Technical Program

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There are a total of 451 nuclear power plants currently in operation around the world and over 165 planned through 2040 and you have a recipe for surging U3O8 prices generating increased M&A activity and large capital requirements in the uranium mining sector.

In addition, Kazakhstan (40% of the world’s production) and Canada, two of the leading U3O8 producers, both made drastic production cuts during the last two years. Coming back on line with a total of 15 shuttered plants approved for restart. In due to increased construction of nuclear power plants and 8 idled plants in Japan drive Uranium prices up rapidly in the next 9-12 months or so. This shortage is expected to provide mining companies with a combination of energy supply and independence, annual land lease payments, capital investment and renewable energy credits. Permitting can be compatible with closure permits with minimal impacts to the surface.

Global Financing of Coal-Fired Power Projects
M. Oommen; Mining Consultant, Bailwin, MO
Outlook for coal in the energy markets in the North America and the World. Review the impact of China, India and other developing nations. A look at technical and technology issues impacting the sector and the appetite of global financing institutions to support development of coal-fired power projects.

What are you token about? Tokenizing a Mining Royalty or Stream to Raise Non-Equity and Non-Debt Financing
N. Johnson, J. Deem and A. Cohn; Bailey & Glasser LLP, Washington, DC
The appetite of large institutional investors for mining projects is waning, and most especially so for fossil fuels projects. In addition to activist pressure to defund mining, returns have been disappointing. Enter tokenization. Blockchain-backed digital financing tools such as tokenization are democratizing mining project finance. This submission will focus on the legal framework and hurdles to token-financed mining projects. Must you register with an exchange? What are the disclosure requirements? Will you bust a covenant in your debt stack? Will it breach your leases? We will explore the fundamental background of tokenization and provide a framework for answering these questions.

Coal - Industry and Financing Trends, Alternatives and Possibilities in the Current Market and the Future R.
Reeves; Northcott Capital, Denver, CO
This presentation will provide an update of the landscape and market for raising capital. It will start with a brief overview of competing energy sources together with coal, and discuss recent developments in the coal industry both nationally and internationally that are relevant for financing at the mine and corporate level. The discussion will focus on financing alternatives for a mature industry and explore possible alternatives or scenarios that could create upside for the industry and facilitate raising capital. The discussion of upside will be intended to stimulate the audience to consider alternative markets for coal as a fuel.

The Future of Uranium R.
McCracken; Energy and Natural Resources, Capstone Headwaters Investment Bank, Dallas, TX
All eyes will be on the Uranium Mining Industry as a production shortage should drive Uranium prices up rapidly in the next 9-12 months or so. This shortage is due to increased construction of nuclear power plants and 8 idled plants in Japan coming back on line with a total of 15 shuttered plants approved for restart. In addition, Kazakhstan (40% of the world’s production) and Canada, two of the leading U3O8 producers, both made drastic production cuts during the last two years. There are a total of 451 nuclear power plants currently in operation in some 30 countries. Add to that 69 nuclear power plants currently under construction...
2:25 PM
Investigations of Longwall Mining Subsidence Impacts on Pennsylvania Highway Alignments
E. Adelsohn, A. Iannacchione and R. Winn; University of Pittsburgh, Pittsburgh, PA
Over 600 longwall panels have been mined in the last 50 years, with 24 panels under interstates in Pennsylvania alone. The Gateway, Emerald, and Cumberland mines undermined I-79 with 17 panels between 1982-1989 and 2003-2008 respectively; Mine Eighty-Four undermined I-70 with 4 panels between 1987-2000. Through the examination of the panels that undermined I-70 and I-79, it is possible to determine which factors have most impacted the highway alignments. In some locations, the highway intersects with panels at angles ranging from 45 to 80 degrees, and at others, it runs between two panels, which simulates the effect of gateroads on the subsidence. The panels width to overburden ratio varies between 0.64 and 1.7, meaning that the interstates were influenced by both subcritical and supercritical subsidence basins. The face advance rates and overburden depths also vary between the panels. The effects of subsidence on the surface from these panels were recorded over the years. Using the Surface Deformation Prediction System, models were developed to relate the effect of overburden, panel size, orientation of the road, and rate of mining to the subsidence impacts on the highway.

2:45 PM
Evaluation of Stress Control Layout at the Subtropolis Mine, Petersburg, OH
A. Iannacchione 1, G. Esterhuizen 1, B. Slater 1, M. Murphy 1, T. Miller 1, N. Cope 1 and S. Thayer 1; 1Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Pittsburgh, PA; 2University of Pittsburgh, Pittsburgh, PA; 3East Fairfield Coal Company, North Lima, OH and 4Mine Vision Systems, Pittsburgh, PA
The Subtropolis room-and-pillar mine extracts the Vanport Limestone near Petersbug, Ohio. Strata instability problems associated with excessive concentrations of lateral stress caused the mine operator to implement a change in layout design. Practical experience has shown that entry headings advance in the direction of the principal lateral stress, producing lower stress concentrations with better mining conditions. It is important to minimize stress concentrations along the mining front, so an arrow-shaped advance is recommended. This technique advances more developments (headings) in a “good” direction and reduces developments (crosscuts) in a “bad” direction. As is expected, the stress control layout enhances the potential for shear failures in crosscuts. It is, therefore, important to focus crosscut engineering interventions that either: (a) lower stress concentrations (for example, an arched roof) or (b) enhance strength of the strata containing the shears (for example, rock reinforcement). This study focuses on observing strata conditions on a regular basis and monitoring the response of this strata to changing geologic and mining conditions through 3D Dynamic LiDAR scans.

3:05 PM
Analysis of ARMPS2010 Database with LaModel and an Updated Abutment Angle Equation
D. Tuncay 1, I. Tulu 2 and T. Klemetti 1; 1West Virginia University, Morgantown, WV and 2Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Pittsburgh, PA
The Analysis of Retreat Mining Pillar Stability (ARMPS) program was developed by the National Institute for Occupational Safety and Health (NIOSH) to help the U.S. coal mining industry to design safe retreat room and pillar panels. ARMPS calculates the magnitude of the in situ and mining induced loads by using geometrical computations and empirical rules. In particular, the program uses an “abutment angle” concept in calculating the magnitude of the abutment load on pillars adjacent to a gob. In this paper, stress measurements from U.S. and Australian mines with different overburden geologies with varying hard rock percentages were back analyzed. Using analytical and numerical methods, the abutment loads are investigated. The results of the analyses indicated that for depths less than 200 m (650 ft), the ARMPS empirical assumption of a 21° abutment angle was supported by the case histories; however, at depths greater than 200 m, the abutment angle was found to be significantly less than 21°. In this paper, a new equation employing the panel width to overburden depth ratio is constructed for the calculation of accurate abutment angles for deeper mining cases.

3:25 PM
The Development of a Multiple Level Underground Mine from Geology through Mine Planning
C. Newman 1, D. Newman 1 and R. Dupuy 2; 1Appalachian Mining & Engineering, Lexington, KY and 2Rogers Group, Inc., Nashville, TN
The development of a multiple level underground mine is a complex task in which geology, engineering, ground control, and unit operations are integrated into a single mine design. The components are inter-dependent and must function cohesively to ensure a profitable underground mining operation. To optimize reserve recovery, mine planning should begin from the lowest level and progress up. This limits any misjudgments or oversights of a given level affecting the underlying levels and ensures the ability to maximize recovery from each level. The process and the decisions are presented through case history examples. The theme is that there is one opportunity to “get it right” and many chances to overlook a small aspect within the design of multiple level underground stone mines that will plague the mine throughout all level and through the entirety of its operating life.

3:45 PM
Understanding Roof Deformation Mechanics and Parametric Sensitivities of Coal Mine Entries Using the Discrete Element Method
R. Aboueleiman, G. Walton and S. sina; Colorado School of Mines, Golden, CO
Although conventional coal mine designs are inherently conservative with regard to pillar strength, local failures in the form of roof-falls and pillar bursts still affect mine safety and operations. Previous studies have identified that discontinuous, layered overburden materials have some self-supporting capacity based on the voussoir beam analog. The research presented herein is a preliminary step towards understanding these mechanics in coal-measure rocks. Although others have considered broad conceptual models and simplified analogs for mine roof behavior, this study presents a unique numerical model that more completely represents in-situ roof conditions. The discrete element method (DEM) is utilized to conduct a parametric analysis considering a range of in-situ stress ratios, material properties, roof support, and joint networks to determine the parameters controlling the local and global stability of an individual coal mine entry modelled in two-dimensions. Results such as stress arch development, immediate roof displacement, failure modes, induced pillar stress, and overburden stress distribution are presented herein.
Monday, February 24  
Afternoon

2:00 PM • North 226A  
**Coal & Energy: Dust Control I**  
**Chairs:** A. Kumar, University of Kentucky, Lexington, KY  
J. Colinet; CDC NIOSH, Pittsburgh, PA  

2:00 PM  
**Introductions**

2:05 PM  
**Computational Fluid Dynamics and Scale Modeling of a Vortex Scrubber for High Airflow Cleaning Applications**  
A. Kumar and S. Schafrik, Department of Mining Engineering, N/A, Lexington, KY  

Fibrous type multi-layered screens are used in filter systems like flooded-bed scrubbers to capture dust particles from airstream in mining applications. Their dust laden air capture efficiency decreases rapidly due to particle loading. A vortex-type inertial wet scrubber was designed in the Department of Mining Engineering, University of Kentucky as an alternative filter to these conventional fibrous type filters. Computational fluid dynamics models and laboratory experiments were set-up and run to establish its performance parameters. Laboratory tests enabled examination of cleaning efficiency up to an airflow of 1.41 m³/s (3,000 cfm). However, underground mine ventilation applications require much higher airflows to combat dust and to comply with dust standards. This paper summarizes the behavior of operational parameters for up to an airflow of 4.72 m³/s (10,000 cfm) as the scrubber is enlarged. CFD models were generated and were compared to the performance parameters predicted analytically. Multi-phase free surface models are presented to show the airflow supporting swirling water film essential to keep the appropriately sized scrubber clog free.

2:25 PM  
**The Impact of Black Lung and a Methodology for Controlling Respirable Dust**  
J. Colinet; CDC NIOSH, Pittsburgh, PA  

Coal Workers’ Pneumoconiosis (CWP), commonly known as black lung, results from the inhalation of respirable coal mine dust and is a disabling and potentially fatal lung disease with no cure. Historically, CWP has taken a tremendous human and financial toll in the U.S. coal mining industry. Recent health surveillance data indicates that CWP continues to occur at elevated levels. Controlling respirable dust exposure is crucial for preventing the development of CWP. The National Institute for Occupational Safety and Health conducts research to identify control technologies that can be used to reduce respirable dust levels. An overview of CWP’s impact and a methodology for controlling respirable dust in underground coal mines will be provided.

2:45 PM  
**Laboratory Testing of a Water Curtain Designed to Reduce Float Dust Accumulations in Longwall Returns**  
C. Seaman and T. Beck; CDC NIOSH, Pittsburg, PA  

Float coal dust (FCD) is a hazard affecting all underground coal mine workers. This hazard is currently mitigated by the application of inert rock dust. NIOSH has conducted research aimed at developing a water curtain to reduce accumulation of FCD in longwall returns. The curtain was tested by varying spray spacing and curtain spans for single and dual spray bar configurations. The knockdown efficiency of the control on FCD ranged from 56% to 16% based on the spray configuration. A single bar with sprays placed in areas of high dust concentration yielded the maximum knockdown per liter of water consumed. Used in conjunction with current FCD controls, this control will further reduce the risk of an FCD ignition resulting in improved mine worker safety.

3:05 PM  
**Field Testing of Roof Bolter Canopy Air Curtain Operating Downwind of the Continuous Miner**  
W. Reed¹, M. Shahani¹, V. Gangrade¹, G. Ross², K. Singh², R. Cross² and T. Grounds³; ¹CDC-NIOSH, Pittsburgh, PA; ²Prairie State Generating Company LLC, Lively Grove, IL and ³J.H. Fletcher & Co., Inc, Huntington, WV.  

The roof bolter canopy air curtain (CAC) is gaining acceptance as a respirable dust control device that can provide roof bolter operators protection for respirable coal mine dust overexposure. Approximately 50 roof bolters in the U.S. have CACs installed. Both lab and field studies on the effectiveness of roof bolter CACs have been published. Field studies, in particular, have shown the effectiveness to be variable. However, in all field studies no studies have been conducted when the roof bolter operates downwind of the continuous miner—a situation the CAC was designed to provide respirable dust control. This study conducted CAC testing on a roof bolter operating downwind of the continuous miner. Results of testing demonstrated that the roof bolter CAC can effectively provide respirable dust protection for roof bolter operators with dust control efficiencies ranging from 11 to 40%.

3:25 PM  
**Guidelines for Selecting the Right Dust Suppression**  
J. Brown; Management, Quaker Chemical, Louisville, KY  

In today’s business environment it is critical to operate safer, more efficiently, and with a greater focus on the environment around us. The generation of dust is an unavoidable consequence of our operational activities and one that can impact onsite safety, health, and production among many other concerns. There are several ways to treat fugitive dust emissions but they do not come in a “one size fits all” solution. As regulations increasingly become more stringent it is imperative that operators know the options available and how to properly select for their specific site. What are the various dust suppression options available and how should an operation choose what means to employ?
potentially dangerous environment to the safer location of a control room. This 
dust. By automating the shuttle car, the operator can be removed from this 
and incidents caused by poor visibility conditions, soft tissue injuries, noise and 
area and the feeder breaker of an underground coal mine. Currently, the shuttle 
One such example is the shuttle car operation which moves between the face 
establishing a framework that will improve personnel safety and mine productivity. 
Led by technological advances, automation is rapidly becoming a key factor 
mining industry. In the complex working environment of a mine, moving 
the ability to automate and analyze this data with IoT sensors, advanced ad-
hoc networks and machine learning allows short session interval and granular 
benchmarking to extract efficiencies in mine operations. The addition of game 
theory techniques has shown to elevate workforce tempo while improving 
employee engagement. IWT will provide real world examples of our Production 
Analytics Solutions being used in various underground mining operations to 
achieve situational awareness of mine activity to attain gains in productivity and 
efficiency.

3:25 PM
Development of a Lab-Scale Autonomous Shuttle Car and 
Implications for the Full-Scale Autonomous Vehicle
V. Androulakis, S. Schafrik, J. Sottile and Z. Agiakountas; Dept. of Mining 
Engineering, University of Kentucky, Lexington, KY

As one of the most catastrophic hazards in underground mining, coal burst 
occurances have been contributed by a range of mining and geological factors. 
The associated energy sources within the rock mass mainly include elastic strain 
energy, gas expansion energy and seismic energy related to rock fracturing and 
faulting together with energy related to mine geometry. This paper introduces a 
coupled analytical tool that can predict the ejection velocity in the event that a burst 
occurrs, taking into account the various energy sources and release mechanisms. 
Based on that, a coal burst risk mapping method will be developed quantifying the 
extent of the potential damage zone in the openings, as well as the requirements 
for the ground support. The results of this study can improve the overall coal burst 
management by quantifying the coal burst risk levels.

3:05 PM
Closed and Abandoned Mines, Bolivia-South America
A. CARDENAS; na, Nane, La Paz, Bolivia, Bolivia, Plurinational State of 
Bolivia, a very well-known mining country, because of its rich tin, silver and gold 
resources. Two private companies conducted closures activities, Empresa 
Minera Inti Raymi S. A., Kori Kollo and Kori Chaca, gold operations in Oruro; and 
Compañía Minera del Sur with one silver heap leaching operation, Potosí, and 
gold CIL on the lowlands, Santa Cruz. This paper reviews results of the efforts 
conducted on closed gold and silver operations in Oruro and Potosí and on the 
tropical area, Santa Cruz, where pits, mine waste, evaporation ponds and tailings 
storage facilities were closed. Special focus was put on physical and chemical 
structure of closed facilities so that no further effluents would come out of them 
and therefore no major threats would be expected to the environment and nearby 
communities. This experience should be considered in the coming mines to be 
closed. The paper also addresses the current situation of some abandoned 
mines which nowadays are considered as an “environmental passives” creating 
environmental problems but on the other hand can be considered as a “mine 
reserves” due to the important remaining metal content.

2:45 PM
Using the Digital Exhaust of Mines for Productivity Gains
J. COLLING; Innovative Wireless Technologies, Inc., Lynchburg, VA

Today’s miners must embrace information technology which transforms the way 
they leverage data across their operations to increase productivity and drive gains. 

