energy Engineering with a concentration in Rock Mechanics in August 2023 from Jeonbuk National University, Jeonju, South Korea. He also holds a Master of Engineering (M.Eng.) in Mining Engineering (Rock Mechanics) and a Bachelor of Engineering (B.Eng.) in Mining Engineering, completed in 2017 and 2012, respectively, from the Federal University of Technology, Akure (FUTA), Nigeria.

Nafiu is an accomplished mining and rock engineer with a strong passion for studying rock and other geomaterials in situ and through practical application, demonstrated by his extensive industrial and academic experience. He has worked with notable mining and geotechnical companies, including Dangote Mines, China Civil Engineering Construction Corporation (CCECC), and Uniglobe Construction Engineering Limited, all in Nigeria. His recent research activities primarily focus on experimental and computational intelligence methods to deeply understand and predict the multiscale deformation and fracture behaviors of rocks and other geomaterials, addressing challenges in mineral extraction, infrastructure development, sustainability, geohazard mitigation, and energy.

Nafiu's current research focuses on advancing sustainable mining practices and geomechanics, implementing smart mining and monitoring operations through artificial intelligence and machine learning, promoting sustainable and rapid access to orebodies in both surface and underground mines, and applying multi-criteria decision-making (MCDM) methods to address challenges in mining and geomechanics. Contributing to academia and advancing knowledge in his field, Nafiu has published several articles in reputable journals and has been a reviewer for various others.

Comparison of machine learning classification for rockburst prediction: A case study of South African gold and platinum mines

N.P. Khumalo and R.T. Masethe
University of KwaZulu-Natal, South Africa

Rockbursts are one of the most challenging hazards in underground mining, known for their sudden and violent nature, posing significant risks to worker safety, operational continuity, and mining productivity. Accurate prediction of rockbursts is critical for geotechnical risk management, particularly in seismically active gold and platinum mines in South Africa. This study investigates the application of supervised machine learning (ML) algorithms for rockburst prediction, comparing their performance in gold and platinum mines. Models such as support vector machines, random forest, gradient boosting, and ensemble bagged trees were implemented and analysed using similar input parameters, including but not limited to mining-induced seismicity, peak particle velocity, hanging wall, footwall, and geological features. Results demonstrated that the models' classification accuracies and overall performances varied significantly, probably depending on the mining environment. In gold mines, the ensemble bagged trees model achieved the highest accuracy, while in platinum mines, the same ML model type outperformed others, with 84.2% and 95.5% accuracy, respectively. Despite using similar input datasets, these variations highlight the influence of localised geological and operational conditions on model performance. This finding underscores the importance of tailoring ML approaches to the specific characteristics of the mining area under study. The research concludes that while ML algorithms show great potential for rockburst prediction, their effectiveness depends on the mining context. This study emphasises the need for site-specific model development and validation to enhance prediction accuracy, ensuring improved safety and operational efficiency in underground mining.

Keywords: machine learning, ML, rockburst, platinum, gold, geotechnical risk

Towards ensuring sustainable mining: Application of a pareto-optimised hierarchical structural interaction matrix for prioritising slope stability influencing factors

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[1]University of Johannesburg, South Africa
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Slope stability is a critical factor in ensuring mining and civil engineering operations' safety, efficiency, and sustainability. Characterising rock slope stability and identifying and prioritising its influencing factors is fundamental to achieving sustainable mining operations, proactive risk management, and mining resource optimisation. This study aims to systematically evaluate and prioritise the factors influencing slope stability in mines using a Pareto-optimised hierarchical structural interaction matrix (P-HSIM), whose prioritisation computation is based on the theory of subordination derived through systems thinking. To achieve this aim, the various factors influencing slope stability were identified and collated from the literature. A binary interaction matrix (BIM) that assesses the relative importance and interdependencies among geotechnical, geological, environmental, and other factors was developed. The outcome of the BIM simulation was evaluated numerically using relevant mathematical equations to calculate the intensity rating score of every slope stability influencing factor. A Pareto optimisation technique was then applied to enhance the prioritisation process to ensure that the most significant slope stability influencing factors are appropriately emphasised. The study highlights the versatility of the P-HSIM framework in addressing complex geotechnical challenges and its potential to support sustainable mining practices by reducing geohazards, minimising environmental impact, and enhancing resource efficiency. The findings offer a novel decision-making tool for mining engineers and sustainability practitioners, contributing to developing safer and more environmentally conscious mining operations.

Keywords: Slope stability; Binary interaction matrix; Hierarchical tree structure diagram; Pareto optimisation, Sustainable mining

Nafiu Olanrewaju Ogunsola

Researcher
University of Johannesburg

Nafiu Olanrewaju Ogunsola is a postdoctoral research fellow at the Sibanye-Stillwater Centre for Sustainable Mining within the Department of Mining Engineering and Mine Surveying, University of Johannesburg, South Africa. Before joining the University of Johannesburg, Nafiu was awarded the Global Korea Scholarship (GKS) by the Korean Government in 2019. He earned his PhD in Mineral Resources and Energy Engineering with a concentration in Rock Mechanics in August 2023 from Jeonbuk National University, Jeonju, South Korea. He also holds a Master of Engineering (M.Eng.) in Mining Engineering (Rock Mechanics) and a Bachelor of Engineering (B.Eng.) in Mining Engineering, completed in 2017 and 2012, respectively, from the Federal University of Technology, Akure (FUTA), Nigeria.

Nafiu is an accomplished mining and rock engineer with a strong passion for studying rock and other geomaterials in situ and through practical application, demonstrated by his extensive industrial and academic experience. He has worked with notable mining and geotechnical companies, including Dangote Mines, China Civil Engineering Construction Corporation (CCECC), and Uniglobe Construction Engineering Limited, all in Nigeria. His recent research activities primarily focus on experimental and computational intelligence methods to deeply understand and predict the multiscale deformation and fracture behaviors of rocks and other geomaterials, addressing challenges in mineral extraction, infrastructure development, sustainability, geohazard mitigation, and energy.