2:45 PM
Using Familiar Tools To Create A Low Cost Environmental Tracking 
System
E. Gibson; Civil & Environmental Consultants, Inc., Hazelwood, MO

Simple environmental compliance tracking is in demand for small and medium-
sized mining companies. Free or inexpensive software, like Microsoft Excel, can 
be used to create a customizable tracking system. When combined with cloud 
storage, a spreadsheet can keep permits, plans, and other key documents in one
project outcomes. The iterative approach to developing and supporting robust CSMs for optimizing evaluation and comparison of the various data types from a particular site and used to assess brine-related impacts in groundwater for other portions of the surrounding shallow groundwater and resulted in a screening value that can be interpretation from the full dataset, which showed a much smaller impact on leading to a refined conceptual site model (CSM). Integration of multiple lines we compared geophysical, hydrogeological, and geochemical data, ultimately historically interpreted to originate from a mine’s tailings management areas, interpretations of the data can sometimes suggest conflicting results. In a recent Complex environmental site investigations often include many data types, and D. Levitan, N. Brandner and J. Greer; Barr Engineering, Minneapolis, MN

2:45 PM  Environmental Software Selection and Implementation
R. Guzman-Sanchez¹ and A. Jones³; ¹Arcadis, Highlands Ranch, CO and ³Freeport McMoRan, Phoenix, AZ

Mining companies have many choices when it comes to Environmental, Health, Safety and Sustainability (EHS&S) Software. With more than 300 different products to choose from, it can be an overwhelming experience to replace and implement EHS&S management information systems (MIS). Freeport-McMoRan embarked on the journey of updating Environmental MIS (EMIS) tools in 2018. Arcadis was hired to assist Freeport in defining and prioritizing functional topics surrounding environmental compliance including; waste, water, air, incidents, compliance assurance, action tracking among a few others. Through a series of workshops and an evaluation of current home grown and legacy commercial systems, Arcadis recommended a short list of systems that could meet Freeports needs. Freeport chose its new software tool, Enablon, and retained Arcadis to assist with implementation. This effort is a multi-year, multi-phase program that is in mid-flight at this time. This presentation will walk the audience through some of the challenges, lessons learned and successes Freeport’s team has experienced in selecting and implementing a new EMIS software solution.

3:05 PM  Big Data Wrangling and Staying on Script
S. Bonucci; Enviromin, Inc., Bozeman, MT

Innovative use of large dataframes and scripted analysis can streamline processing and storage of complex environmental chemistry data. Past paradigms of spreadsheet-based data management and analysis are inefficient. They require re-invention of the wheel each time a new figure is generated. A few simple techniques can be used to create multi-variate databases that automate analysis. These techniques significantly reduce human-error and create more powerful management systems that can be used to apply a unique analysis to any source of data at the touch of a button. A case study will be presented displaying the capacity of scripts written in R and Python. The same scripts were used to analyze geochemistry from 10 distinct pits within a permitting expansion. Challenges from the study, such as cleaning and wrangling both new and historic data, the importance of proper annotation in scripts, and the devil in the details will be presented. When these challenges are managed, utilizing open-source programming languages allows for high speed data processing and analysis that lead to faster results for clients, regulators, and shareholders with higher quality deliverables and less effort.

3:25 PM  Integrating Multiple Data Streams to Refine a Conceptual Site Model
D. Levitan, N. Brandner and J. Greer; Barr Engineering, Minneapolis, MN

Complex environmental site investigations often include many data types, and interpretations of the data can sometimes suggest conflicting results. In a recent study conducted to define the extent of an apparent groundwater brine plume, historically interpreted to originate from a mine’s tailings management areas, we compared geophysical, hydrogeological, and geochemical data, ultimately leading to a refined conceptual site model (CSM). Integration of multiple lines of data was used to demonstrate the validity of the revised CSM and to design a simple field study to address the remaining gaps. Results yielded a new interpretation from the full dataset, which showed a much smaller impact on surrounding shallow groundwater and resulted in a screening value that can be used to assess brine-related impacts in groundwater for other portions of the facility. Graphical depictions of the data played an important role in interpreting and communicating the results. This study underscores the importance of critical evaluation and comparison of the various data types from a particular site and the iterative approach to developing and supporting robust CSMs for optimizing project outcomes.

3:45 PM  Monitoring Impacts of a Tailings Dam Failure with Satellite Images and Machine Learning
J. Moraga, G. Gurkan and S. Duzgun; Mining Engineering, Colorado School of Mines, Golden, CO

In this study, we present an approach for monitoring the inundation area due to a tailings dam failure using satellite images and machine learning. We used Sentinel-2 images to map the inundation area around Brumadinho tailings dam (January 25th, 2019), and delineate land use and cover impacted by the dam failure. We classified satellite images of the region in seven classes, for before and after the disaster by implementing a machine learning algorithm. The developed classification algorithm yielded a high accuracy (above 95% for before and above 80% for after event images). We calculated the amount and type of inundation area for each land use and land cover and mapped it.

4:05 PM  Post Mining from Space: Innovative Approach to Improve the Risk-Management in Mining
P. Guerke-Mallet¹, J. Brune², J. Kretschmann³, T. Rudolph¹, A. Müterthies⁴ and S. Möllerherm¹; ¹Research Institute of Post-Mining, Technische Hochschule Georg Agricola University, Bochum, Germany; ²Colorado School of Mines, Golden, CO; ³Technische Hochschule Georg Agricola University, Bochum, Germany and ⁴EFTAS Fernerkundung Technologietransfer GmbH, Münster, Germany

Mining activities have increasingly become a focus of politics, the authorities and the public. This development is driven by the climate and environmental discussion. Political conditions for mining are steadily deteriorating. In Germany the extraction of energetic raw materials has ceased or is declining. Dam breaks at tailing ponds attracted worldwide attention. Public views of mining and minerals extraction in the United States of America are quite similar. Yet, critical materials require mining and processing of specific minerals, for which responsible natural resources development is essential. Therefore, in todays mine life cycle, risk management is an integral part of the mining process. This paper describes innovative methods monitor mine environmental impacts. These include sensor-based early warning systems for mining risk management processes throughout the mine life cycle into the post-mining phase. It discusses how mining engineers utilize big data from earth observation and digital technologies to mitigate environmental impacts and create value.

Monday, February 24
Afternoon

2:00 PM • North 127B
Environmental: Holistic, Regional Mine Water Management
Chair: A. Tinklenberg, Intera, Reno, NV

2:00 PM  Introductions

2:05 PM  Coupling Water Balance and Geochemistry Models for a More Dynamic Water Modeling Experience
B. Johnson, A. Johnson, E. Guldbech and J. Waples; HydroGeoLogica, Golden, CO

Mining operators strive to improve water management decision-making tools to minimize risks and costs related to water quantity and quality issues. These issues are typically interrelated and complex such that interpretation and prediction of system dynamics requires implementation of innovative approaches that make use of observed data and fundamental hydrochemical concepts. HydroGeoLogica has developed an approach that couples the dynamic systems modelling framework of GoldSim with the geochemical reaction simulation capabilities of PHREEQC and Geochemist’s Workbench. The approach utilizes a dynamic link library (DLL) to
seamlessly transfer data between programs. The coupled approach simulates mixing and geochemical reactions taking place at key points along flow paths and at key water storage locations. Empirical factors affecting chemical loads can be calibrated to observed flows and chemistry at multiple locations and then used for predicting future water quality as operating and environmental conditions change. Mass-balance mixing can be directly compared to post-reacted waters to cross-check model results. Case studies will be presented.

2:25 PM
**Mine Water Rebound Processes in Europe**
B. Reker, S. Westermann and C. Melchers; Research Institute of Post-Mining, TH Georg Agricola, Bochum, North Rhine-Westphalia, Germany

In recent years, many European coal mining districts have been abandoned or are in the process of termination, in most cases due to the end of governmental subsidies. With the closure of the mines and the cessation of pumping, a lot of mine water rebound processes are taking place. For a better understanding of this process, the experiences regarding the rebound processes gained in whole Europe have been collected and analysed in a three year study at the Research Institute of Post-Mining at the TH Georg Agricola in Bochum / Germany.

2:45 PM
**Setting Your Mine Up for Success with Sound Water Treatment**
D. McBride; Burns & McDonnell, Kansas City, MO

Mining operations can require significant amounts of water to meet various needs (e.g. process versus potable needs). Depending on the use, the water quality requirements may vary significantly. Mines are often in remote locations or may be significantly constrained on freshwater availability or both. Mining operations need to consider water use (both quantity and quality per application), source water availability, as well as wastewater discharge requirements. This paper will discuss some concepts regarding the modeling of water systems, potential pre- and post-treatments, and the potential for water reuse to minimize fresh water demands.

3:05 PM
**Mine Water Resource Planning in Arizona**
L. Hixson; Engineering, WestLand Resources, Inc, Tucson, AZ

Water is critical to operating a mine but is not always located where or in the quantity you need it. In Arizona, there are multiple types of water resources available but obtaining those resources takes an understanding of Arizona Water Law. This presentation will cover a basic overview of the types of water resources available in Arizona and how to obtain these new sources. We will discuss groundwater, surface water, Central Arizona Project water, exchanges, leases, and transfers. The purpose is to provide the vocabulary required to plan for the future water needs of a mine in Arizona.

3:25 PM
**Water-What, Why and Where**
J. McCallum and R. Dunne; Robert Dunne Consulting, Perth, WA, Australia

The World Economic Forum has consistently ranked water, energy and food security issues among the top global risks facing governments and businesses. Water-energy-food (WEF) security is a concept that accounts for the interlinkages between water, energy and food. Mining activity has a direct impact on the environment as it requires access to land, water and energy, scarce resources that are shared with the communities in which it operates. The mining sector faces the challenge of resolving the problem of its large local water demand without affecting the availability of water for agriculture and for the urban population, and without increasing pollution. Mining companies and research organisations worldwide continually seek ways to develop sustainable water management practices to reduce water consumption by promoting efficient water recycling, minimising water losses and contamination of water and where required environmentally acceptable disposal of water. This paper will provide an update of government/mine organisations and research institutions that have programmes/projects to meet these objectives and provide information on what they are doing and why this is a focus.

3:45 PM
**The Miner's Guide to Electric Leak Location Technology for Geomembrane-Lined Containment Systems**
S. Calendine; Development, HydroGEPHYSICS Inc., Tucson, AZ

Mines have come to depend on geomembranes as an integral component of the mining process, principally as substrates for ponds, heap leach pads, and tailings piles. A geomembrane liner’s primary function is to create an impermeable barrier between the substance it contains and the earth below. Leaks can happen at any time in the life of a lined containment system thru poor installation procedures, improper usage, environmental factors, age, and repeated stress from regular use that create tears, rips, or punctures. Left undetected, these failures can cause loss of product, shutdowns, regulatory fines, and remediation costs. For over thirty years, electrically-based leak location methods have been the primary technology for finding breaches in lined structures. However, mine operators often do not understand leak location technology or how to prepare for a leak location survey. In this presentation, we will discuss leak location methods, equipment, and associated challenges with the leak location process for lined containment systems in the mining industry. The case study presented demonstrates successful use of electric leak location in a mining pond.

4:05 PM
**Using Membranes to Solve Difficult Water Treatment Issues in Mining**
G. Lohse; Business Development Director, SafRon Water Technology, Houston, TX

Beginning with permitting and treatment of source water for various mining processes and ending with the discharge of clean water to the environment, water management is a large operational expenditure at most mines. Recent innovations in the manufacture of various types of water treatment membranes make the treatment of process water and troublesome waste streams such as mine tailings, milling wastes and acid mine drainage often containing hazardous constituents such as selenium and NORMs much more cost effective from both a capital and operations viewpoint. This paper will examine conventional treatment methods used in mining processes including “floc and drop” systems, mixed media filters and ion exchange, but will focus on the use of new generation ceramic and polymeric Microfiltration, Ultrafiltration and Reverse Osmosis membranes to increase re-use opportunities, protect the environment and reduce life cycle expenses for various mining facilities. Additionally, this paper will discuss existing mining facilities that are currently using membranes to both desalinate source water and treat the process waste stream to acceptable reuse limits.

4:25 PM
**Use Of Ion Exchange Resin for Process Water Treatment**
I. Can, O. Bicak, S. Ozzeik, M. Can and Z. Erkmecon; Mining Engineering, Hacettepe University, Ankara, Turkey

In flotation plants, water from tailing is generally recirculated with some fresh water as make up water. Water chemistry is influenced by the type of minerals in ore, reagent scheme and environmental conditions. Reducing concentration of some of the ions, which adversely affect flotation performance and operation is usually more beneficial for flotation performance than complete cleaning. In this paper, use of ion exchange resins as an economical and practical method for decreasing concentrations of problematic anions in the process water was investigated. The adsorption tests with synthetic plant water samples were performed using a laboratory scale column filled with anionic resin. The results showed that surface modification of the resin from Cl- to OH- form was essential. Following adsorption tests with synthetic plant water samples were performed using a strong base type ion exchange resin was found more beneficial for flotation performance than complete cleaning. In this paper, modification of the resin from Cl- to OH- form was essential. Following adsorption tests with synthetic plant water samples were performed using a strong base type ion exchange resin was found more beneficial for flotation performance than complete cleaning.
Monday, February 24
Afternoon

2:00 PM • North 128 B
Foundations of AI in Mining
Chair: A. Scott, GMG, Toronto, ON, Canada

2:00 PM
Introductions

2:00 PM
Foundations of AI in Mining
A. Scott; GMG, Toronto, ON, Canada

The mining industry is increasingly using AI-based innovation as a tool to optimize processes, enhance decision-making, derive value from data, and improve safety. That said, levels of maturity vary throughout the industry and there is still confusion about what AI is and how it can be applied to mining. As a result, mining operations still face many challenges with implementing AI, such as establishing a data infrastructure. Many mining stakeholders also have concerns about how AI will affect the workforce; they also worry about the risk of committing to a multi-year project and failing at it. This panel session will cover the basics needed to cut through the hype, address concerns, and clarify what methods are useful.

3:15 PM
Enabling the Mine of the Future
H. Ednie; Global Mining Standards and Guidelines Group (GMSG), Howick, QC, Canada

This panel will address a unified vision of where the industry needs to head based on common priorities such as safety, sustainability, productivity, and workforce of the future. To achieve this vision there are a number of key developments that are required such as autonomous mining and electric mine realized through enablers including AI, asset management, interoperability, cybersecurity, communications, and KPIs - all critical ingredients of tomorrow’s advanced mines. This panel will focus on practical approaches to achieving this vision.

Monday, February 24
Afternoon

2:00 PM • North 127C
Health & Safety: Recent Advancements in Mine Health and Safety Solutions
Chairs: V. Matthews, Siemens, Alpharetta, GA; A. Lashtari, CleanAir Engineering, Pittsburgh, PA; M. Scholl, Envirosuite

2:00 PM
Introductions

2:05 PM
Tailings Performance Management using Drone Technologies
D. Gehring; Newmont Goldcorp, Greenwood Village, CO

Recent global tailings storage facility failures indicate that step changes in operational performance are needed across the mining industry. Drone technologies provide an important opportunity to improve data collection accuracy and efficiencies allowing companies to utilize engineers and operators more effectively in managing tailings performance. Tailings storage facilities stability performance is monitored and evaluated through a variety of data outputs including visual inspections, piezometer and inclinometer readings, survey points, reclaim pond levels and now increasing using satellite and drone technologies. Reliance on visual inspection for many of early warnings of seepage, deformation or pipeline leaks is time consuming and potentially less accurate than other imaging technologies now available through drones. This presentation will provide an overview of how drone technologies piloted at the Newmont Goldcorp Boddington can provide significant improvements in operational effectiveness and improved accuracy in deformation monitoring, construction survey volumes, identification of seepage areas, deposition and freeboard monitoring, and reclaim pond volume monitoring.

2:25 PM
Back to Basics Approach with a Twist of Technology
S. Kramer and M. Kruger; Freeport McMoRan, Phoenix, AZ

In today’s world of digital, big data and emerging technologies we have many more options to add to our health and safety toolbox. However, there are so many emerging technologies it can get overwhelming and difficult to assess the best options. Sometimes those options are nice to have but they aren’t necessary or may even distract from the core health and safety efforts. Adding the latest technology doesn’t guarantee improvement. You need a good solid foundation to your H&S systems. We will share our approach of how we use technology to meet our strategic objectives. Rather than run after every new shiny gadget, we first ask, what are we trying to accomplish and is there technology to help us get there quicker, more efficiently or that will make for a safer workplace? Learn how we are using technology to accomplish our strategy while keeping a back to basics approach to our health and safety efforts and some of the indirect ways AI and agile methodology in our operations are driving positive safety performance.