Nafiu's current research focuses on advancing sustainable mining practices and geomechanics, implementing smart mining and monitoring operations through artificial intelligence and machine learning, promoting sustainable and rapid access to orebodies in both surface and underground mines, and applying multi-criteria decision-making (MCDM) methods to address challenges in mining and geomechanics. Contributing to academia and advancing knowledge in his field, Nafiu has published several articles in reputable journals and has been a reviewer for various others.

Role of machine learning in optimising prediction of blast fragmentation in mines using site-specific geological data

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Rock fragmentation by blasting remains a critical challenge in geomechanical engineering, being strongly influenced by geological discontinuities. However, conventional predictive models often fail to account for these discontinuities, leading to inaccuracies in blast performance assessments. This paper introduces a site-specific discontinuity index that quantifies these discontinuities and integrates them into machine learning (ML) models for improved fragmentation prediction. Key parameters such as joint volume, orientation, persistence, infill and alteration were consolidated into the index, providing a structured input for predictive modelling. Validation through Pearson correlation confirmed strong relationships between the index, rock mass rating and fragmentation outcomes, reinforcing its predictive reliability. A dataset of 110 blast events from Eureka Delta gold mine in Zimbabwe was analysed using violin plots and kernel density estimation to identify trends, while feature selection techniques refined critical predictors for fragmentation. Three ML models: Random Forest, support vector regression (SVR)and XGBoost, were applied to predict fragmentation outcomes. XGBoost outperformed the other models, achieving R^2 = 0.989, RMSE = 0.692, MAE = 0.484, demonstrating high predictive accuracy. Random Forest showed moderate generalisation (R^2 = 0.82), while SVR model exhibited overfitting (R^2 dropping from 0.771 to 0.73). By embedding geological discontinuity effects into predictive models, the site-specific discontinuity index enhances fragmentation prediction, reduces bias, improves generalisation and optimises blast design. These findings highlight the potential of ML in integrating geological heterogeneity into predictive models, offering a robust tool for improving blast design and fragmentation outcomes in mining operations.

Keywords: Fragmentation prediction, site specific discontinuity index, machine learning, blast design optimisation

Makomborero Salachi Kanongovere

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Currently pursuing a Master of Engineering (MEng) in Mining Engineering by Research at Botswana International University of Science and Technology (BIUST), specializing in blasting engineering and geomechanics. Research focuses on numerical modelling and analysis of blasting performance in discontinuous rock masses, aiming to optimize fragmentation, ground stability, and mine efficiency in structurally complex rock formations. Professional career began in 2020 as a Plant Operator at Chimona Mines, gaining experience in mineral processing operations. In 2021, joined Trade River Investments T/A Progress Mines as a Graduate Trainee, specializing in mine planning, ground control and geotechnical monitoring. In 2022, transitioned into academia as a Teaching Assistant at Manicaland State University of Applied Sciences (MSUAS), contributing to mining research and student mentorship. Since 2023, working as a Teaching Assistant at BIUST, supporting academic instruction and research in rock mechanics, numerical modelling, and geotechnical engineering. With a strong background in both industry and academia, dedicated to advancing sustainable mining practices through rock mechanics and geomechanical innovations.

The MDA CHORUS SAR constellation: A unique perspective for improved slope stability monitoring and geotechnical risk assessment

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Satellite synthetic aperture radar observations are integral to a comprehensive monitoring program for ground stability. Interferometric processing of a sequence of images collected over time can provide time series measurements of ground displacement with mm-precision at high resolution over wide areas. The amount of ground displacement that can be measured for a particular target is strongly affected by the orientation from which the target is imaged, which is described by the line-of-sight between the satellite and target. If the direction of ground movement is not aligned with the line-of-sight, the measurement may be significantly underestimated. Furthermore, the side-looking imaging geometry of these satellites introduces imaging distortions, such as foreshortening and shadow, that also depend on the line-of-sight as well as surface topography. These limitations on the quality of interferometric measurements are significant over mining sites with complex accumulation of ground-based deformation. MDA Space will soon be offering MDA CHORUS, a next-generation dual-frequency C- and X-band synthetic aperture radar satellite constellation which will deliver significantly enhanced Earth observation capability. The novel mid-inclination orbit for CHORUS provides unique imaging geometries across the world, increasing measurement coverage in areas with variable topography and enabling high precision three-dimensional ground displacement time series monitoring. In this work, we present simulations of the expected increase in interferometric measurement coverage and performance of three-dimensional processing for the Venetia diamond mine in South Africa. We illustrate how CHORUS will change the way we monitor ground stability to reduce risk and increase the safety of mining operations.

Dylan Hickson

Senior Member of Technical Staff - Systems
MDA Space

Dylan is a Senior Engineer at MDA Space in the Geointelligence business area with over 11 years of professional experience and graduate education in a wide range of radar applications, geophysical inversion, remote sensing, and data analysis. He obtained two B.Sc. degrees in Earth and Environmental Science and Physical Science from McMaster University in 2014 and his Ph.D. degree in Earth and Space Science from York University in 2019. Prior to joining MDA Space, Dylan was a Preeminent Postdoctoral Scholar with the University of Central Florida researching in planetary radar applications at the Arecibo Observatory and a Research Associate in the Department of Geophysics at the Colorado School of Mines researching in orbital radar sounding applications. In his current role, Dylan develops new capabilities for analyses of interferometric (InSAR) and polarimetric synthetic aperture radar (SAR) data in Earth observation. His efforts support geospatial analysis services offered by MDA Space in environmental monitoring for surface deformation and change detection leveraging InSAR/SAR data. He has published over 65 peer reviewed papers and conference abstracts on various aspects of radar applications, Earth observation, and planetary science. The asteroid 33896 Hickson is named after him by the International Astronomical Union.

Klipgat boxcut portal entrance and decline system: Long-term stability assessment and monitoring

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[2]University of KwaZulu-Natal, South Africa

This study assesses the long-term monitoring of the Klipgat boxcut portal entrance, as well as the long-term stability analyses of the three-decline cluster. The cluster consists of one decline measuring 6 m x 4.5 m and two other declines, each measuring 5 m x 4.5 m, separated by 8-metre-wide pillars. The evaluation focuses on the first 20 m of the declines and the associated pillars, where the rock is classified as competent but still requires an effective support system. Ground conditions range from poor and fair to good. A multi-faceted approach was used to analyse stability, including geological surveys, stress and kinematic modelling, and ground monitoring. The monitoring system employs geotechnical instruments such as early warning extensometers, Bluetooth extensometers, and Interferometric Synthetic Aperture Radar to detect rock movement. Initial monitoring indicates overall stability, with minimal displacement observed. However, localised weak zones due to weathering suggest additional reinforcement may be needed. The support system includes rock bolts, mesh, and shotcrete. Continuous monitoring and adaptive reinforcement strategies are essential to maintaining stability and ensuring safe mining operations.

Keywords: boxcut, portal, kinematics modelling, declines, portal, optimization, long-term stability

Siphamandla Vezi

Bokoni Mine, South Africa

I am a certified Rock Engineer with extensive experience in various aspects of mining and rock engineering. My operational expertise spans from surface, shallow, intermediate, and deep-level gold, copper, and platinum operations. I have also had the opportunity to work with different commodities across multiple countries. I gathered geotechnical data from exploration drilling and contributed to pre-feasibility and feasibility studies as part of a project team.

I support mine production teams in managing geotechnical hazards on-site, conducting rock engineering investigations into hazards, falls of ground, excavation stability, and support design. Additionally, I assist in developing risk mitigation strategies that align with Mine Health and Safety regulations and industry standards. As a visible leader in the workplace, I promote a strong safety culture by increasing awareness of geotechnical hazards through clear decision-making and effective communication.

Compact radar system for rockmass movement monitoring in an underground narrow reef stope

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[1]Anglo American, South Africa;
[2]Geobotica, Australia.

The introduction of radar technology in open pit mines has made a significant contribution to the prevention of fatalities and damage to equipment from uncontrolled slope failures. This paper introduces a novel way to transfer the same benefits into underground mines. The purpose of the technology is to warn workers of potential instability in the immediate area of their work.

Conventional underground stopes present challenges for geotechnical risk management. The restricted height in which workers have to operate, typically 1 to 1.6 m, makes it difficult to mechanise as drill and blast activities are generally done with conventional hand-held equipment. The mining method is very labour-intensive compared with a mechanised mine, resulting in high exposure to uncontrolled rockfalls.

Current trigger warning monitoring equipment is activated mechanically and drilled into the hangingwall of the stope. This only provides data for a very small surface area relative to a spread area or the complete stope and the likelihood of not identifying anomalous deformation indicating potential instability is very high.

The narrow geometry of stopes combined with the large number of active stopes per mine has meant that traditional radar equipment that is physically large requires significant power and communications infrastructure; and skilled operators are not suitable.

To address this gap, a compact radar system has been developed that offers contactless, continuous, spatial monitoring of rock deformation. Operating on interferometric principles, the system achieves sub-millimetre precision and can be deployed in a distributed configuration across multiple stopes. Its low-power and lightweight design enables extended autonomous operation without complex infrastructure or specialist training, making it well-suited to underground mining environments with limited access and high operational demands.

Dewaldt van Rooyen

Specialist Geotechnical Engineer
Anglo American

Dewaldt is a Specialist Geotechnical Engineer at Valterra Platinum. Previously with Anglo American Group Mining he brought 23 years of mining experience to his role with Underground Future of Work and technological improvements within the Group Mining Team. He started as a learner official in 2000 and quickly advanced to eventually managing a number of employees as a Rock Engineering manager. Besides earning the COM Rock Mechanics certificate, his academic achievements include holding six University Post Graduate Competency Certificates in the field of Geotechnical Engineering.

Demonstrating notable leadership and technical skills, some of his key achievements include revising the mine pillar design and support optimisation for a business unit with four operational mines, developing the Trigger Action Response Plan in 2009, integrating a routine monitoring system into operational cycles, and introducing Strata Control technicians to audits before blasting. His innovative side led to the development of a machine learning algorithm to forecast risk areas of fall of ground and UG radar technology.

Dewaldt is an active member of the South African National Institute of Rock Engineering (SANIRE) and the Rock Engineering Technical Counsel (RETC) in collaboration with the Mineral Council of South Africa to combat falls of ground in the mining industry.

On a personal note, Dewaldt has been happily married to his lovely wife, Frieda, for 19 years. They have two children: a 16-year-old daughter and a 12-year-old son. Dewaldt's dedication to excellence and continuous improvement has made him a respected leader in geotechnical engineering field and a sought-after peer to go to for advice. His impeccable sense of humour also makes him all round great guy to work with.