2:45 PM
Digitalization of safety, health and environment through the OiS solution
C. Badenhorst; Safety & Sustainability, Anglo American, Johannesburg, Gauteng, South Africa

The Anglo American Operational Intelligence Suite (OiS) aims to achieve real-time visualization of workplace conditions and controls, enabling proactive response to potential risk situations through quicker and easier access to information. OiS uses an event-centric approach to deliver information that empowers employees, front-line supervisors and subject matter experts to make better decisions, based on complete and actual information, as the starting point for further analysis. OiS eliminates lag times from measurements and create the ability to measure both workplace conditions and control performance together, in real-time to enable prompt response when conditions or control performance are substandard. Sensor data pertaining to the workplace environmental conditions and controls are consolidated into a single dashboard enabling key stakeholders to act promptly on any deviations including the immediate investigation of failed controls and rectification without delay. It furthers allows for predictive performance-based monitoring and maintenance of controls.

3:05 PM
Comparing the Performance of Self-Contained Self-Rescuers Approved to NIOSH's Old and New Requirements
S. Moore, G. Walbert and P. Yorio; National Personal Protective Technology Laboratory, NIOSH, Pittsburgh, PA

Self-contained self-rescuers (SCSRs) protect mineworkers when breathing air is compromised. These devices must be approved for use in the U.S. by the National Institute for Occupational Safety and Health (NIOSH) under 42 CFR Part 84. Prior to January 2016, approval requirements were defined in Subpart H and subsequently have been redefined in Subpart O after addressing several performance concerns. The protective benefit of SCSR that meet the Subpart O requirements has not yet been demonstrated. This study compares performance characteristics of Subpart H and O devices sampled from active mines and explores the impact of deployment location and deployment time.

3:25 PM
Changes to MSHA’s Workplace Examination Rule: Practical Implications & Best Practices
A. Abrams; Law Office of Adele L. Abrams PC, Beltsville, MD

MSHA's workplace examination rule for metal/nonmetal mines has been in place since the first efforts by the agency to strengthen requirements, via policy, in 1975. The 1970s era rule was the subject of rulemaking during the Obama administration, with a final rule issued in January 2017. That rule is currently in litigation in the US Court of Appeals, 11th Cir., brought by multiple mining industry litigants in the US Court of Appeals, 11th Cir., brought by multiple mining industry
groups. In the Trump Administration, the 2017 rule was reopened, and substantive changes were made to relax inspection and recording requirements. A final rule, issued in April 2018, took effect but was also the subject of litigation brought by mining unions. In June 2019, the US Court of Appeals, DC Cir., held that MSHA’s 2018 rule was invalid because it reduced protections for miners. This action now has significant enforcement implications on what will be required going forward to comply with 30 CFR 56/57.18002. Learn the latest on enforcement, policy, and legal status, as well as best practices for protecting miners through diligent examinations and audits.

3:45 PM
Increasing Safety Using IoT-Based Solutions for Mine Tailings Monitoring
M. Risco¹, M. Momayer¹, M. Saavedra², C. Aguiller² and P. Campos³; ¹Mining and Geological Engineering, The University of Arizona, Tucson, AZ; ²Electrical and Electronics Engineering, Universidad del Bio Bio, Concepcion, Chile and ³Sistemas de Informacion, Universidad del Bio Bio, Concepcion, Chile

Safety has become an integral part of every mining activity. It also includes hazard identification and prevention during all stages of production. Past and recent failures in tailings storage facilities around the world have raised the awareness and the need for improved disposal of mining waste and monitoring techniques. However, a holistic approach and reliable commercially available instrumentation to evaluate the stability of tailings structures are currently lacking. Advances in new technologies, such as wireless sensor networks, computer vision systems and drone-based data acquisition offer exceptional opportunities to automate and improve the process of collecting and analyzing environmental and engineering factors that can affect the overall stability of mine tailings. In this paper, we present a design proposal for an Internet of Things (IoT) based solution which uses low cost sensors, data fusion and data analytics techniques. Our proposed system can be easily integrated into existing mine wide data infrastructures, and will provide real time alerts and proactive maintenance strategies in order to minimize risk in the future.

4:05 PM
Role of Innovation and Technology in Framing the Future of Mine Health and Safety
A. Lashgari; CleanAir Engineering, Pittsburgh, PA

Health and safety have been of primary importance for the mining industry in the past few decades. Yet, the industry is facing serious challenges in addressing some of the outstanding issues. In the past years with the fast development of technology, innovative solutions have been introduced to improve the health and safety of miners. A discussion around the theme of innovations and new technologies in mine health and safety will be held at the end of this session will all the participants. The focus of this discussion is to gather executives, mine professionals, and researchers to discuss recent advances, existing needs, and future trends in mine health and safety.

Monday, February 24
Afternoon

2:00 PM • North 128 A
Beneficiation and Physical Separations in Industrial Minerals & Aggregates I

Chairs: S. Saurabh, Millcreek Engineering Company, South Jordan, UT R. RAITANI, USG CORPORATION, Buffalo Grove, IL

2:00 PM
Introductions

2:05 PM
Practical Vacuum Filtration
J. Peterson¹ and G. Peterson²; ¹Engineering, Peterson Filters, Salt Lake City, UT and ²Field Service, Peterson Filters, Oak Hill, WV

John G. Peterson Peterson Filters Corporation ABSTRACT The last few decades have seen a decline in the engineering knowledge base and the use of practical vacuum filtration. This is due to the use of alternative liquid-solid separation technologies and fewer young professionals being made aware of the art of vacuum filtration technology. This paper will attempt to counter this trend by presenting the basics of practical vacuum filtration to the young engineer so they can develop a more balanced approach to solving liquid-solid separation problems. It will also cover a brief history of vacuum filtration and why its simplicity remains economical and practical. The paper will review the criteria used for the selection of vacuum filtration and why it is a practical solution, as well as techniques that will enhance the filtration process. It will also touch on those cases when other separation means should be considered instead of vacuum filtration. The paper will close with a discussion of the economic aspects and challenges posed by vacuum filters and the associated ancillary equipment.

2:25 PM
Dewatering Agents for Iron Ore and Bauxite
W. Da Silva, P. Fernandes, P. Rollo and L. Bicalho; Clariant, The Woodlands, TX, Brazil

Operations have been demanding increasingly challenging operational targets for dewatering processes, requiring lower humidity for concentrates and higher productivity for tailings disposal. Therefore, CLARIANT developed a new range of dewatering reagents. The aim of this paper is to address the reagent effects on dewatering processes for iron ore and bauxite. Clariant reagents substantially decreased the moisture of iron ore sinter feed (particle size 0.150 – 6.3 mm) and granulated bauxite (particle size > 3”). The results of these laboratory scale tests and industrial trials realized a 2-4% (absolute) moisture reduction, which reinforced the strong interaction between Clariant dewatering agents and particle surfaces of iron ore sinter feed and granulated bauxite. Filtration tests with iron ore pellet feed (particle size < 0.150 mm) in laboratory and industrial scale showed that use of Clariant filter aids substantially reduced the cake moisture, while enhancing the filtration rate. These test results achieved 3-5% (absolute) moisture reduction. Also, Clariant dewatering agents did not present any undesired foam formation on concentrate and tailings filtration and ore handling.

2:45 PM
Filter Revamping, the Economic Way to Get Old Filters Back on Track
J. Hahn; Sales, BOKELA GmbH, Karlsruhe, Germany

Rotary filters in coal, mineral and ore processing plants are often not operated under optimal conditions and the results do not meet expectations because they are operated up to their capacity limit or beyond. Reasons can be increased production rates, higher quality requirements or a change of product characteristics like the particle size distribution. In this case, it must be decided whether the production target should be achieved with a new filter or by optimizing the existing filter system. To answer this question it is necessary to evaluate the potential for
improvement and to have ideas as to which concrete measures are to be taken for an effective filter modification. The optimization of running filters with the BOKELA filter revamp program is a very economical alternative to new investments. With this revamping program inadequate performance, excessive maintenance and high operating costs of existing filters can be quickly and inexpensively eliminated. Benefits include: a 30% to 135% increase in filtration capacity, improved cake moisture, improved filter operation and reduced maintenance. However, the costs amount only some 20% to 30% compared to a new investment.

3:05 PM
Correlative Tomography for 3D Multi-Phase Structure in a Phosphate Ore
R. Macver and M. Pawlik; Mining Engineering, University of British Columbia, Vancouver, BC, Canada

Organic matter is a challenging gangue found in the phosphate ore deposits of the mid-western United States. Typical flowsheets that include washing and sizing or flotation do not address recalciarant organic matter, while roasting is a less desirable option due to environmental concerns. This paper describes the application of a correlative tomography method to visualize the 3D structure of the mineral, organic, and pores phases in an organic-rich sedimentary phosphate ore. Scanning electron microscopy with energy dispersive X-ray was used to identify the mineralogy, which was then correlated with the macro-scale 3D images obtained by micro-computed tomography measurements. The results show the phosphate ore has a granular texture, which is caused by the aggregation of porous, 100 - 300 micron sized phosphate grains. The organic phase is mostly found in the interstitial spaces with other gangue minerals such as clay and silica.

3:25 PM
An Overview of Calcite Beneficiation by Flotation
P. Dhar, M. Thornhill, I. Chernyshova and H. Kota; Department of geosciences and petroleum, Professor, Trondheim, Norway

In general, precipitated calcium carbonate (PCC) is commonly used as mineral filler in paper industries; while natural calcite material can also be used in industries if it is a finely ground with a little or no impurities. In northern Norway, a very high-grade calcite deposit is located and this material can be used as mineral filler in various industrial products. However, this calcite material contains two types of typical impurities: i) graphite and silicates, and ii) pyrite and pyrrhotite, depending on the location in this deposit. These impurity minerals can be recovered by froth flotation process using alkyl amines and xanthate collectors. However, xanthates are toxic and hazardous and due to strict environmental and health controls in Norway, their use in the purification of calcite is not acceptable, in particular of its end-use in papermaking. Accordingly, for a judicial choice of reagents in flotation, various reagent schemes that were used for both high and low-grade calcite ores beneficiation in the literature has been reviewed and presented in this article.

3:45 PM
Determination of Particle Adhesion for the Development of a System for Sustainable Mineral Beneficiation
B. Moreno Baqueiro Sansao, J. Kellar, W. Cross, A. Romikes and K. Schottler; *Materials Engineering and Science, South Dakota School of Mines and Technology, Rapid City, SD; 2*Mechanical Engineering, South Dakota School of Mines and Technology, Rapid City, SD and 3*Department of Materials and Metallurgical Engineering, South Dakota School of Mines and Technology, Rapid City, SD The mineral industry uses tremendous amounts of water every year in the processing of ores. Sustainable practices associated with the processing of ores is of critical importance. This research evaluates a dry particle separation process based upon adhesive forces. Glass spheres were chosen to represent silicate minerals. Disks and beads were surface treated with trichlor(octadecyl)silane (TCOD) and trimethoxysilylpropyl diethylenetriamine (TMPA). A horizontal impact test was designed to measure the adhesion force between the spheres and a glass disk substrate. Impact of the disk/particle puck causes particle removal as tensile forces act on the particles. The tensile detachment force and adhesive force are equal at a critical particle size. The Johnson-Kendall-Roberts theory was used to determine the particle-substrate interfacial energy. The average interfacial energy of pure glass, glass treated with TCOD and with TMPA were 48.5 mJ/m2, 21.6 mJ/m2 and 40.1 mJ/m2 respectively, which are in good agreement with literature values. The van Oss-Good-Chaudhuri method was used to measure the surface energy of microline and quartz in order to evaluate the results of glass impact tests.
3:05 PM
Assessing The Feasibility of a Commercially Available Wireless Internet of Things System to Improve Conveyor Safety
R. Jacksha and K. Raj; Spokane, WA, CDC NIOSH, Spokane, WA
Conveyor systems for sand and gravel operations persist in being a source of injuries and fatalities in the mining industry. To reduce these incidents, better methods are needed to enhance the monitoring of probable hazards and improve situational awareness during the normal operation and maintenance of conveyor systems. To address these issues, researchers from the National Institute for Occupational Safety and Health (NIOSH) continue to investigate emerging technologies which show the potential to improve miner safety around conveyors. This paper presents a feasibility assessment by NIOSH researchers of a fully integrated commercially available Internet of Things (IoT) system to improve situational awareness around conveyor systems. Included are discussions of a full scale laboratory test bed that was designed to simulate a working conveyor system as well as the challenges and successes of integrating the IoT system with the test bed.

3:25 PM
Developing a Novel Application for High-Resolution Imaging and Tension Cracks Monitoring at Open Pit Mines using Unmanned Aerial Vehicle
J. Sattarvand and R. Battulwara; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV
With the open-pit mines becoming bigger and deeper around the globe, it has become essential to identify the cracks and monitor them for analysis of potential failures in a more efficient way. This NIOSH supported research work presents a new technology for remote detection of tensions cracks in US open-pit mines using a UAV and artificial intelligence. Firstly, a novel android application has been designed and programmed for collecting high-resolution images of an area in open-pit mines. Secondly, tension cracks are automatically detected from these images using photogrammetry and state-of-the-art machine learning techniques.

3:45 PM
Potential of 3D Computed Tomography for Industrial Waste Agglomerates
M. Firsching¹, J. Lucic², R. Wagner³, C. Bauer³, B. ORBERGER³, A. Ennen³, J. Dubos⁴, J. Banchet⁵ and J. Milazzo⁶; ¹Fraunhofer EZRT, Fürth, Germany; ²Catura Geoprojects, Paris, France; ³ERAMET IDEAS, Trappes, France and ⁴EUROTAB GROUP, St Just-St Rambert, France
Mine and processing wastes often present secondary raw materials. For recycling, these wastes need to be agglomerated prior to reprocessing. Agglomerates must mechanically withstand transport, mechanical loading and introduction into the reactor. X-ray computed tomography (CT) on agglomerates gives information on porosity, density, grain size distribution and fractures, which are important factors deteriorating the agglomerates. We studied binder-free tablets of manganese oxyhydroxide, bentonite, kaolinite and slag powder right after production and after 3 months aging. Visible cracks were analyzed and the distribution of highly absorbing particles was investigated. Further, the iron content in the slag agglomerates could be determined. Acknowledgment: This study was performed in the frame of the KIC-EIT ANCORELOG project led by DMT, Essen, Germany (Carlos Garcia Pina) and GO40 project led by ERAMET (Jean Michel Milazzo).

2:00 PM • North 125B
Industrial Minerals & Aggregates: Innovations in Industrial Minerals and Aggregates I

2:05 PM
Pozzolans-Part III: Characterization And Determination on the Degree of Reactivity and Crystallinity of the Pozzolan Reaction for Natural and Synthetic Minerals on a Microscope using Laboratory Instrumentation
G. Tomaino; Minerals Technologies Inc, Easton, PA
This talk and experiments adds to previous work presented in 2018 and 2019 on the characterization and determination on the degree of reactivity and crystallinity for the pozzolan reaction [AS + CH + H₂O → C-S-H and C-A-H-J] on a microscope using laboratory instrumentation. Additional experiments for natural and artificial pozzolans along the saturated vapor pressure-critical point for H₂O at 250°C under isothermal conditions will be evaluated and findings compared to upper limit 350°C experiments from Part II work. Characterizations utilizing XRD, TGA-DSC and TGA-DSC with specialized pressure-DSC crucibles that are capable of achieving low pressure (100 bar) and intermediate temperature (≤ 500°C) processing conditions.

2:25 PM
The Role of Natural Zeolites in the Changing Market for High-Performance and Low CO₂ Producing Cement Raw Materials
D. Eyde; St Cloud Mining, Tucson, AZ
Cement production uses huge amounts of heat and energy. It is responsible for 7% of man-made carbon dioxide emissions. If a country the industry would trail only the United States and China in emissions of the greenhouse gas. One method of reducing CO₂ emissions is to incorporate zeolites into the cement product. One ton of CO₂ is removed for every two tons of zeolite used. St Cloud Mining Company (SCM) is the largest producer of natural zeolites in the Western Hemisphere. SCM has four natural zeolite deposits and one volcanic ash deposit. These deposits constitute the largest drilled out and characterized reserve of natural zeolites in the US. Both the Bowie and Ash Meadows deposits were qualified for specialty pozzolanic downhole cement. In 2017, additional test work confirmed that the Ash Meadows zeolite and volcanic ash meet ASTM standards. The closure of coal-fired power plants is creating a demand for alternative pozzolanic products. Natural zeolites and associated volcanic ash deposits are proven substitutes. More interesting is recent work showing that the SCM zeolites can form the mineral tobermorite in cementitious mixes creating a stronger more resistant cement product.