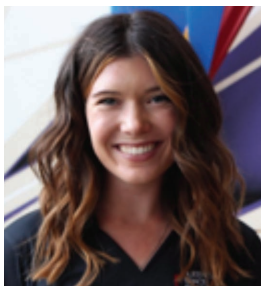
Monitoring mining-induced subsidence and sinkholes using multi-band InSAR: A case study from Lubambe Copper Mine

P. Chipola[1], R. Sililo[1], A. Mkandla[2], M. Douglas[3], M. Spreafico[3]
[1]Lubambe Copper Mine, Zambia
[2]TRE Altamira, South Africa
[3]TRE Altamira, Italy

A holistic geotechnical monitoring approach is vital for ensuring operational safety and minimising risks that could impact production and human lives. Comprehensive monitoring requires the integration of multiple geotechnical sensors and a dynamic adaptive strategy. This technical paper is a multiband interferometric synthetic aperture radar (InSAR) monitoring case study of a shallow underground mine located near critical infrastructure and challenged by the presence of sinkholes and dense vegetation.

The presence of dense vegetation required the use of a multiband InSAR approach to effectively monitor surface deformation across the site, including its impact on adjacent infrastructure. The InSAR data was integrated with ground-based surveys and field inspections to provide further understanding of ground behaviour. This integrated approach enabled the detection of precursor movements, allowing for proactive risk mitigation and enhanced operational safety.

This paper will outline the key challenges faced, the innovative techniques employed, and the tangible benefits of integrating satellite monitoring systems in mitigating geotechnical risks and ensuring operational continuity.



McKenzie Douglas

Geospatial Data Analyst
TRE Altamira

Studied at Queen's University in Kingston, Canada. Worked as a geotechnical engineer in the Vancouver area for three years before moving to Italy to work with InSAR data. While working in Vancouver, I was involved in geohazard assessments and seismic design for infrastructure, buildings and deep foundations in the greater Vancouver area. I was involved in the research for the 2025 BC Seismic Building Code and had studied the seismic response in the typical soils in the Victoria area. Since moving to TRE Altamira, most of the work has been focused on safety in mining applications and landslide monitoring. This work has exposed me to projects all over the world and I have thoroughly enjoyed the diverse approaches all of the people I work with have taken to designing slopes and monitoring high risk areas.

Closure and accelerometer measurements to enhance mine safety

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[1]SibanyeStillwater
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[3]Hoogenboezem Industries

Mining operations inherently involve risks, and ensuring the safety of workers in underground mines is of paramount importance. In recent years, advancements in instrumentation have provided valuable tools for monitoring and managing risk. In this paper, we review the closure and accelerometer data acquisition techniques described previously and describe two interesting cases.

1. Instrumentation Development: Closure meters
   - o A closure meter has been developed as a robust and reliable instrument designed specifically for underground mine use. Its primary function is to measure closure in a narrow tabular stope accurately.
   - o Its versatility allows it to adapt to various situations. Whether readings are taken every second or every 10 seconds depends on the specific context.
   - o With readings taken every 10 seconds, it can operate for a year on a single battery charge.

2. Data Flow and Real-Time Monitoring
   - o Closure readings are collected by intermediate devices, transferring data to the surface via the mining infrastructure.
   - o Surface personnel can access real-time closure readings. This capability would allow for timeous response to any anomalies or safety concerns once implemented mine-wide.
   - o The accuracy of closure measurements achieved by the SmarTrac is approximately 0.01 mm. Additionally, we capture ride data—the perpendicular movement relative to the instrument's axes—with lower accuracy (around 1 to 2 mm).

3. Insights from Large-Scale Data Collection
   - o Deploying multiple closure meters in a test area of the mine yields beneficial insights into the rockmass response. This will be expanded to more areas on the mine.
   - o Blasting effects become quantifiable. By analysing closure data before and after blasts, we can assess their impact on mine stability.
   - o Seismicity is a critical factor in deep level mines. By correlating closure variations with seismic events, we gain a deeper understanding of safety risks.
   - o The challenge lies in aggregating sufficient data to predict unsafe situations reliably. Our ongoing research aims to address this challenge.

In summary, comprehensive data collection using instruments like the SmarTrac empowers mine safety professionals to make informed decisions. By leveraging real-time insights, we move closer to a safer mining environment.

Lourens Johannes Scheepers

Manager Rock Engineering
SibanyeStillwater

Mining career start: April 1997 Vaal Reefs (Orkney).

Now 28 years in Rock Engineering, mostly in deep level (seismically active) gold mines. Currently the Manager Rock Engineering in Mining Technical Services for SibanyeStillwater, with a portfolio including the seismic service, modelling service, research and projects.

Keynote Address: Rockburst risk management in deep hard rock mines – a multi tiered approach with dynamic ground support as the last line of defence

B. Simser
Glencore Sudbury Operations, Canada

Rockbursting around underground excavations continues to be a core risk for many deep mining operations. Numerous advancements in mine design, preconditioning, monitoring, mining equipment, exclusion zones, and ground support have significantly lowered the risk to mine workers. As mining continues in deeper, more challenging environments, a multi-tiered approach to rockburst risk mitigation, starting with mine design, is required. Both the overall mine sequence, for example avoiding converging mining fronts, and local design 'stick handling' can play an important role in risk reduction. Rockburst case studies dating back to the late 1990s up until 2024 are used to highlight risk factors and risk mitigation (tactical and strategic). Examples from several deep hard rock mines are used, generally in high horizontal stress fields (k ratios 1.5 to 2), and strong brittle rock (> 200 MPa unconfined compressive strength). Mining induced stresses as well as high in situ stress due to depth are discussed. The context is Canadian Mining which typically has highly mechanised operations, large openings and equipment. Examples from a narrow-vein mine and shaft sinking are also given because neither environment is simple to mechanise, highlighting the need for other risk mitigations.

A 'sieve' analysis based on mine incident reports is used to show how a multi-tiered risk management plan can lower exposure to violent ground failures. A few incidents still make their way through the 'sieve,' indicating a need for further improvements. Thoughts on future/current developments, and their strategic importance are given.

Ground support is the last line of defence. The proliferation of multiple styles of yielding tendons and support systems has made many choices available to rock engineering professionals. Despite the increased availability of dynamic ground support components, there are still difficulties getting clean load transfer to bolts, determining support demand, monitoring loss of capacity over time/mining and evaluating true system capacity.

Virgin development in deep high stress brittle rock can result in high strainburst exposure prior to any stoping operations. The mining process must reduce worker exposure to unsupported rockmasses. Successful preconditioning in a shaft sinking operation, the use of high early strength shotcrete, and mechanised equipment are also discussed.

This paper will be published in the SAIMM Journal

Pillar assessment at Bindura Nickel Corporation's Trojan mine in Zimbabwe

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[2]Bindura Nickel Corporation, Zimbabwe

This paper presents the findings of a preliminary geotechnical investigation conducted at Bindura Nickel Corporation's Trojan Mine in Zimbabwe. The study aimed to assess the pillar area between two of its three mineable orebodies: the Main Ore Body (MOB) and the Massives Ore Body (Massives), and to determine optimal pillar sizes between the orebodies, if any. The investigation focused on evaluating the feasibility of mining around historically mined-out areas, highlighting potential geotechnical risks, and assessing the adequacy of existing support systems. The study aimed to evaluate the potential requirement for pillar between the mined-out Massives stopes and the surrounding MOB. The results of the investigation concluded that it was not necessary to leave a pillar between the Massives and the MOB, provided that the proposed extraction sequence and support recommendations were adhered to. Site investigations were conducted to assess the effect of stress build-up from historically mined-out areas. Thereafter, three-dimensional elastic finite element numerical modelling was carried out, providing more insight and correlating with underground observations. With a better understanding of these stress interactions, site observations and numerical analysis results were then utilised to develop an optimal extraction sequence and recommend adequate support regimes.

The investigation identified significant stress concentrations near mined-out stope abutments, primarily due to historical mining practices, which correlate with damage observed during underground assessment. The findings highlight the importance of strategic stope extraction and support installation to mitigate stress-induced damage and ensure operational safety.

The investigation concluded that with the adoption of the proposed extraction sequence and enhanced support strategies, the Hangingwall Ore Body and the remainder of the MOB could be safely extracted. Recommendations on additional geotechnical drilling, enhanced support strategies, and the implementation of a seismic monitoring system were made to mitigate risks associated with stress-induced damage and to ensure the stability and safety of mining operations.

Keywords: Trojan mine, geotechnical assessment, pillar extraction, stress analysis, mining safety.

Fungai Kwangwari

Mining Engineer- Geotechnical
SRK Consulting (SA) Pty Ltd

Fungai Kwangwari is a Geotechnical Engineer with over 15 years of experience in the field of Mining and Rock Engineering. She holds a BSc Degree in Mining Engineering and a Master's degree in Rock Engineering. She has worked and consulted independently for companies such as Zimasco Chrome Mine, Murowa Diamond Mine, SRK Consulting (SA), WorleyParsons RSA, Practara, and MSA Group.

Her experience in the Rock Engineering field includes site geotechnical characterization, underground and open pit slope designs stability analyses, excavations and support designs and analyses, and geotechnical risk assessments. She is conversant with several rock engineering modelling software for analysing rock mass response to mining through stress build-up and rock deformations. She has worked on several Preliminary Economic Assessments (PEA)/scoping studies, Prefeasibility Studies (PFS), and Feasibility Studies (FS), and has carried out due diligence studies for various commodities on different projects. Throughout her career, Fungai has been involved in a wide range of projects and commodities, optimizing them and bringing them to fruition while ensuring sustainability and safety.

She is currently a member of the South African Institute of Mining and Metallurgy (SAIMM), South African National Institute of Rock Engineering (SANIRE), and Zimbabwe National Institute of Rock Engineering (ZINIRE).

Outside of her professional life, Fungai enjoys spending time outdoors, appreciating nature.

Keynote Address: Finding signal in a noisy world during a Fourth Turning

F.R.P. Basson
BasRock Founder

The Witwatersrand Basin in South Africa is home to the largest gold deposit ever discovered and has yielded over two billion ounces of gold, more than a third of all gold ever mined. Gold mining shaped South Africa's economic and political landscape by sparking the Witwatersrand Gold Rush in 1886 and the Second Boer War in 1899. At the time, gold played a pivotal role in the global monetary system and countries adhered to the gold standard, pegging their currencies to the metal.

Fast-forward to the 20th century. In 1971, the 'Nixon Shock' severed the link between gold and the U.S. dollar, and gold has ceased to formally back any currency. Despite this, its price has surged more than 85-fold in U.S. dollars. The question arises as to why gold preserves such considerable value, considering its limited industrial utility, cultural connection primarily to jewellery, and the extensive idle holdings within central banking institutions.

Since 2008, the global financial system has entered an era defined by physical assets and digital trust. As exponential technologies, from blockchain and artificial intelligence to quantum computing reshape the foundations of commerce, governance, and identity, our understanding of value, scarcity, and monetary systems is evolving. This paper aims to connect the past with the present to illuminate future possibilities by drawing on historical cycles as described in the 'Fourth Turning' by William Strauss and Neil Howe. We will examine how emerging technologies are transforming the way we transact and challenge the definition of money itself.

Geotechnical design of coal bord and pillar panels: Some complementary suggestions

A. Vervoort
KU Leuven, Belgium

The design of coal bord and pillar workings focuses primarily on the pillars, i.e., the load on the pillar and the strength of the pillar. However, if one were to start a bord and pillar design on a blank piece of paper, one would start with the design of the rooms and first look at the redistribution of the stresses around the rooms. Elastic simulations clearly show that relaxed zones occur in both the roof (and floor) and in the sidewalls. These zones are located within the peak stress arcs. The size of these zones is influenced by the excavation dimensions and by the vertical-to-horizontal ratio of the initial stresses. A second concern is the common reflex to approximate the in situ pillar behaviour with a vertical loading experiment; for example by performing uniaxial compression tests. The latter could be realistic if one were to build a pillar, but that is not the case: one excavates a room. Before mining, the coal is in equilibrium in a three-dimensional stress state and depending on the position within the future pillar, the stress components decrease and/or increase. The various stress paths are illustrated by elastic and elasto-plastic simulations. At the end of the paper, suggestions are formulated for future work and improvements to our knowledge in the design of coal bord and pillar workings.