2:45 PM
Collateral Damage from the War on Coal: Can Natural Pozzolans Cost-Effectively Replace Fly Ash in Concrete
e. mears¹ and J. Carusone²; ¹Haley & Aldrich, Phoenix, AZ and ²Salt River Materials Group, Scottsdale, AZ
The war on coal, recent EPA regulation of Coal Combustion Residuals (CCR) and abundant natural gas are causing many coal fired power plants to retire. This is substantially impacting the availability and long-term security of fly ash, a by-product of coal combustion and a necessary ingredient in concrete and a carbon-friendly cement substitute. Many companies are looking towards mining natural pozzolans or harvesting legacy fly ash monoliths to supplement the fly ash market but there are substantial obstacles to cost-effectively mining and processing natural pozzolans or legacy fly ash deposits and getting them to market. This presentation will discuss the present-day landscape for fly ash
substitutes, characterize the challenges associated with the discovery, exploration and development of natural pozzolan deposits, discuss how market conditions affect the viability of high quality pozzolan resources and how fly ash marketers are preparing for the future needs of the ready mix industry.

3:05 PM
Creating Revenue From Mining Byproducts and Discharge Streams
K. Anderson; Kraemer Mining & Materials Inc, Burnsville, MN
Mining and Processing of Aggregates and Industrial Minerals typically create byproducts and discharge streams. In some cases these discharges streams and byproducts can create an opportunity for direct or indirect additional revenue. By working with governmental entities and businesses in the area of their operation there may be opportunities for beneficial use of byproducts and some discharge streams. A review of a successful approach to work with state and local government to create a beneficial use of a discharge stream and sales of a byproduct will be discussed along with upcoming additional opportunities and challenges that the project presents. These innovations not only can be economically beneficial for the company but can create better relationships between the industry and government/public going forward.

3:25 PM
Best Practices - Condition Monitoring and Advanced Asset Health Tracking in Conveyor Belt Systems
E. Botelho and T. Prata; Process Industries - Mining, ABB, São Paulo, São Paulo, Brazil
Healthiness of a conveyor is largely determined through physical inspections at regular intervals and time-based maintenance. However, in many cases the conveyor belt damage happens between the actions causing huge production and time losses to the plants. The presentation purpose is to introduce how some traditional maintenance gaps on the conveyor condition based monitoring can be filled through the application of systematic failure modes monitoring, taking advantage of existing data and delivering valuable information about potential failures on the conveyor systems. The existing information on the traditional systems can be integrated providing a full-view, online dashboard for the maintenance teams embracing mechanic, electric and control. Main savings of predictive approach aligns with studies of the Dept. of Energy achieving up to 40% over reactive and 12% over preventive maintenance, extending the life of the assets and avoiding unnecessary people exposure to the field. A reliable maintenance time-window for a planned action and an enhanced condition-based approach, monitoring the conveyor main components as belt, motor, gearbox, drives and transformers are key benefits.

3:45 PM
Utilization of Stamp Sand from Copper Mining
T. Eisele; Chemical Engineering, Michigan Technological University, Houghton, MI
The history of copper mining in the Keweenaw Peninsula of Michigan left substantial deposits of “stamp sand” from the copper extraction process. This sand is now migrating into Lake Superior where it interferes with fisheries, and needs to be removed. Rather than simply transferring the sand to new dumping sites, it is desirable to find applications where it can be marketed, allowing it to be completely removed from the site. This presentation will consider the options for separating the sand into separate marketable products, potentially along with the recovery of additional copper.

Monday, February 24
Afternoon

2:00 PM • North 132A
International I: Women in Mining

Chairs: R. Furey, Stantec, Broomfield, CO V. Gosteva, Black & Veatch, Denver, CO

2:05 PM
Diversity Aspects in Global Mining Engineering Education
A. Binder1, A. Brickey2 and O. Langefeld3; 1Department of Underground Mining Methods and Machinry, Clausthal University of Technology, Clausthal-Zellerfeld, Germany and 2South Dakota School of Mines & Technology, Rapid City, SD
Diversity in a workforce can be understood to represent many different aspects. Whether it is diversity of gender, race, cultural background, or thought, it is something we hear is often lacking or limited in the mining industry. On the other hand, diverse teams are proved to be more productive. The presentation focusses on diversity in mining engineering education (MEE) and takes a deeper look at what this means in different global regions. We take a particularly close look at how gender diversity is being addressed and incorporated into education at a variety of universities throughout the world while highlighting challenges, approaches, successes, and lessons learned.

2:25 PM
Satisfaction Level of Female Stakeholders of Ghana’s Mining Industry
B. Kansake1, G. Barnes Sakyi-Addo2 and N. Dumakor-Dupey3; 1Mining and Nuclear Engineering Department, Missouri University of Science and Technology, Rolla, MO; 2Georgette Barnes Limited, Accra, Ghana and 3Safety and Environmental Research and Consultancy Limited, Accra, Ghana
The mining industry is male-dominated. Previous studies show that females constitute 20% of Ghana’s mining workforce. Efforts are being made by educational institutions, mining companies, and professional organizations to attract females to the industry. To understand the reasons for low female participation in the industry, we undertook a survey that sought to identify challenges faced by female stakeholders in Ghana’s mining industry. The study focused on sexual harassment, gender-based discrimination, and availability of support facilities for handling these challenges. Ultimately, we seek to suggest ways that will create a conducive work atmosphere to encourage female participation in the industry.

2:45 PM
Women in Mining in Unexpected Places: How leadership by Women in Post-Conflict and Frontier Markets is Changing the Face and Backbone of the Mining Industry
E. Scott; Global Venture Consulting, Fort Lauderdale, FL
Western mining professionals and companies often think that it will be difficult to have women employees and leadership work in emerging and frontier market countries, in particular culturally and religiously conservative ones. Emily King will speak about her experience leading exploration efforts, transaction advisory teams and facilitating investments in Afghanistan, Libya, Algeria, Mexico and others. Emily will share lessons learned - challenges and tools - from her career and seeing first-hand that having female leadership of challenging technical projects in these markets opens new doors for women in the mining industry. Her experiences will show the opportunities that exist and should be pursued by developing companies and mining companies alike.
3:05 PM
Practical Approaches to Advancing Diversity in Mining Companies
T. Albanese; Director, Nevada Copper & Franco-Nevada, Neshanic Station, NJ
The importance of diversity and inclusivity has been widely accepted by many in the mining sector. Moreover, being a leader in D&I is a competitive advantage for enticing investors and being able to attract top talent in modern times. As a business imperative, mining companies need to figure out ways to accelerate their diversity agenda efforts. This presentation will discuss the role of senior management in achieving diversity goals in the company and organization. Practical approaches for efficient application of D&I principles will be addressed from the global mining business perspective.

3:25 PM
Newmont Goldcorp’s Inclusion and Diversity Journey, A CEO’s Perspective and Call to Act
G. Goldberg and B. Opoku-Asare; Newmont Goldcorp, Greenwood Village, CO
Newmont Goldcorp has committed to gender parity in senior leadership by 2030 through the Paradigm for Parity coalition. The tactics to achieve this objective are focused around the company’s value of inclusion and Global Inclusion and Diversity Strategy. This session will focus on Newmont Goldcorp’s inclusion and Diversity journey since Chief Executive Officer Gary J. Goldberg joined the company in 2011. Gary will share both Newmont Goldcorp lessons and his personal lessons on this journey and propose some critical next steps for making industry-wide progress to build an industry with an inclusive culture and a place where everyone can thrive.

3:45 PM
CEO Panel Discussion: Diversity in Mining – What Works?
R. Furey¹ and V. Gosteva²; ¹Stantec, Broomfield, CO and ²Black & Veatch, Denver, CO
Panel: T. Albanese, former CEO of Rio Tinto and Vedanta; G. Goldberg, former CEO of Newmont Goldcorp and Rio Tinto Minerals; E. Smith, CEO of Global Venture Consulting. Moderators: R. Furey, Stantec; V. Gosteva, Black & Veatch CEO panel discussion focused on proven strategies and tactics that advance diversity goals within the mining industry. Panelists will delve deeper into corporate programs and efforts that work and the ones that don’t as well as share personal perspectives. Panelists will be asked to share their views on such less discussed topics as ‘niceness’, ‘personal trade offs’ and others, and the differences of how these softer, more personal aspects play into career development for women and men. Panel moderators: R. Furey and V. Gosteva.

Monday, February 24
Afternoon

2:00 PM • North 222A
Mining & Exploration: Geosciences: Geology: Integration Throughout the Mining Cycle
Chair: J. Baar, Rio Tinto Bingham Canyon, West Jordan, UT

2:00 PM
Introductions

2:05 PM
Integration of Mine Geology with Geotechnical Engineering, Metallurgy, and Mine Planning; How Knowledge of the Rocks can Add Value Across the Value Chain
m. sorensen, J. Gibbs and N. Vetz; Rio Tinto, South Jordan, UT
Geologists spend the majority of their working time in the field and are familiar with the pit and underlying rocks and structure. Mappers record mineralization, which allows them to make recommendations of assay density for ore control and geo-metallurgical decisions, as well as advice on areas for metallurgical sampling, and attend weekly meetings to discuss processing concerns. Rock quality metrics, alteration, and structure characteristics are compared with the Geotech department’s instrumentation during investigations of slope instabilities. Field data becomes an important part in determining the failure mechanism and pervasiveness, as well as making predictions of failure tonnage and the plausible extent of the instability. Geologic perspective and understanding has aided implementation of mine design and operational certainty of excavation of a failure mechanism during remediation, or certainty of a potentially hazardous structure not being day lighted in the current design.

2:25 PM
The Many Styles of Mapping: How Mapping can Impact the Mining Cycle
M. Moore¹ and W. Chávez²; ¹Maptek, Golden, CA and ²New Mexico Tech, Socorro, NM
Since the seventeenth century, geologists and engineers have been collecting geologic observations and generating geologic maps. Over the years, geologic mapping techniques, purposes, and impacts on the downstream mining cycle, and the importance of the associated data has fluctuated. These key geologic observations are often forgotten or overlooked in the evaluation process and general mining cycle, but incorporating this data is crucial to downstream efficiencies. This presentation will identify the various aspects of mapping in the mining cycle, outline the various purposes and techniques of mapping, and identify impactful ways of using the results throughout the mining cycle.

2:45 PM
The Temporal Relationship Between Magmatism, Hydrothermal Fluid Flow, and Gold Mineralization at Sedimentary Rock-Hosted Deposits in the Battle Mountain Mining District, Nevada: Using Today’s Data to Discover Tomorrow’s Deposit
D. Huff¹, E. Holley² and W. Guenther³; ¹Geology and Geological Engineering, Colorado School of Mines, Golden, CO; ²Mining Engineering, Colorado School of Mines, Golden, CO; and ³Engineering, University of Illinois at Urbana-Champaign, Champaign, IL
The Battle Mountain district contains gold deposits that show similarities to both magmatic-hydrothermal and Carlin-type deposits. Historic dating techniques misinformed the mining community’s interpretation of when and how these deposits formed, hindering new exploration and highlighting the importance of integrating new data into conceptual models across the mining life cycle. We studied the timing of magmatism and hydrothermal fluid flow in mineralized intrusions at five deposits in the district using zircon U-Pb geochronology and zircon-apatite (U-Th)/He thermochronology. Whole rock geochemistry of intrusions allowed us to assess the magmatic evolution of the district. Lone Tree intrusions are Eocene and hydrothermal fluid flow dates extend from the Eocene into the Oligocene. Zircon He ages reveal intrusions at Brooks are Cretaceous. Intrusions at Marigold-Valmy are dated as Cretaceous, but display Eocene hydrothermal fluid flow ages that overlap with the emplacement of intrusions at Lone Tree. Trenton Canyon Au has an Eocene zircon He age, but Cretaceous to Mid-Eocene apatite He ages. We report thermochronology ages for the margins of the Trenton Canyon stock here.

3:05 PM
The White Mica 2200 nm Spectral absorption Feature; Significance in the mining Cycle, and Imaging Spectrometer Design Considerations
J. Meyer¹, E. Holley¹ and R. Kokaly²; ¹Mining Engineering, Colorado School of Mines, Golden, CO and ²Spectroscopy Laboratory, United States Geological Survey, DENVER, CO
White micas are hydrothermal alteration products commonly found in ore deposits. Information regarding characteristics of white mica minerals in a deposit is useful in exploration, mineral processing, and ground control design. Variations in white mica chemical composition shift the position of the 2200 nm Al-OH combination absorption feature while variations in modal abundance of white mica change the depth of this feature. Numerous past studies show these parameters are discernible with imaging spectroscopy. Our sensitivity analysis revealed that a 10 nm bandpass and sampling interval or finer is required to accurately determine these parameters with imaging spectroscopy.
3:25 PM
Sulfide Trace Element and Isotope Compositions as Indicators of Fluid Source Characteristics in Carlin-Type and Carlin-Like Gold Deposits
A. Fulton1 and E. Holley2; 1Geology and Geological Engineering, Colorado School of Mines, Golden, CO and 2Mining Engineering, Colorado School of Mines, Golden, CO

Nevada’s Carlin-type deposits lack a validated genetic model despite being among Earth’s largest gold producers. This study aims to resolve fluid and metal sources for Carlin-type-/like deposits from Nevada and the Yukon by comparing ore-stage sulfides to determine if any systematic trace element/isotopic signatures exist. The deposits could be connected to a magmatic source if they exhibit magmatic δ34S values or if they can be linked in time and space to distal disseminated deposits that have magmatic δ34S in ore-stage sulfides. This work may serve as a valuable tool in future exploration for Carlin-type gold in Nevada and beyond.

3:45 PM
Correlation of 3-D Geophysical Data with Drilling Data for Exploration Targeting
A. Irons; Gustavson Associates, Littleton, CO

3-D geophysical data can be of significant benefit within the mining industry for early stage exploration. It is less frequently used in advanced stage projects, but there are instances where re-combining original geophysical data with closely spaced drilling information that can lead to new insights. This paper will present a study of a Central Nevada gold project that demonstrates integration of geophysical data with drilling and interpretations to enhance the understanding of deposit geometry and effectiveness of exploration targeting.

4:05 PM
Integrated Geological Modeling: The Key to Success at Miski Mayo Mine
J. Sanchez and J. Lyons-Baral; Hexagon, Tucson, AZ

Miski Mayo Fosfatos de Bayóvar is a phosphate mine producing agricultural nutrition products. They recently upgraded to an integrated geological modeling platform and away from a manual workflow. From spending much of their time trying to integrate data from various sources requiring extensive validation. They used paper logs and Excel spreadsheets modeling through direct triangulation of drillhole intercepts. Now, using an integrated 3D geology platform with: SQL database for drillhole and sample management with a 3D viewer for managing and compositing; geostatistical and drillhole correlation analysis tools; explicit and timeline-based implicit geological modeling tools that honor true-thickness and paleo event timelines; resource estimation using kriging and resource validation and classification; and a 3D variable height gridded seam block model, the results have been significant. They have optimized their workflow and recovered 30% of their time. Time used to make deeper analysis and geological interpretation. Data integrity and security improved with true permission-based database programs and fully integrated data transfers. Geologists get more accurate results in less time.

4:25 PM
Definition and Infill Drilling Methods, Pros and Cons and Alternative Sampling Methodologies, Pros and Cons to Thinking Outside the Box
K. Rodenrick; Member, Montrose, CO

In the mining industry, we are constantly reminded of our need to generate free cash flow from our operations. This means running lean and mean and efficient. Ensuring the delivery of high quality ore to the mill, minimizing waste and optimizing the ore body are all key aspects of the role of geology in the production phase of the mining cycle. In this talk, we will discuss some case studies of alternative drilling methods for infill and grade control. There are places where core drilling is not the most effective method for definition drilling and RC drilling can deliver accurate results in a more efficient manner. Additionally, this talk will review alternative analytical methods for sample analysis that accurately and cost effectively can characterize the samples.

4:45 PM
Seismic Velocity Changes in an Underground Narrowvein Mine
S. Ghaychi Afrouz1, E. Westman1, K. Dehn2 and B. Weston3; 1Mining, Virginia Tech, Blacksburg, VA; 2NIOSH, Spokane, WA and 3Americas Silver Corporation, Wallace, ID

Time-lapse passive seismic tomography collected from an in-mine microseismic monitoring system is used to evaluate changes in stress conditions around five major seismic events that occurred in one year in a deep narrow-vein mine. The tomographic analysis identified zones of high seismic velocity around the mining areas which is a proxy for increases stress loading of the rock mass. The daily average seismic velocities from the high-stress zones are compared to identify if there are similar velocity profiles both before the events and after to determine the effects of the major events on the stress loading in the area. The results indicated a consistent trend of velocity decrease within four days prior to all events in at least one of the proximal high-velocity zones. This study indicates a strong potential for the method to help identify areas with an increased seismic hazard potential in the future that mine operators can use to improve safety for mining operations.

2:55 PM
J. Monsalve, A. Pfreundschuh and N. Ripepi; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

Rock mass characterization and structural mapping are fundamental to identify possible rock fall hazards in excavations presenting structurally controlled instability. In the past years, advances in remote sensing techniques such as photogrammetry and LiDAR have allowed engineers to generate millimetric-precision point clouds that have been proven to be useful for the above mentioned applications. Along with these remote sensing techniques a series of point cloud processing tools and algorithms have been developed to aid during rock mass discontinuity mapping, including both manual and automated discontinuity extraction codes. This work reviews and compare automated discontinuity extraction software with manual virtual discontinuity mapping software. A comparison between the manual and automated software is performed based on reviewing orientation, trace length, spacing, number of extracted discontinuities, and processing time. In addition, recommendations on virtual discontinuity mapping are presented.

2:25 PM
Risk Based Slope Monitoring Guidance Process
R. Sharon2, C. Williams3 and B. Ross1; 1Geotechnical Center of Excellence, University of Arizona, Tucson, AZ and 2Sharon Geotechnical Services, Tucson, AZ

This paper describes a new Risk Based Slope Monitoring Guidance (SMG) process that has been developed to aid engineers in the design of slope monitoring systems for open pit mines. The SMG process is a method that rates the geotechnical conditions as well as the design and slope performance of an open pit operation to determine a Slope Stability Rating that addresses the likelihood of an unwanted geotechnical event occurring in each defined slope sector of an open pit. The Slope Stability Rating is combined with the Consequence Rating from a mining operation’s risk assessment process to determine an overall Risk Rating for each
Various Rock Properties

A Correlation Between Schmidt Hammer Rebound Numbers with Various Rock Properties

M. Khandelwal; Federation University Australia, Ballarat, VIC, Australia

In this paper, an attempt has been made to establish statistical correlation between Schmidt hammer rebound numbers with P-wave velocity, uniaxial compressive strength, Brazilian tensile strength, Protodyakonov index, Impact strength index, Skahe Durability Index and density of different rock types. These properties are crucial to characterize a rock mass and are being widely used in geological and geo-technical engineering projects. Due to its importance, Schmidt hammer rebound number is considered as one of the most important property for the determination of various physico-mechanical properties of different rock types of Igneous, sedimentary and metamorphic rocks. It takes lot of time, effort, energy as well as expertise is required to determine these properties, whereas Schmidt hammer rebound number can be easily get on site, fast and reliable. The sample preparation is also not required while determining Schmidt hammer rebound values, which is another added advantage. So, here simple, fast and easy to use correlations will be developed between Schmidt hammer rebound numbers with various rock properties.
A cooperative robotic system incorporating time-lapse hazard mapping from in situ monitoring with advanced remote sensing on mining and metallurgical sites. This site-scale approach allows for large continuous areal mapping of discrete mineralogical boundaries on the ground. Preliminary results indicate that this technique is capable of rapidly mapping the surficial distribution of spectrally active minerals (clays, other phyllosilicates, carbonates, sulfates) on highwalls, leach pads, dumps, and other areas of mapping interest. The coupling of a LiDAR unit on the UAV also delivers accurate 3D topographic digital surface models tied to hyperspectral orthomosaics. The accurately mapped continuous 3D mineralogical data allows for informed site decision-making and planning for ore control, mineral processing and slope stability.

Mapping Surface Moisture Distribution of Heap Leach Pad Using Unmanned Aerial Vehicle
M. Tang and K. Esmaeili; Civil and Mineral Engineering, University of Toronto, Thornhill, ON, Canada

Understanding of the spatial and temporal variations of surface moisture content over a heap leach pad (HLP) is essential for leaching production and to achieve a high ore recovery. The current practice of leach pad monitoring and data collection remains highly manual which is labor-intensive and exposes technical staff to hazardous material (e.g. cyanide solution). To address these challenges, we propose using unmanned aerial vehicles equipped with thermal imaging sensors to remotely obtain image data with high temporal and spatial resolutions for monitoring surface moisture distribution over HLPs. A field study was conducted over a sprinkler-irrigated HLP at El Gallo Mine, and the acquired data were used to derive an empirical relationship between the surface moisture content and the remotely sensed surface temperature using linear regression. Moreover, the data were used to generate moisture distribution maps over the entire HLP. In-situ samples were taken manually during the field experiments to measure the ground-truth material moisture at selected sampling locations. The results show a good agreement between the remote sensing method and the measured ground-truth samples.

Autonomous Robotic Early Warning System for Underground Stone Mining Safety
I. Tulu¹, J. Gross², Y. Gu² and G. Pereira²; *Mining Engineering, West Virginia University, Morgantown, WV and *Mechanical and Aerospace Eng., West Virginia University, Morgantown, WV

In general, underground stone mines experience good ground stability. However, in these mines, previously mined sections stay open for the life of the mine and subject the pillars to time-dependent degradation. In a recent massive pillar collapse in an old section of the Whitney mine, three miners were injured due to an air blast. This incident highlights the potential safety impact on the miners in underground stone mines from unstable abandoned areas. This paper introduces the development of an enhanced monitoring and warning system for old workings in underground stone mines using an autonomous robotic system that is comprised of an Unmanned Aerial Vehicle (UAV) tethered to an Unmanned Ground Vehicle (UGV). This combination of remote vehicles can optimally provide high-resolution 3D maps, which are then used as input to an early warning system that incorporates time-lapse hazard mapping from in situ monitoring with the advanced state-of-the-art cooperative robotic system.
GMD Cycloconverter Control Upgrade - Barrick Goldstrike  
M. Perrucci; ABB Switzerland, Baden-Daettwil, Aargau, Switzerland

Obsolescence is one key topic that needs to be addressed by maintenance teams in mining operations. With the advancements in technology, especially on the control and automation fields, sometimes it is necessary to upgrade the existing system to prevent major downtimes due to e.g. threats on cyber security. In Gearless Mill Drives application, the Cycloconverter that drives the ring motor has a control system that, in the recent case of Barrick Goldstrike, had to undergo a control upgrade. This presentation shows the highlights and the challenges of the control upgrade at Barrick, where operators received a modern, very fast and state-of-the-art technology platform, including several new useful functionalities.

Design, Development, Construction and Commissioning of the Stillwater Mine’s Blitz Sand Backfill Plant  
B. Spencer; Engineering, Sibanye Stillwater, Fishtail, MT

The design of the Stillwater Mine’s Blitz Sand Backfill Plant involved optimizing the plant location between available delivery envelope, geologic structures and planned access in addition to the capacity to meet both current and expected backfill demand capacities. Lessons learned from previous sand backfill plants and other construction projects were leveraged to develop a plant that meets the needs of both operators and maintenance personnel. The plant design included multiple storage silos, positive displacement pumping system, the opportunity to remote/autonomous operation and included growth options for expanded delivery capacity and the creation of underhand quality fill. Project execution and control was carried out through a standardized project management framework being implemented at the Stillwater Mine. The project management framework covers the management of scope, schedule, cost, personnel, changes, commissioning and lessons learned for the benefit of all future projects. An overview of the completed project along with lessons learned through the design, excavation, construction, and commissioning of the project will be covered.

Alternative Project Delivery. Has its Time Arrived for Mining Projects?  
S. Taylor; Mining, Jacobs, Phoenix, AZ

Projects delivered in an alternative manner to the traditional Design-Bid-Build, including Design-Build, Progressive-Design-Build, and Construction-Management-at-Risk can provide shorter schedules, less conflict, greater innovation, and better safety for large and small construction projects. This paper explores the methodology and rationale behind alternative project delivery methods, how they compare to Design-Bid-Build, EPC, and EPCM; their pros and cons; their applicability to industrial projects; and their track record after extensive use especially in the municipal and state government world. The paper considers viewpoints of all project stakeholders, including: financiers, owners, engineers, operators, contractors, lawyers, regulators, politicians, non-governmental organizations (NGOs), and the public.

22 Forward-Thinking Questions to Ask Your Bulk Material Handling Design Team  
C. Hartford; Jenike & Johanson, San Luis Obispo, CA

If you are in the mining and mineral processing (M&M) business, you are really in the business of bulk solids flow. As a raw solid, ore (and its derivatives) are some of the most challenging bulk solids to handle in a controlled manner. This often overlooked, critical design challenge is reflected John Marsden’s (former SME President 2014) career inspired Top Ten things all mining and metallurgical graduates should know. In 2016, Dr. Marsden rated knowing how to design a chute as his number 1 tip for graduates. While the ability to design a materials handling systems requires specialized knowledge and resources beyond the access of most M&M engineers, knowing the right questions to ask those who are involved in providing the system is critical. The pain and cost of correcting design errors, if even possible, is usually crippling. When it comes to bulk solids, prevention is definitely much better than the cure. So, for people who are not material science experts, what are the right questions to ask? In this talk, we provide 22 forward thinking questions that can be posed to those providing bulk material handling systems that need to work perfectly, from the start.
Optimizing the Load Cycle at a Large Tier-1 Mine in Africa

B. Weisheit; Machine Guidance, Modular Mining, Tucson, AZ

Optimizing the load cycle at surface mines continues to represent a prime opportunity for productivity improvements. With the recent site-wide implementation of the mining industry’s first integrated operator-assist technology at a large tier-1 mine in Africa, the challenges often associated with optimization attempts are swiftly being addressed. This paper will present real data from this full-site deployment to identify the true productivity improvements that mines can attain by leveraging high-precision GNSS to guide their truck operators to the correct loading spot at the shovel, including dual-side loading, minimizing shovel hang time and truck re-spotting, equalizing operator performance, and more.

Crusher Location and Conveyor Network Planning in Multi-Pits and Multi-Plants Open Pit Mines

m. paricheh; mining and metallurgical university, amirkabir university of technology, Tehran, Iran (the Islamic Republic of)

Given the current characteristics and the expected future of open-pit mines, transportation optimization is one main goal of every Greenfield or Brownfield project. There is high connectivity between facility location and transportation efficiency. This dilemma is more crucial when the mining complex includes multi-pits and multi-plants. In this paper, the primary crusher location and the conveyor network in an open-pit iron ore mine complex consisting of a set of multi-pits and multi-plants are investigated. A new Mixed Integer Programming (MIP) model is developed to solve this relatively complex problem in a multi-periods time horizon during the mine life. The model aims to maximize the total net present value gained from the project. The model considers production plan, trucking costs, and conveying costs as the main inputs and optimizes the number of crushers, crushers’ locations, crushers’ relocations and conveyors network. It is also capable to be applied with a minor modification in other metallic and nonmetallic open-pit mines where the same situations exist.
2:25 PM
**Leveraging Unconventional Experiences in Early Professional Development**
C. Kircaid; Mining and Earth Systems Engineering, Colorado School of Mines, Golden, CO

Mining engineering development is often portrayed as a straight line through college, to an operational position, and then directly up the ladder. However, pursuing more unconventional experiences as part of your engineering education can provide valuable and unique perspectives on mining and expose students to new career paths, research areas, and opportunities. ‘Traditionally Diverse’ engineers in particular may benefit from atypical experiences, as it distinguishes them from their peers. Throughout my early academic and career development, I have pursued atypical projects, research, and internships to supplement my mining & engineering coursework. I currently research diversity & inclusion in the mining industry with Colorado School of Mines, and my undergraduate capstones focused on social development in mining-heavy contexts such as Ghana and South Africa. I pursued internships with an early development phase mine and Komatsu America Corp. to provide a cross-sectional perspective on several mining engineering career paths.

2:45 PM
**My First Five Years of Experiences in Academy**
Q. Huang; Mining Department, West Virginia University, Morgantown, WV

Qingqing Huang is an Assistant Professor in the Department of Mining Engineering at West Virginia University (WVU). She holds a Ph.D. in Mining Engineering from the University of Kentucky and a Bachelor in Mineral Processing Engineering from Central South University in China. After obtaining her Ph.D. degree in 2016, Huang started working as a postdoctoral researcher at WVU, where she was later promoted to Research Assistant Professor. Shortly after that, she was further promoted to Assistant Professor. During this journey made so far, Huang has been working on multiple research projects funded by the U.S. Department of Energy’s National Energy Technology Laboratory. In addition to research, she has also been heavily involved with Society for Mining, Metallurgy, and Exploration (SME). During this presentation, Huang will share her first five-years of working experience in academia, the research she has been working, and her involvement with SME.

3:05 PM
**My First Five Years of Experiences in Growing a Business in the Industry**
N. Rouse; DynoConsult, Lexington, KY

Nathan Rouse graduated from the University of Missouri-Rolla with a BS in Mining Engineering in 2009 and an MS in Explosives Engineering in 2010. He went to work for a small mining engineering firm in Lexington, KY called Morgan Worldwide Consultants upon graduation; Morgan Worldwide was subsequently acquired by Respec in 2014. While with Morgan Worldwide and subsequently Respec, he completed his PhD in Mining and Explosives Engineering from Missouri S&T in 2015. He was part of a small group that started a new business focused on drill and blast consulting within Respec. He worked with his team to develop the group into earning 0.5 to 0.6 million per year revenue. The team was successful each year, always bringing in positive net revenue. Nathan is now a principal consultant with DynoConsult and is based in Lexington, KY. In his presentation, Nathan will share his experiences of growing a new business from scratch.

Monday, February 24
**Afternoon**

2:00 PM • North 227C
**SOMP: Careers in Academia - Choosing the Best Path for You**
**Chairs:** A. Brickey, South Dakota School of Mines and Technology, Rapid City, SD G. Barakos, TU Bergakademie Freiberg, Freiberg, Germany

2:25 PM
**Career Power in Mining Engineering**
P. Nelson; Mining Engineering, Colorado School of Mines, Golden, CO

From Peace Corp to Provost and National Science Foundation to Colorado School of Mines, Dr. Priscilla Nelson has done it all. While it may appear that there are right ways and wrong ways to go about obtaining a career in academe, the truth is there is no fixed path. In this presentation, Dr. Nelson will describe the benefits and challenges associated with career transitions in academia and research organizations and how she created a successful, exciting, and adventurous career by following her passions.

2:45 PM
**Transitioning from Industry to Academia: Is the Grass Really Greener?**
M. Hitch; Geology, Tallinn University of Technology, Tallinn, Harjumaa, Estonia

In recent years, academic institutions have become more open to industry professionals making the transition and return to education and research. Academia isn’t for everyone and for many, the change can be remarkably rewarding. The following points highlight five aspects of the transition that took the author from the position of senior executive of some of the world’s most successful mining companies into the polished linoleum hallways of academia. These aspects include: A new rhythm to the day where the 9-5 grind is replaced with a new sense of flexibility and independence to plan your activities; The relevance of industrial leadership, management, organizational structure, and corporate demands, can directly translate into research and development and assist restructuring a faltering department; It’s ok to fail and projects can be long term and a failed experiment or faulty hypothesis still equals a significant result; Individual credit for your work is ok and even celebrated; and finally part-time academic involvement can give you a sense of that that transition might look like.