Keywords: strata control, coal bord and pillar mining, geotechnical design, stress paths

Andre Vervoort

Professor
University of Leuven

Prof. Andre Vervoort is a mining engineer and obtained his Ph.D. in 1987 at FPMs, Belgium for a study of roof behaviour in coal longwalls. From 1988 to 1992 he was a researcher at COMRO, South Africa and was mainly involved in ground control studies for the South African coal mines. Since 1992 he is a professor at the University of Leuven, Belgium. His academic teaching duties include courses in rock mechanics, geostatistics, mining methods and aspects of sustainable development. The emphasis of his research is on rock mechanics. He has published about 250 technical papers.

Back analysis of ore pass design at Big Gossan sublevel open stope mine, Indonesia

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[1]PT Freeport Indonesia, Indonesia
[2]ESG Solutions, Australia
[3]Freeport-McMoRan Inc., USA

The Big Gossan sub level open stope mine is part of the Grasberg mining complex at PT Freeport Indonesia that consists of two active cave mines and one cave mine being developed. Access ramps, ore passes, and other infrastructure excavations are planned outside the influence of mining-induced stress around the stopes. The mine design is planned to consist of 23 production levels with nine ore passes. Most ore passes are planned to last for a life-of-mine. In 2022, ore pass 7 (OP 7) lasted only three years before it experienced rock burst damage and stress-related spalling that caused it to be shut down for geotechnical evaluation. A geotechnical assessment was conducted to determine the cause of the elevated stress and seismicity. The assessment included stress measurement, seismic analysis, 3D modelling, geotechnical drilling and numerous observations in and around OP 7. Detail stress analysis also included the evaluation of core discing associated with high stresses as well as the depth of failure in OP 7. During this study, it became clear that a localised elevated stress field associated with a shear zone was present in the vicinity of OP 7. This paper briefly describes the various geotechnical methods used to determine stress orientation and magnitude based on observations and measurements. The design process of a new ore pass system (OP 8) is also discussed.

Jurgens Hamman
Technical Expert
PT Freeport Indonesia

JP has been involved in mining as a geologist and rock mechanics engineer since 1984. He worked for AngloGoldAshanti and OHMS in South Africa, Mining One Consultants in Australia, KCC in the DRC and PTFI in Indonesia.

He worked in the mining industry as a rock engineering practitioner as well as a consultant in hard rock open pit and underground mines.

Seismological and numerical characterisation of stability pillar behaviour at South Deep Mine

S.M. Sibanda, B.P. Watson
University of the Witwatersrand, South Africa

South Deep Mine operates at depths near 3000 m, where massive mining activities adjacent to stability pillars result in a decreasing pillar width-to-height ratio and the potential for stability pillar yielding. This paper integrated numerical modelling and seismological analysis to characterise the behaviour of a stability pillar during decreased width-to-height ratios with massive mining. Finite element models assessed stress distribution and damage evolution. The results showed gradual pillar yielding with core plastic strains reaching about 2%, indicating the transition from peak strength to strain softening. Seismological tools, including Energy Index (EI) and Cumulative Apparent Volume (CAV), identified distinct strain hardening (high EI, low CAV) and softening (low EI, high CAV) phases. Pillar failure was marked by sustained low EI and reduced seismicity. These findings highlight the value of combining numerical and seismological approaches to monitor pillar stability, offering actionable insights for safer deep-level mining practices.

Keywords: Stability pillars, numerical modelling, seismology, pillar yielding, strain hardening, strain softening, South Deep Mine.

Sifanekiso Sibanda

Geotechnical Engineer

Sifanekiso Sibanda is a highly experienced geotechnical engineer with over two decades of expertise in underground hard rock mining, spanning both shallow and deep-level operations within South Africa's most complex geological environments—namely the Bushveld Complex and the Witwatersrand Basin.

He holds a Bachelor of Science and a Master of Science in Mining Engineering, and is currently pursuing a PhD in Mining Engineering at the University of the Witwatersrand, focusing on Stability Pillar Behaviour in deep-level mining. His academic grounding is complemented by a strong track record of applied rock engineering and strategic geotechnical management.

Sifanekiso has held senior technical and leadership positions at major mining companies including Anglo American, Sibanye-Stillwater, and Gold Fields. His experience encompasses operational support, project management of large-scale geotechnical initiatives, execution of feasibility studies, and the integration of geotechnical considerations into safety systems, mine design, and business optimization. He has led multidisciplinary teams and provided expert guidance on seismicity management, backfill strategies, ground control systems, and regulatory compliance.

Currently serving as Geotechnical Engineering Manager at South Deep Mine (Gold Fields), he is responsible for driving the geotechnical strategy for one of the world's deepest and most mechanized gold mines. His role involves leading a high-performing team, ensuring geotechnical input across the mine life cycle, and supporting safe, efficient production through innovation and applied rock engineering principles.

A passionate advocate for knowledge transfer and professional development, Sifanekiso is deeply committed to mentoring and coaching the next generation of mining professionals. He is actively involved in internal talent development programs and often contributes to industry workshops, technical panels, and academic-industry collaborations.