3:05 PM
**Female Faculty Development in Southeast Asian Mining Schools**
N. Nguyen; Mining Department, Hanoi University of Mining and Geology, Hanoi, Viet Nam

Mining is obviously a male-dominated job, however, there is an increasing number female recruitment both in the industry and academy nowadays in both developed and developing mining countries. In Southeast Asian mining schools, female students and faculty are improving their presence and engagement into their study, lecturing and research, but their performance is still less evaluated than males’. What challenges have they been facing and how they have been overcoming those challenges are discussed to find out the appropriate career development in Southeast Asian context.
While there are immediate technical reasons that tailings dams fail, the overall technical and governance system of tailings management is in most cases the root cause. This paper will explore this matter to evaluate the importance of understanding and managing this system appropriately. The recent experience of the Boeing 737 MAX as well as other literature will be drawn upon to help clarify the importance of understanding these systems. Characteristics of robust and resilient tailings systems will be identified.
experiences after two years of project work show enormous challenges to motivate assistance for the mines. The vision is zero fatalities and accidents. The first private owner of a thermoplant started a project to improve the health and safety techniques. Families or miners’ associations usually own those mines. In 2017, are characterized by artisanal mining, such as pick and shovel or semi-machined department with the highest accident rate in underground mining in Colombia.

Dr. Bochum, Germany

Sized Coal Mines in the Department of Boyacá, Colombia

inexpensive wireless respirable dust sensing networks for use in surface mines. A aerosol generating system. The overall goal of the project is the development of including a TSI Dusttrak II aerosol monitor, Thermo Scientific PDM 3700 (personal and Laser SEN0177) were evaluated and compared using reference instruments light-scattering-based PM sensors (Shinyei PPD42NS, Sharp GP2Y1010AU0F, and Laser SEN0177) were evaluated and compared using reference instruments including a TSI Dusttrak II aerosol monitor, Thermo Scientific PDM 3700 (personal dust monitor), and pDR-1500 aerosol monitor. Test atmospheres were prepared using Arizona Road Dust and coal dust in a chamber equipped with a fluidized bed aerosol generating system. The overall goal of the project is the development of inexpensive wireless respirable dust sensing networks for use in surface mines.

9:25 AM
Improving Occupational Safety and Health in Small and Medium Sized Coal Mines in the Department of Boyacá, Colombia

D. Lezcano1 and J. Kretschmann2; 1Phd Student, Bochum, Germany and 2Prof. Dr. Bochum, Germany

Boyacá produces 4% of Colombia’s coal, approx. 2,580,000 tons, per year in 2,778 mines. According to Colombian law, 1,670 of them are legal, the others are missing either a mining title or an environment license. In 2018, it was the department with the highest accident rate in underground mining in Colombia. Because of limited occupational safety and health measures 35 fatalities and 50 emergencies were officially reported. The mining operations in the department are characterized by artisanal mining, such as pick and shovel or semi-machined techniques. Families or miners’ associations usually own those mines. In 2017, a private owner of a thermostat started a project to improve the health and safety standards of its supply chain. The project includes technical and organizational assistance for the mines. The vision is zero fatalities and accidents. The first experiences after two years of project work show enormous challenges to motivate the coal suppliers to follow the new safety standards. The original strategy of the project had to be revised. Besides, an educational process and practical trainings had to be included to change the work routine from accepting risks to safe work.

9:45 AM
Longwall Ventilation in a Gassy Trona Mine: Is it Different from Coal Mine Ventilation?

V. Gangrade and S. Schatzel; National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA

The National Institute for Occupational Safety and Health conducted a ventilation research study with a cooperating trona mine using the longwall mining method. The mine is ventilated using a main blowing fan and a bleeder shaft. For this study, two separate monitoring experiments were conducted using sulfur hexafluoride (SF6) tracer gas. The first test focused on airflow along the longwall face of the active panel and showed the airflow patterns to be more complex than just head-to-tail flow in the main ventilation air stream on the active panel. The second test focused on gas transport in the mined-out portion of the same active panel. The gob test showed a pathway of movement through the front of the active panel gob that moved outby from the tailgate corner. The primary pathway of tracer gas movement in the active panel gob was towards the headgate and tailgate bleeders and out of a bleeder shaft. The rate of movement towards the back of the gob was measured to be 0.19 m/s(37 fpm). The results from this field study are compared to two other coal mine field studies. The findings related to alternate pathway of ventilation air contribute towards improving miner health and safety.

10:05 AM
Evaluation of Alternative Technologies for Underground Mining Proximity Detection Systems

C. DeGennaro, J. Can, C. Zhou, J. Yonkey and B. Whisner; NIOSH, Pittsburgh, PA

In underground coal mines, a leading cause of permanent disability and fatality is striking and pinning accidents involving continuous mining machines and powered haulage equipment. From 2009-2018, United States underground coal mines experienced 99 permanent disability injuries and 48 fatalities attributed to powered haulage or machinery. Magnetic proximity detection systems (PDSs), designed to detect workers in close proximity to these machines and to automatically stop machine motion, were introduced to prevent such accidents. While these devices are expected to improve worker safety, environmental influences and electromagnetic interference may cause inconsistent PDS performance. Therefore, the National Institute for Occupational Safety and Health (NIOSH) has researched alternative proximity detection technologies for underground mining including RADAR and LIDAR. A sensitivity analysis was conducted to evaluate different variables that may affect detection performance. Test results illustrating the variables that may affect detection performance are discussed. PDS manufacturers may use this study to inform future system design and improve mine worker safety.

10:25 AM
Characterization and Sampling of Sub Micrometer Sized Particles at Edgar Mine Using a Specialized Novel Sampling Device

C. Tsai1, J. Brune1 and D. Janes2; 1Colorado State University, Fort Collins, CO; 2Colorado School of Mine, Golden, CO and 3Purdue University, West Lafayette, IN

Submicrometer- and nanometer-sized particles are a potentially severe but largely unstudied exposure in the mining environment. Workers in the mining environment might be exposed to high amounts of nanometer-sized particles from coal dust, silica particles and diesel exhaust, but currently available methods are unable to quantify this exposure. A novel sampling device was designed to collect particles within the respirable size range. A grid-attached filter is used to collect particles; deposited particles can then be analyzed through both real time measurement with a sensor attached to the device and offline analysis. An on-site evaluation of particle emissions from running a diesel operated locomotive and the feed- leg drilling activity was conducted at Edgar mine to collect particles for those in the submicrometer sizes. Sampling was taken at the emission sources, air intake and exhaust at mine. Air quality in the mine was also monitored. Emitted submicrometer- and nanometer-sized particles were found to be in a number concentration above 105 particle/cm3 nearby the locomotive and drilling location indicating a significantly high level of small particles have been generated.
9:00 AM • North 227B
Coal & Energy: Coal Mining and Gas Interface
Chair: S. Kravits, Target Drilling

9:00 AM
Introductions

9:05 AM
An Assessment of Ground Movement and Permeability Changes Occurring Near Gas Wells Positioned in Abutment Pillars Of Active Longwall Mines and Potential Impacts on Underground Ventilation
S. Schatzel¹, W. Su¹, P. Zhang¹, V. Gangrade¹, E. Watkins¹, H. Dougherty¹, M. Van Dyke¹, C. Hollerich¹, J. Addis¹, T. Minoski³ and C. Kacaran²; ¹National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA and ³United States Geological Survey (USGS), Reston, VA
A diverse group of stakeholders recognizes the need for scientific input in the positioning of unconventional gas wells near active longwall mines to minimize the potential risk of casing damage associated with ground movement and fracture development. Previously, gas wells proximal to longwall coal mining were positioned according to the 1957 Pennsylvania Gas Well Pillar regulation. Substantial changes in coal mining since then have resulted in the need for new, technically-based input for positioning gas wells. Experimentally-based data indicated permeability for the coaled nearest the mined unit increased by up to three orders of magnitude following the second panel mine-by. Overall research findings for the potential impact on underground ventilation in the event of a well breach will be discussed.

9:25 AM
Innovation in Ventilation Systems -- How to Make Money from VAM and gob Gas
J. Savage; Nextera Energy, Austin, TX
Bleeder fans and degas wells are a critical component of the ventilation systems for underground mining operations. Leading mine operators have learned how to generate revenue from the mine methane that most operators continue to vent into the atmosphere from these sources. In this session, you will learn about the technology that is available to capture and utilize methane from bleeder shafts and gob wells, the markets that innovative operators are tapping into to generate revenue from mine methane, and the operating characteristics that you can use to determine if your mine is a good candidate for this opportunity. In addition, case studies of existing, operating projects will be reviewed and will address technical design, operational, regulatory, and financial considerations. Videos of operating projects will provide “in person” insight into these projects.

9:45 AM
Prediction of Gas Emission Quantity Based on Gas Content Uncertainty using Random Simulation Method
S. Rahimi; AmirKABIR UNIVERSITY OF TECHNOLOGY, Mining engineering, Tehran, Iran (the Islamic Republic of)
Gas emission quantity is a key factor in the productive process of a coal mine. However, because of the complexity of determination, the measurement process is time-consuming. At present, the mine has only realized the real monitoring of gas, but not forecasting of gas emission before mining is difficult since it depends on a number of geology, geographical, and operation factor. The large amounts of gas released during mining present concerns about sufficient airflow for ventilation to ensure worker safety. On the other hand, a poor ventilation system often results in serious consequences such as mine gas explosions, production loss or higher operational costs. Hence, the functions of mine ventilation system are vital for an underground mining system. This paper presents an approach for the prediction of gas emission based on a random simulation method, Monte-Carlo Simulation (MCS). The result shows that the prediction model has enough prediction accuracy for application of actual engineering in the coal mine.
Tuesday, February 25
Morning

9:00 AM • North 226A
Coal & Energy: Rare Earth Elements In Coal I
Chairs: J. Werner, University of Kentucky, Sadieville, KY T. Gupta, Graduate Student, Fairbanks, AK

9:05 AM
Pilot-scale Production of Rare Earth Elements from Coal Ash
J. Groppo; Mining Engineering, University of Kentucky, Lexington, KY
This paper describes an on-going effort to develop and demonstrate at pilot scale, continuous processes to economically produce salable REE concentrates, including Y and Sc (REYSc), and commercially viable co-products from pulverized coal combustion fly ash using environmentally safe, and high yield physical and chemical enrichment processes. The specific objective is to demonstrate both the physical and chemical enrichment processes continuously at a decoupled operating capacity of 0.4 tons/day. The physical processing stage has been completed, producing over 13 tons of processed fly ash from two different sources, with enriched grades of 680 and 806 ppm REYSc, respectively. Chemical processing is currently in progress, with a goal of achieving >15% overall REYSc recovery from the parent fly ashes. A particularly unique aspect of this processing approach is that after chemical processing, the residual fly ash meets ASTM C618 physical and chemical specifications and is marketable as a pozzolan. In addition, other salable by-products are generated during physical processing, which improve both chemical processing performance and overall economics.

9:25 AM
Rare Earth Elements and Critical Minerals from Coal-Based Resources
M. Alvin; NETL, Pittsburgh, PA
Since 2014, DOE-NETL has been engaged in addressing the techno-economic feasibility of producing rare earths from coal-based resources. Technical feasibility has been demonstrated for the extraction, separation and recovery of rare earths from coal refuse, power generation ash and acid mine drainage sludges, producing high purity concentrates. Current efforts are focused on process scale-up, as well as process optimization and efficiency improvements, production of high purity rare earth oxides (REOs) and rare earth metals (REMs), improvements to process economics, and the generation of critical materials and high value carbon products from these coal-based resources. Accomplishments in each of these areas will be discussed.

9:45 AM
Recovery of Rare Earth and Other Critical Elements from Acid Mine Drainage
B. Vaziri Hassas, M. Rezaee, S. Pisupati and M. Klima; Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA
A recent analysis of Pennsylvania acid mine drainage (AMD) streams that originate from abandoned mines, and coal refuse streams revealed that these streams contain not only favorable quantities of rare earth elements (REE) but also high HREE/LREE ratios. AMD streams, however, pose environmental concerns and hence are treated before being discharged to the environment. A sustainable AMD treatment practice is to recover REE and other critical elements while treating to address the environmental concerns. However, the REE recovery directly from AMD is challenging due to the very low REE concentration (typically in the order of hundreds of ppb). This paper presents an ongoing work on the recovery of rare earth and critical elements from AMD through staged precipitation process and utilizing proprietary ligands and discusses the elemental recovery results.

10:05 AM
Recovery of Rare Earth Elements from Coal Fly Ash
J. Pan, B. Vaziri Hassas, M. Rezaee and S. Pisupati; Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA
Coal fly ash is one of the most promising secondary sources of rare earth elements (REE) due to its elevated content of these elements. However, REE recovery from fly ash through acid leaching is challenging as these elements are entrained in the predominant glassy aluminosilicate phase, hindering their solubilization and requiring strong acidic conditions. This paper addresses this challenge through an environmentally sustainable process which includes chemical fusion followed by a two-step leaching process. This process will result in maximizing REE resources utilization and sustainable improvement of fly ash disposal practices.

10:25 AM
Bridging the Domestic Supply-Demand Gap of Critical Materials Production
S. Bhattacharyya and P. Rozelle; Energy and Mineral Engineering, Penn State University, University Park, PA
The importance of Rare Earth Elements (REE) and Critical Materials (CM) has been felt in recent decades. Demand for these commodities has increased dramatically, and the United States has become import-dependent for many CM commodities. These elements are used in medical, electronic, and defense applications, and advanced energy technologies are often dependent on the supply of these materials. The domestic availability of mineral resources will depend on research involving geologic exploration and extraction technology development. The Penn State research community is involved with both of these topics. An additional type of research is required in conjunction with these activities- the viability of production at commercial scale has to be established by technoeconomic feasibility studies. Penn State has all components of research facilities and competence to develop the extraction techniques and bridge the gap towards commercialization. The research approach in techno-economics is described here.

10:45 AM
Leaching Characteristics of Rare Earth Elements from Bituminous Coal-Based
Xinbo Yang, Research Professor Mining Engineering at the University of Kentucky, Lexington, KY
Coal-based materials represent a potential source for REEs extraction and concentration. The current study focused on investigating REEs extraction from the pre-combustion coal sources. The leaching characteristic of REEs associated with different compositions in heterogeneous coal material showed that there are different REEs mode of occurrence. By reducing the particle size, more leachable forms of REEs were liberated and recovered along with the associated mineral matter embedded in the coal structure. Kinetic test using sulfuric acid over a range of temperatures showed that the initial 20 minutes leaching process was relatively fast than the rest of the reaction. The initial activation energy determined for the Illinois No. 6 coal source was 14.6 kJ/mol, and 36 kJ/mol for the Fire Clay coal source. The activation energy determined from experimental data suggested that the extraction of heavy REEs from coal sources were much lower than that of the light REEs. The reaction products formed on the solid-liquid interface caused blockage of pores as well as a barrier between the reactants.
Tuesday, February 25
Morning

9:00 AM • North 226B
Coal & Energy: Upcoming Legislation and Ethics for Mining
Chairs: P. Dennison, Fisher & Phillips, LLP, Pittsburgh, PA
T. Ball

9:00 AM
Introductions

9:05 AM
Petition for Modifications, Technology, and the Balance of Safety
R. Moore¹ and J. Grover²; ¹Fisher & Phillips LLP, Pittsburgh, PA and ²U.S. Department of Labor, Arlington, VA

Mine safety and health is regulated primarily through mandatory safety and health standards promulgated under § 101(a) of the Mine Act. However, under § 101(c) of the Act, operators may petition for, and the Secretary may modify the application of, mandatory safety standards. Such requests seek to allow mine operators to comply by means different than those required by the existing standard. Modification requests often concern the use of new technologies, and this presentation will feature a panel of industry and government mine safety lawyers to share perspectives on current issues surrounding the petition for modification process.

9:25 AM
“Safety Measures” and S&S Citations
C. Pence and J. McHugh; Hardy/Pence, Charleston, WV

The presentation will focus on the importance of other “safety measures” in defending “Significant and Substantial” (“S&S”) designations for citations issued by the federal Mine Safety and Health Administration. For years, the Federal Mine Safety and Health Review Commission and Courts have steadfastly refused to consider what they call “redundant safety measures” in determining whether a cited condition may be deemed S&S. This has often created a legal fiction where the courts find that a condition is reasonably likely to cause an injury (and that the citation is S&S), even where other “safety measures” make this unlikely or implausible. Recently, at least one Administrative Law Judge has suggested that other “safety measures” should be considered in determining the likelihood of a “hazard.” Given the Court’s recent re-discovery of the second element of Mathies, this different analysis is timely. If adopted, this would logically work to encourage operator safety and innovation. Operators have developed many innovative safety features - at times over MSHA’s objections - and it is time courts recognize the importance of recognizing and encouraging such safety innovations.

9:45 AM
Time to Change the Coal Mine Plan Approval and Review Process
G. Harstsg; Alpha Engineering Services, Beckley, WV

Congress recognized and embedded in the 1969 and 1977 Mine Acts that mining operations are different and unique by outlining a plan approval process for such areas as Ground Control and Ventilation. The Operator is required to develop a suitable plan and submit to MSHA for approval. From the 1970’s, the “Bishop Process” was used to resolve conflicts over Plan approvals. The Mach and Prairie State decisions in 2009 and 2013 resulted in further changes to the plan development and approval processes. Perhaps it is time to legislatively revisit the Plan process in order to make the it a more balanced process between the Operator and MSHA.

10:05 AM
A Minerals Appraiser’s Fight to Defend Against a State’s Accusations and Proposed Penalties
T. Ellis; Ellis International Services, Denver, CO

The seven-year timeline of conservation easement appraisals involving the donation of mineral development rights on a rural property, which led to a State Board’s accusations of appraisal standards violations, will be described. An overlapping timeline of actions by two State Government Departments and the Real Estate Appraiser Board, pertaining to conservation easement donations and the appraisals of those donations, will also be described. The minerals appraiser’s subsequent legal fight to defend against the Board’s proposed penalties and multiplying accusations, covered more than four years. Stages and factors involved in the regulatory and administrative court process will be described. The paper concludes with the appraiser’s decision logic for settlement and some takeaway lessons.

Tuesday, February 25
Morning

9:00 AM • North 126B
Environmental: Innovative Characterization, Modeling, and Prediction Solutions for an Adaptive Mining Environment
Chairs: N. Tucci, Water & Environmental Technologies, Butte, MT C. Schumacher, Knight Resold and Co

9:00 AM
Introductions

9:05 AM
Three Dimensional CSM Development as a Precursor To Numerical Groundwater Modeling
M. LeFrancois and Z. Walter; ERM, Minneapolis, MN

Conceptual Site Models (CSM) are the precursor to support complex geological processes before beginning a numerical effort. Historically, numerical modeling resides in a two dimensions world used to examine and explain what, in effect, is a Three Dimensional (3D) world, especially at large expansive mining sites. Simplifying assumptions still hold, but the ability to compile informational streams allows for larger control and understanding. Within the mining industry, 3D geological modeling has been nearly standard for various efforts including geological conceptualization, mine design, and production planning. As 3D software evolves beyond the mining industry with interfaces such as Leapfrog Geo, CSM development effectively includes a hydrogeological framework with an end result being the numerical groundwater flow modeling process. This will further allow for more efficient model development via better representation of the geological environment. Groundwater modeling will be more robust where the 3D environment assists in presenting system complexity and results. A case study is presented to demonstrate the role and cost-effectiveness of the 3D CSM development approach.

9:25 AM
Innovative Technologies to Improve Mine Site Characterization: Extracting Value from Your Drone Data
C. Bowles, M. Rawitch and K. Haas; Earth Observation Data & AI, Ramboll, Saint Louis, MO

Recent improvements in the fields of remote sensing, computing power, and web-based GIS, allow for the implementation of new workflows facilitating an unprecedented level of understanding in mine restoration. Large volumes of data can quickly be collected and compiled into three-dimensional models, digital surface models, volumes, high-resolution orthomosaic images, oblique photography, and aerial videography. This large volume of data can be processed into a cohesive story using web-based GIS to share with stakeholders including consultants, regulators, clients, and local communities. During this presentation, we will discuss the collection of imagery data using remotely piloted aircraft systems (RPAS or drones) on mine restoration sites and review innovative methodologies that can be used to characterize these sites through several case studies. These case studies will show how we create value from drone data by automating advanced imagery analyses, including methodologies for change detection over time, abandoned mine feature identification, and vegetation monitoring.
Copper Toxicity in the Upper Clark Fork River Basin According to the Biotic Ligand Model
J. Naughton; RESPEC Inc., Missoula, MT
The Biotic Ligand Model (BLM) has been recommended by EPA as a copper standard since 2007 although few states have thus far adopted it. Although more realistic than prior hardness-based standards, the BLM requires a much greater set of field data, has greater quality control demands, and is more computationally complex. To evaluate the practical consequences of adopting the BLM as a standard in Montana, the relative restrictiveness of the EPA's hardness-based and BLM-based standards were compared for samples collected throughout the upper Clark Fork River basin. Streams within the basin have a variety of chemistry regimes and also a variety of environmental stressors including metal contamination (primarily copper), nutrient enrichment, chronic dewatering, and an array of various habitat disturbances. Overall, restrictiveness was similar between each standard (when comparing dissolved copper concentrations) but there were stark seasonal and spatial differences. The BLM-standards were typically more lenient in nutrient-enriched waters and were more restrictive during low flow periods.

10:05 AM
Expedited High-Resolution Characterization of Dissolved Metals Emanating from a Former Vanadium Extraction Facility, Soda Springs, Idaho
M. Einarson¹, N. Tucci¹, L. Peterson² and T. Lewis²; ¹Haley & Aldrich, Burlington, MA and ²Greenfield Environmental Trust, Boise, ID
An expedited remedial investigation of solid- and dissolved-phase COCs (As, Mn, Mo, and V) beneath and downgradient from a former V extraction plant in Soda Springs, ID was performed in one field season. Work at this EPA Region 10 Superfund site utilized sonic methods to collect cores of interlayered basalt and sedimentary strata to depths up to 300 feet. CMT multilevel wells were installed at 200-foot spacings along five transects positioned along the 3-mile long dissolved plume. Estimates of solute velocity were made using a coiled borehole scope and analysis of solute breakthrough curves. Detailed geologic analysis was performed using lithologic data, nuclear logs, and basin composition data obtained from screening the cores with handheld XRF. A COC mass balance was performed using historic release records and estimates of solid-phase mass and dissolved COC mass discharge. Key adaptive management modifications included changing the drilling method from rotary drilling to sonic, characterizing mineral-phase COCs in the basalt rather than bulk concentrations, increasing the depth of investigation, and documenting the natural occurrence of manganese and lithium in groundwater.

10:25 AM
Using Advanced Technology to Identify and Characterize Seepage Through a Lined Residual Storage Dam
A. Small² and R. Blanchard¹; ¹Geophysics, Willowstick Technologies, Draper, UT and ²Senior Geotechnical Consultant, Kloth Crippen Berger, Fredericton, NB, Canada
Piping and internal erosion are major problems that dams around the world face. Preferential seep paths and deterioration are a few of the early indicators that piping and internal erosion may soon follow. Traditional investigative techniques, which involve the chance intersection of drilled bore holes and seepage paths, can become prohibitively expensive. An alternative is to use advanced technologies to investigate the dam, looking for subsurface preferential seepage flow paths. One of these technologies is called Magnetometric Resistivity (MMR). This method uses a low voltage, low amperage, alternating electrical current to directly energize the seepage flow paths through the area of interest by way of electrodes placed in direct contact with the subsurface water, and mapping the resulting magnetic field. This method effectively and efficiently charts groundwater flow in complex environments, at significant depths, and over large areas. The results from a recent MMR investigation at a Residual Storage Dam in Canada is presented. Using the MMR method, the client discovered the precise location and depth of leakage, thus obtaining the information to undertake targeted remediation.

10:45 AM
Large Open Pit Closure Considerations: Dry Pit or Lake?
J. Stefanoñ and A. Parry²; ¹Worley Advisian, Spokane, WA and ²Parry Engineering, Salt Lake City, UT
Planning for closure of a large open pit presents numerous challenges and requires complicated decision making, especially when the mineralogy can generate acid rock drainage, as is common with porphyry deposits all over the world. Benefits of a pit lake could include the potential to reduce acid production, defer water pumping and treatment costs, increase pit wall stability, and provide a convenient location to store site water. Careful study is recommended to determine if these benefits are real, or just a myth. Should a pit lake be allowed to form and to what depth? What is the expected water quality compared to goals, and how can the chemistry be controlled, if necessary? If a dry pit is maintained, how is that done, and how is the extracted water managed? These and other considerations are described, along with options and examples for each.

11:05 AM
Case Study: Removal of Heavy Metals and TDS in a Mine Tailings Application
J. Wheeler¹, S. Billin² and J. Felicetti²; ¹Linkan Engineering, Elko, NV and ²Westech Engineering, Salt Lake City, UT
This presentation details a thorough case study of a comprehensive water treatment plant design and implementation for a mine influence water resulting from mineral extraction. Many year of water management by evaporation and ore oxidation by sodium hypochlorite resulted in a large inventory of heavily impacted water. Stored water contained concentrated chlorides, sulfate, WAD cyanide, thallium, mercury and other heavy metals. This case study presents the design, testing and implementation of a multi-process treatment plant consisting of chemically controlled chemical removal of mercury, thallium, mercury and other heavy metals. This case study presents the design, testing and implementation of a multi-process treatment plant consisting of chelating chemical pretreatment, oxidation, solids separation, ultrafiltration and sea water reverse osmosis. To achieve exception removal of mercury and thallium, a polishing mixed bed ion exchange resin is provided. The case study will compare test data and operational data, discuss the key factors in design, highlight the importance of equipment selection, address the flexibility required for mining impacted waters and discuss the need for rigorous operations. We will present the technical challenges resulting from a broad spectrum of contaminants required to meet direct underground injection permit levels.

Tuesday, February 25
Morning

9:00 AM • North 127B
Chair: A. Martin, Foth Infrastructure & Environment, LLC, De Pere, WI

9:00 AM
A. Martin; Foth, De Pere, WI
Panellists: Moderator; Dr. Kwame Awuah-Offei of Missouri University of Science and Technology, Rolla MO. Professor Awuah-Offei provides brings an academic perspective and experience with rule development committee work to the moderator role for the panel. Greg Gosson: Wood PLC, Vancouver, BC. Mr. Gosson has been active in the CIM Environmental and Social disclosure guidance committee for content to be included in NI 43 101 tech report. His cross border expertise is valuable in the US rules. Jason Lehner, Attorney active in Capital markets, head
of leads the Mining and Metals Group of Shearman, Toronto Ontario. Lee Terry, Attorney specializing in filings with the SEC for Davis Graham & Stubbs, Denver CO. Patrick Williamson, Principal Hydrogeochemist well versed with preparing the environmental sections as a Qualified Person of NI 43 101 reports, with Intera, Bolder CO. Stella Searston, a Consulting Geologist with Mine Technical Services, Denver CO. Don Hulse, VP of Mining, Gustavson Associates, Denver CO

Tuesday, February 25
Morning

9:00 AM • 127C
Health & Safety: Safety Culture and Health and Safety Management Systems


9:00 AM
Introductions

9:05 AM
Analyzing the Safety Performance of Coal Mining Industry in the United States using Longitudinal Data Analysis Methods

S. Agrawal and S. Bhattacharya; John and Willie Leone Family Department of Energy and Minerals Engineering, Pennsylvania State University, University Park, PA

Safety and work culture of any mining operation significantly impact its safety performance and bringing about any change within the existing culture requires time and commitment. Moreover, measuring the impact of such changes requires analyzing safety indicators in a continuum rather than in isolation. In this research, longitudinal data analysis methods were used to determine whether there are differences in the safety behavior among coal mines in the US and whether they can be categorized into different groups based on their safety performance. Growth-based trajectory models were built to determine the optimal number of trajectory groups that the mines can be categorized into based on how their Incidence Rates changed from 2005 to 2017. Results show that coal mines can be categorized into three distinct trajectory groups with 46.5% of the mines in the “very safe with constant incidence rate” group; 46.1% of the mines in the “safe with declining incidence rate” group; and 7.4% of mines in the “not very safe with steeply declining incidence rate” group.

9:25 AM
On-site Assessment of Safety Health Management Effectives—Quantifying Qualitative Data

M. Nelson, A. Richins and H. Wallin; Mining Engineering, University of Utah, Salt Lake City, UT

The authors recently concluded an assessment of the intervention effectiveness of safety and health management systems (SHMS) at 10 U.S. mines. The assessment for each mine was done primarily through site visits, which included interviews with management personnel, a perception survey of all mine employees, informal conversations with maintenance and operations employees, and detailed of the mine’s leadership and culture. It was desirable to quantify the results of each visit, for comparison among the various sites, and for analysis of changes in sites that were visited more than once. Quantification of the survey results was straightforward. Likert-scale responses were simply converted to integers. Quantification of the interviews, informal conversations, and observations led to the development of an SHMS Matrix, in which each site was rated from 1 to 5 in each of the components of a standard SHMS. These ratings were then combined to characterize safety and health management as observed during each visit. The SHMS Matrix ratings were compared with the survey results and the accident and citation rates for each mine to determine relationships and correlations.

9:45 AM
Intervention Effectiveness in Safety Management: One Mine Over Three Years

A. Richins, H. Wallin and M. Nelson; Mining Engineering, University of Utah, Salt Lake City, UT

The intervention effectiveness of safety management was assessed using surveys, interviews, and observations at one mine site on each of three annual visits. Worker perceptions of key safety and health management variables were compared with MSHA injury and citation rates. The mine has a strong intrinsic safety culture which shows up in low injury and citation rates but a leadership change in 2018 appears to have had some negative effects. The authors believe that an accurate assessment of leadership can be a leading indicator for safety performance.
from about 3% to 1% or less, and phosphate (P2O5) recovery ranged from 60%
separation using packed column jig (PCJ). In all the tests, MgO content was reduced
consequences. Under an extensive laboratory testing program, high-dolomite
Separation of dolomite from phosphate is a worldwide challenge to the phosphate
University, Bartow, FL and 2Wuhan Institute of Technology, Wuhan, China
Pilot Scale Demonstration of Innovative Gravity Separation for
9:00 AM • North 126A
Industrial Minerals & Aggregates: Beneficiation and Physical Separations in
Industrial Minerals & Aggregates II
CORPORATION, Buffalo Grove, IL
9:05 AM • North 126A
Pilot Scale Demonstration of Innovative Gravity Separation for
Removing Dolomite from Phosphate
J. Zhang1, W Xiao2 and D. Zhang3; 1FIPR Institute, Florida Polytechnic University, Bartow, FL and 2Wuhan Institute of Technology, Wuhan, China
Separation of dolomite from phosphate is a worldwide challenge to the phosphate industry. Based on results from a 1989 FIPR Institute study, Florida phosphate pebble from the lower zone of the Hawthorn Formation averages 6.19% MgO. This zone accounts for over 50% of the future phosphate reserves. Available technologies for removing MgO from phosphate include flotation, chemical leaching and calcination, which are complex and expensive, and generate environmental consequences. Under an extensive laboratory testing program, high-dolomite phosphate pebbles were crushed with different size fractions subject to gravity separation using packed column jig (PCJ). In all the tests, MgO content was reduced from about 3% to 1% or less, and phosphate (P2O5) recovery ranged from 60% to 85% for the following size fractions: 35 by 65 mesh, 65 by 150 mesh, and 65 by 150 mesh. These results on separation of dolomite from phosphate by gravity separation have never been achieved before using any devices. The encouraging lab results prompted a pilot plant demonstration using a 1-3 tons/hour PCJ. This paper presents pilot testing results and discusses commercialization scenarios.
An ongoing concern for phosphate mining operations in central Florida is to produce a product from pebble phosphate containing sufficiently low dolomite content (<1% MgO) for the efficient and economic production of fertilizers. Attrition scrubbing of roll crushed pebble phosphate samples (top size of 1 mm and 2.97% MgO grade) has been performed under different conditions of scrubbing time, pH, temperature and rpm. The samples subjected to scrubbing were wet screened at 53 µm and the chemical analyses (ICP analyses) of the coarse and fine products indicated that scrubbing can help in the rejection of dolomite in the fines product, which contains a significant amount of MgO. The best scrubbing results were obtained for a scrubbing time of 20 minutes, and an MgO content in the coarse product (concentrate) of approximately 1.72%, with a phosphate P2O5 recovery of 63.47%. It is evident that the phosphate concentrate (+53 µm) from scrubbing does not meet the required MgO level as desired for further processing by acidulation. These results are contrasted to the results reported in the literature for HPGR crushing, in which case a product containing less than 1.0% MgO was achieved.