Prediction of mine tunnel conditions in a deep Austrian mine by means of numerical back- and forward analysis

P. Gams[1], B. Moosbacher[2], H. Wagner[1], T. Fruehwirt
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As mining goes deeper and rock pressure problems increase, rock stress management becomes imperative. Advances in rock mechanics knowledge and understanding, together with significant improvements of soft- and hardware available to the rock mechanics practitioner, make it possible to analyse complex mining and geological situations. What is often lacking are reliable rock engineering criteria to convert numerical results into meaningful mine design and operational criteria. In this paper an example is given of how an Austrian industrial mineral mine where an irregular lens type mineral deposit is being extracted at a depth of about 1000 m is dealing with the rock pressure situation. The dimensions of the mineral body are several hundreds of metres in the dip and 100 m to 500 m in the strike direction. The thickness varies from a few metres to more than 100 m. This mineral deposit is situated in a weak shale formation. In the overburden are water-bearing rock formations. For these reasons a sub-level cut and fill stoping method, using pillars to control overall ground movement, is applied. The backfill serves as a working platform and provides stability to the slender, and in instances up to 100 m high, stope-pillars. The geological situation of that mine is very complex and it is predicted that with greater depth more geological formations with weak graphite layers can be expected. A comprehensive geological mapping system is in place. Pillar and ground conditions are monitored regularly. Based on structural geological data it is planned to change the direction of stopes, to intersect these zones of weakness in a more favourable angle. However, already the existing stopes and drifts show that sublevel stoping is an appropriate method to mine in those conditions. Beside several operational advantages, the rock mechanical situation will be improved with the rotation of the stope direction. The actual mining direction is parallel to the strike of the deposit, which is approximately 75° to the north. The new mining direction will be 140° to the north which is approximately perpendicular to the striking direction of the deposit. In this paper a comparison based on numerical simulations of mine layouts with these two different orientations is given. It is pointed out that these simulations are based on the situation in the mine. In a comprehensive study it is shown that the rockwall condition factor (RCF), proposed by Wiseman in 1979, is a suitable criterion for predicting the rock pressure situation in this mine. As a first step the input parameters for the numerical simulations (eg., primary stress situation and the stiffness of so called 'stope-pillars') are determined by means of back analysis. The approach for this calibration procedure is the comparison of the calculated RCF (Wiseman 1979) with in situ observed tunnel conditions in the mine. Based on the determined input parameters, numerical models based on potential future mining layouts are built and analysed. Results gained on models of different types and geometry are introduced and layouts with different orientations are compared against each other. Finally, based on objective criteria, the most favourable layout is selected and proposed for implementation by the mining company.

Keywords: deep mining, design criteria, sublevel stoping, numerical analysis, rock mechanics

Patrick Gams

Junior Researcher
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Patrick Gams is currently a PhD candidate at Montanuniversitaet Leoben, one of Europe's leading universities in mining and rock mechanics. His doctoral research focuses on design criteria in mining and numerical simulations under the supervision of Prof. Dr. Horst Wagner. He completed his master's degree in Mining Engineering in 2022 with a thesis titled "The Role of Pillars in Raise Caving." As the Chair of Mining Engineering and Mineral Economics at Montanuniversitaet Leoben, he is engaged in various industry projects, working on rock mechanics and mine planning for different operations.

Development of a multi-stage large excavation crusher chamber at Palabora mining company

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Palabora Mining Company (PMC) is extending its life of mine by deepening its operations from the Lift I cave, located 1200 m deep, to Lift II at about 400 m further below. An essential element of Lift II involves the implementation of two high-capacity jaw-gyratory crushers to improve production efficiency. In contrast to Lift I, which required four crushers to manage 1000 tons of ore every hour, Lift II combines this capability into two larger crusher chambers, with each crusher processing 2000 tons per hour. This allows PMC to reach its production target of 32 kilotons per day while enhancing underground operations. Developing the extensive crusher chambers (35 m in length, 30 m in height, 14 m in width) posed considerable geotechnical and operational challenges, necessitating meticulous planning, specialised equipment, and a multi-phase excavation strategy. In spite of the challenges encountered, such as equipment malfunctions, discrepancies from the intended mining configuration, and geological disturbances, the first crusher chamber successfully housed its crusher. In addition to this, no fatalities or injuries were reported during the development phase, demonstrating the success of the strategy. This paper provides valuable insights into the planning, excavation, and ground control of large underground chambers. This is to serve as a replicable framework for similar large excavations, especially in South Africa, where such developments are rare.

Keywords: Crusher chamber, large excavation, underground chamber, excavation stability, massive mining

Mohlapachila Matsapola

Mining Superintendent
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I am a results-driven Mining Professional with a proven track record of success in managing complex mining operations and projects, leading cross-functional teams and implementing process improvements that drive efficiency, safety and productivity. With 12 years extensive experience combined in underground deep-level gold, and block caving in copper mines I possess a unique blend of project management skills, technical expertise, and leadership acumen.

Throughout my career, I have grown through the mining ranks. In addition, I have held technical roles such as Strata Control Officer and Drill & Blast Engineer for the Palabora Mining Company Lift II Expansion Project. As a seasoned mining professional, I hold a B.Tech Mining Engineering Degree, Mine Manager's Certificate of Competency and Strata Control Certificate. I am serving as a PROTO Captain and affiliated with Association of Mine Managers South Africa (AMMSA).

Effect of pyroxenite layers on the strength of UG2 pillars

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The Bushveld Complex in South Africa is a stratified igneous formation stretching approximately 350 km from east to west. The platinum group metals are found in two gently sloping, narrow ore bodies known as the Merensky and Upper Group 2 (UG2) Reefs. This paper focused on the UG2, which is essentially a chromitite reef with pyroxenite layers of varying thicknesses. Most shallow-depth UG2 operations use a bord and pillar mining method. Extensive research has been carried out to determine the strength of these pillars. Laboratory tests indicate that pyroxenite is stronger than chromitite and possesses different geomechanical properties. The impact of these pyroxenite layers on pillar strength and behaviour remains unknown. This study investigated the effects of these layers using FLAC3D numerical modelling, calibrated from laboratory tests. Importantly, the test data was not downrated as the research took the form of a sensitivity analysis. The results showed a strengthening effect of pyroxenite on UG2 pillars of over 30%. An equation has been developed to determine the strengthening effects as a function of the percentage of pyroxenite in the pillar. The models showed that little damage occurred in the foundations at 100% chromitite, suggesting reasonable results could be obtained using metal platens in a laboratory. It is recommended that further studies be done using carefully prepared laboratory samples to confirm this research.

Keywords: chromitite pillars, UG2 pillars, pillar modelling, strain softening

Tatenda John Maphosa

PhD candidate (Student)
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Tatenda Maphosa is a PhD candidate in Rock Engineering at the University of the Witwatersrand, specialising in the development of failure criteria for predicting the post-peak behaviour of hard rock pillars, with a focus on underground platinum mining in the Bushveld Complex. His research integrates laboratory rock testing, in situ stress measurements, and numerical modelling to improve the understanding of pillar stability and failure mechanisms.
Tatenda holds both a Bachelor of Science in Mining Engineering and a Master of Science in Mining Engineering (Rock Engineering specialization) from the University of the Witwatersrand. His master's research investigated crush pillars, laying the foundation for his current doctoral work.

In addition to his academic pursuits, Tatenda has gained significant industry experience. He worked as a Geotechnical Stress Measurement Technician under Wits Enterprise from 2023 to 2024, conducting underground stress measurements at Booysendal Platinum Mine. This hands-on fieldwork complements his theoretical work and supports the practical application of his research findings.

Currently, he also serves as a Teaching Assistant at the University of the Witwatersrand, assisting undergraduate students in mining engineering. Known for his engaging and supportive teaching style, Tatenda is passionate about academic development and fostering curiosity in future mining professionals.

His research interests include rock failure mechanics, pillar behaviour, empirical and numerical modelling and rock mass characterisation. His work aims to contribute to safer and more efficient underground mine designs by enhancing the predictive capabilities of rock failure models used in hard rock mining environments.

Tatenda is committed to bridging the gap between academia and industry through applied research and collaboration. His current research includes partnerships with leading mining companies, contributing to the broader goal of improving mine safety and design methodologies in challenging geotechnical conditions.

Improvements in stope designs, and sequencing at the Big Gossan sub level open stope mine, Indonesia

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PT Freeport Indonesia, Indonesia

The Big Gossan (BG) Sub Level Open Stope (SLOS) mine is part of the Grasberg mining complex at PT Freeport Indonesia (PTFI) that consists of an additional two active cave mines and one cave mine being developed. The BG mine started development in 2005 and production in 2010.

The orebody is vertical, approximately 40 m wide, 1,500 m on strike 400 m in depth. The mining method consists of 15 m wide, 40 m high and <60 m long transverse stopes that use cemented paste fill (CPF). The mine design is planned at over 23 production levels, and production will be divided into two mining districts separated by a 20 m wide sill pillar.

The Modified Stability Graph (MSG) method was used to record the stability of almost 171 stopes. The stability levels were classified as stable, minor failures and major failures. Cavity Monitoring Systems (CMS) were used to

This paper briefly discusses the geotechnical methods used and the results that provided critical insights into the stability characteristics of the SLOS mining method at Big Gossan. The findings indicate areas where a change in stope dimensions or sequencing is required and highlight the importance of strategic sequencing to minimize stope failure risks. This assessment serves as a model for the application of advanced geotechnical tools in sub-level stoping environments, offering practical solutions for stability management in complex underground mining conditions.

Keywords: Big Gossan Mine, Sub Level Open Stope, Stope Stability Assessment, Modified Stability Graph

Andika Febrian

Geotechnical Engineer
PT Freeport Indonesia

Andika Febrian is a dedicated and results-driven Geotechnical Engineer with over 5 years of experience in underground mining, geotechnical monitoring, and cost control. Since August 2023, he has been serving as a Geotechnical Engineer at the Big Gossan Mine, PT Freeport Indonesia, where he plays a critical role in ensuring ground stability and operational safety in one of the world's most complex underground mining environments.

Andika's expertise spans seismic monitoring, geotechnical data analysis, and the integration of advanced instrumentation systems. At Freeport, he is actively involved in the installation and maintenance of seismic sensors, collaborating with global vendors such as ESG and IMS. His responsibilities include monitoring seismic activity, conducting geotechnical mapping, and analyzing deformation data using tools like Z+F Laser Scanners, Maptek Sentry, extensometers, and borehole cameras. He has also developed integrated dashboards to centralize geotechnical data, enabling real-time monitoring and early warning systems for tunnel deformation and ground movement.

Prior to his current role, Andika worked as a Cost Control Specialist at PT Darma Henwa Tbk, where he successfully managed multi-million-dollar budgets for coal mining operations. His strategic planning and cost-efficiency initiatives led to significant savings, including a 32% reduction in external hire costs and a 13% decrease in fuel excess through the implementation of Activity-Based Fuel (ABF) analysis.

Earlier in his career, Andika served as a Geotechnical Engineer Consultant at PT Heksa Mitra Sinergi. There, he contributed to several high-impact projects, including feasibility studies, underground mine design, slope rehabilitation, and geotechnical system development for gold mines across Indonesia. His work helped increase ore reserves by 14% and optimize mine designs for safety and profitability.

Andika holds a Bachelor's degree in Mining Engineering from the Bandung Institute of Technology (ITB). He is certified as a Mining Operations Supervisor by the Indonesian Mining Expert Association (Perhapi/BNSP) and is proficient in a wide range of industry software, including Deswik, Vulcan, GEM4D, RS2, and SeisVis.