Tuesday, February 25
Morning

9:00 AM • North 125B
Industrial Minerals & Aggregates: Innovations in Industrial Minerals and Aggregates II
Chairs: R. Jain, Outotec USA Inc., Savage, MD L. Olsen, Minerals Technologies Inc., Easton, PA

9:00 AM
Introductions

9:05 AM
Scope for Innovation in the Industrial Minerals Business
N. Tripathi, Idekin International, Easton, PA
This presentation will list possibilities for innovation in the industrial minerals business. The non metallics are unique in the sense that a good industrial minerals business has many opportunities to innovate in all aspects, i.e. production, marketing, transportation, application, recycling, reuse and reclamation. We will examine the scope and possibilities with some case histories.

9:25 AM
Prediction of Brightness in Processed Kaolin Using Machine Learning
C. Petter¹ and I. Gonçalves²; ¹UFRGS, Porto Alegre, Brazil and ²Mining Department, UNPAMP/A, Caxangaba do Sul, RS, Brazil
Machine learning already permeates most activities in daily life, such as face recognition, language translation, recommender systems and self-driving vehicles. The success of machine learning is these tasks is due to the advances in hardware processing power and, more importantly, vast amounts of data on which to train the models. This work presents a machine learning model to predict the brightness in processed kaolin, based on the reflectance spectrum of the raw ore in the visible range. Approximately 2000 degritted kaolin samples were processed in the laboratory, following the steps of centrifugation, magnetic separation, and chemical bleaching. The reflectance spectrum, from which the brightness is derived, was measured before and after the process. The data was split in a training set containing 80% of the data points, with the remaining set aside for validation. A linear regression model used as a baseline yielded a mean absolute error (MAE) of 0.68 brightness points. With the Gaussian Process model we obtained a MAE of 0.53, a 22% reduction.

9:45 AM
The Saga of a Frac Sand Mine in Central Texas: The Good, The Bad & The What Do We Do Now?
M. Lee; Westward, Boerne, TX
In September 2015, Westward performed a subsurface exploration program for frac sand at a location near Voca, Texas. At that time, frac sand had become an incredibly popular commodity almost overnight after years in a trough of inactivity. Fracking was evolving to the finer grain sizes and the ‘in-basin’ sands in West Texas were still merely a playground for ATV enthusiasts. In 2015, Permain Frac Sand set up shop in Voca, Texas, alongside others, and were having trouble keeping up with the orders coming in. The Hickory Sandstone was being mined in the area by many since the 1940’s for glass and was now becoming a hub for frac sand. By 2017, there were 4 companies mining frac sand in Voca. In 2018, the tide turned in a dramatic way and now in mid-2019, only one of them is still operating, but not primarily as a frac sand producer. The name has changed to PFS Aggregates and they are revamping a slumping frac sand product line into industrial and aggregate sand that has brought new life, and business wherewithal, into this part of Texas. This presentation will discuss the methods and the foresight that went into righting the ship of a former frac sand mine in Central Texas.

10:05 AM
Chemik CB: A New Family of TCE-Free, ETACFree, Cold-Bonding Adhesives for Rubber-Lining
J. Williams; Elastomer Adhesives & Coatings R&D, LORD Corporation, Erie, PA
Vulcanized rubber linings are utilized extensively in material extraction, handling, and processing operations. Existing adhesive solutions for bonding vulcanized rubber linings utilize carcinogenic or increasingly-restricted solvents, like trichloroethylene (TCE) and chlorinated ethyl acetate (ETAC). These potentially hazardous adhesives have been made available to industry for use for decades, without significant training. This paper will present a new family of TCE-free, ETAC-free adhesives for bonding Vulcanized rubber linings to metal: Chemik CB. The paper will review the mechanisms for how the adhesive functions differently from traditional solutions. Topics covered include: -Chemistry-developed and how it differs from traditional solutions -Methods used to validate the adhesive system during development -Standardized application methods -Savings offered in: Labor Cost, Waste Disposal, VOC-reduction, and Carcinogen Elimination Calculation -Ongoing trainings offered to industry to improve application and safety.

10:25 AM
Controlling Crosscut Damage in Response to Excessive Levels of Horizontal Stress: Case Study at the Subtropolis Mine, Petersburg, OH
N. Evanek¹, A. Iannacchione² and T. Miller³; ¹Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Pittsburgh, PA; ²Civil and Environmental Engineering, University of Pittsburgh, Pittsburgh, PA and ³East Fairfield Coal Company, North Lima, OH
The Subtropolis Mine is a room-and-pillar mine extracting the Vanport Limestone near Petersburgh, Ohio. In February of 2018, mine management began implementing a new layout to better control the negative effects of excessive levels of horizontal stress and the conditions in the headings improved. As expected, stress related damage concentrated within crosscuts. Over the last 18 months, the mine operator has worked to lessen the impact of the instabilities in the outby crosscut by implementing angled crosscuts, crosscut offsets, increase crosscut spacing, arched crosscuts, cable bolted crosscuts, altered blasting pattern, and windows. Conditions were monitored and analyzed using observational and measurement techniques. The advantages in ground conditions were weighed against impacts to haulage, ventilation and other mining considerations. This paper examines how each engineering control was implemented and assessed. All of these controls are based on well-established geomechanics principals, but experience has shown that local modifications are needed to deal with the unique conditions such as geology, mining method, mine equipment, and stress characteristics.
of mining activities in Myanmar and the success of foreign investors are at risk. Therefore, the mining regulation and management skills, especially negotiation and approval processes, and better collaboration between Myanmar and local communities, should therefore seek to improve their mining exploration and environmental impacts. Key players, including the government of Myanmar and local communities, should therefore seek to improve their mining management skills, especially negotiation and approval processes, and better explain the mining situation in Myanmar to the public. Otherwise, the expansion of mining activities in Myanmar and the success of foreign investors are at risk.

11:05 AM
Case Study: Results from the Implementation of a Maintenance 4.0 Application for Plant Asset Management in a Mine & Processing Site
E. Botelho and E. Ingegneri; Process Industries - Mining, ABB, São Paulo, São Paulo, Brazil
This study presents results obtained through the implementation of a Condition Monitoring System integrated to the Process Control System, focused on early diagnosis and optimization of maintenance planning activities in a Maintenance 4.0 application. Major advantages of integrating operational and maintenance data are: - Break silos of information across maintenance and operation - Detect problems that cannot be identified using current predictive techniques - Holistic figures of plant assets, can be drilled down and detailed to each asset of the plant, per family of assets or process area, supporting failure analysis and identification of root causes. Installed in a mine or processing plant, such application monitors on-line more than 6000 assets, assessing the health status of the assets and the process plant, defined by the combination and intelligent treatment of the available information on assets and the process, which is only possible through the integration between the process control system and the maintenance system. The benefits refer to losses of production and maintenance avoided in real cases in assets like crushers, vibrating screens, stackers and long-distance conveyors.

Tuesday, February 25
Morning

9:00 AM • North 132A
International II
Chair: M. Gavrilovic, GR Engineering Services, Denver, CO

9:00 AM
Introductions

9:05 AM
Mining in Myanmar: Perspectives and Challenges
J. Kretschmann¹ and M. Thwe Aye²; ¹TH Georg Agricola University, Bochum, Germany and ²Department of Geology, University of Yangon, Yangon, Myanmar
Myanmar is a country with a long mining tradition and enormous potential. Modern mining started in the British colonial times. The country is endowed with huge unexploited geological resources, which will make exploration and mining a major opportunity for the country in the future. To date, mining is the third largest beneficiary of international direct investments in Myanmar. Still, the full realization of the countries potential is lacking of advanced mining technologies and modern surveying techniques. What is more, Myanmar faces some distinct challenges in the mining regions like conflicts over the use of land or disagreements about forced exploration and environmental impacts. Key players, including the government of Myanmar and local communities, should therefore seek to improve their mining management skills, especially negotiation and approval processes, and better explain the mining situation in Myanmar to the public. Otherwise, the expansion of mining activities in Myanmar and the success of foreign investors are at risk.

10:05 AM
Post Mining Activities in Coal Mining in Amagá, Antioquia – Colombia, Challenges and Possible Solutions
D. Velasquez¹, J. Kretschmann² and O. Restrepo Baena¹; ¹Maters and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia and ²President, Technische Hochschule Georg Agricola, Bochum, Germany
Colombia is an important coal producer, with 84 million tons sold at the end of 2018. Mining contributed with 1.66% to the country’s GDP in 2018, while 1.09% came from coal. However, the prospects for Colombia’s mining regions are different as in the mining region of Amagá, located in the department of Antioquia, coal production has been reduced by 93% from 2012 to 2017. Mine closures that were not properly planned, designed and implemented had a negative impact on the environment and social security. The adaptation of the post-mining knowledge of Germany shows options to face the challenges of Amagá. In addition, it seeks to promote and broaden the vision of post-mining with the aim of developing strategies and mechanisms adapted to the different mining areas throughout the national territory and thus to find long-term solutions in favor of the environment and the community.
Formalization of artisanal and small-scale gold mining (ASGM) operations continues to be a high priority for governments around the world. In Peru, during the last decade, the government has made considerable efforts to formalize the sector and promote better and safer working conditions for miners. Although the majority of ASGM activities continue to operate informally, the Peruvian government has formalized over 5,800 artisanal and small-scale miners. Many of these operations are quite profitable and have begun to commercialize their gold in international markets. This study provides one of the first analyses of formal ASGM activities and focuses on the unexpected benefits and unintended consequences of formalization in the Puno region of southern Peru. We demonstrate that although formalization poses significant challenges for small-scale miners, such as complicated procedures and fluctuating guidelines, it has also had some positive impacts. We argue that although Peru’s formalization strategy has not solved all the issues surrounding ASGM, it has helped to foster a vision among artisanal and small-scale miners of more sustainable and responsible ASGM livelihoods.

10:45 AM  
**Capacity Building in Artisanal and Small-Scale Gold Mining: An Example from Peru**

F. Gonzalez¹, K. Smith², L. McDonald³, N. Smith⁴, J. Lucena⁵, G. Martinez⁶, O. Restrepo Baez⁷ and S. Rosas⁸; ¹Geography and the Environment, Pontifical Catholic University of Peru, Lima, Peru; ²Colorado School of Mines, Golden, CO; ³Massachusetts Institute of Technology, Cambridge, MA; ⁴University of Texas at Arlington, Arlington, TX; ⁵Colorado School of Mines, Golden, CO; ⁶Universidad Nacional de Colombia, Medellin, Colombia and ⁷Pontifical Catholic University of Peru, Lima, Peru

In Peru, artisanal and small-scale gold mining (ASGM) lies at the center of discussions related to resource extraction. These discussions are often contentious because of illegal and informal activities associated with ASGM, the impacts of ASGM activities on the environment, and the large and growing informal and unregulated nature of ASGM operations. In recent years, policies and development initiatives have emphasized the importance of community capacity building within this sector; however, there are few examples of what this means or should look like, and therefore capacity building remains a somewhat abstract concept. This paper provides one example of how universities, government, non-governmental organizations (NGOs), industry, and ASGM communities can work together to build capacity within the ASGM sector to address some of ASGM’s most pressing challenges. In this presentation, we report on a Voces Mineras Iworkshop held in Lima, Peru in April 2019 where miners, academics, NGOs, and government officials participated in a co-design workshop aimed at identifying challenges facing the ASGM sector in Peru and practical pathways forward.

Tuesday, February 25

9:00 AM • North 222A

**Mining & Exploration: Geosciences: Geometallurgy**

**Chairs: I. Barton, UA Lowell Institute for Mineral Resources, Tucson, AZ M. Enders, Colorado School of Mines, Golden, CO**

9:05 AM

**Process Mineralogy of Colorado Plateau Uranium and Vanadium Ores**

I. Barton², L. Shumway³ and M. Barton¹; ¹UA Lowell Institute for Mineral Resources, Tucson, AZ; ²Mining and Geological Engineering, University of Arizona, Tucson, AZ, and ³Energy Fuels Inc., Blanding, UT

The Colorado Plateau hosts most of the USA’s strategic resources of primary uranium and vanadium, mainly in the Triassic Chinle and Jurassic Salt Wash sandstones. Ore minerals include pitchblende, coffinite, monzontelite, and V-silicates (e.g. roscoelite), along with uraniumiferous asphalt and various supergene vanadates, sulfates, and phosphates. Gangue is commonly quartz, feldspar, clays, and micas, and the Chinle ores also commonly host barite and calcite. Pyrite, chalcopyrite, and galena are common accessory sulfide minerals in both deposit types, and the Chinle ores also contain sphalerite and greenockite. Very fine grain size makes physical separation of U and V generally uneconomic. Processing is by acid leaching followed by solvent extraction, stripping, and precipitation of U as yellowcake, then of V as ammonium metavanadate. Potential problems include locking, contamination from dissolving asphalt, and buildup of conservative elements (P, Si, Fe) dissolved from the ore minerals.

9:25 AM

**Machine Learning for Geometallurgy**

S. Sharma; Chemical Engineering, Michigan Technological University, Houghton, MI

Traditional statistics though transparent and clear as opposed to most machine learning techniques, mostly rely on linear regression and often not suited for processing complex datasets and prediction. While statistics is used to develop scientific understanding and discover relationships between variables, machine learning aims for most accurate prediction without dwelling into the significance of variables. Both of these techniques were applied on a drill hole geometallurgical data to draw insights on hardness for comminution domaining. In order to predict hardness in form of SPI and Bon Mod from drill hole test data, supervised machine learning was used. Initially convoluted neural networks (CNNs) were used. This modelling was not a successful since the dataset was tiny compared to the requirements. The model at best could generate only an averaged out prediction for reserved test dataset. Later an efficient form of random forest classifier/regressor called XGboost was used to yield satisfactory accuracy. Optimization, though computationally expensive was defining line between good and bad prediction.

9:45 AM

**Contrasting Copper Mineralized Systems of the Paradox Basin, Colorado Plateau**

M. Barton¹, J. Barton², J. Thorson³, A. Whitehead⁴ and C. Getz⁵; ¹Geosciences, University of Arizona, Tucson, AZ; ²Mining and Geological Engineering, University of Arizona, Tucson, AZ and ³Consultant, Parker, CO

Multiple types of Cu mineralization occur in the Paradox Basin, illustrating the chemical, temporal, and spatial diversity and complexity of Cu-bearing systems therein. Classic sediment-hosted Cu-Au deposits occur throughout the stratigraphy, exhibiting multiple types of structural and stratigraphic control as well as evidence for multiple, distinct trapping mechanisms (sulfide replacement, sulfate reduction, etc.). Regionally coextensive U-V deposits have highly varied but locally abundant Cu sulfides with a similar diversity of possible origins. Finally,
Development of the Freeport-McMoRan Safford Lone Star Deposit NIR Model

Knowledge of clays, micas and other alteration minerals is vital in optimizing ore material routing, blending, and processing. These minerals can cause significant permeability issues with leaching. Near Infrared (NIR) spectrometers are quick and inexpensive mineralogical tools for identifying these minerals. However, to quantitatively predict these minerals by NIR, a statistical calibration model must be created and updated periodically. Model updates are required as ore types and mineralogy changes according to the mine plan. The Safford mine in Arizona has transitioned out of the San Juan pit and into Lone Star. In order to accurately characterize the Lone Star mineralogy, a new NIR model needed to be built. This model will help provide important mineralogical information for the future of Safford’s mine plan. In this presentation the methodology for developing the Lone Star NIR model will be reviewed, as well as how the model data is applied at Safford.

New Approach to Integrating Geology and Metallurgical Performance
C. McClung; Rio Tinto Kennecott, South Jordan, UT

Although integrating geology and metallurgical performance is nothing new, relating performance of sediment-hosted ores with host rock depositional environment or sequence stratigraphy is novel. Sequence stratigraphy is routinely used in the oil industry to evaluate economic potential and reservoir performance, but can it also be used to improve performance and economic potential of metallic ores? With increasing start up and closer costs, mining and processing of lower-grade ores will be necessary to extend the life of current and future operations. This presentation serves as a case study focused on the non-traditional, sediment-hosted, ores of the Bingham Canyon Cu-Mo mine in Utah.

Considerations for Integration of Metallurgical Characteristics into Resource Block Models
T. Matthews; Geology, Gustavson Associates, Lakewood, CO

Resource geologists are generally well versed in domain construction, geostatistical analysis, and interpolation methodologies for estimating grade for resource estimation and reporting. Geometallurgical models require an additional set of analyses including solid understanding of the metallurgical test work available, careful characterization of geological and alteration domains, and integration of diverse data sets into the modelling process. Including these parameters in the block model can give a more comprehensive understanding of the metallurgical character of the resource and allow for additional insights to drive pit design and economic models.

Effects of Hydrothermal Alteration on the Geomechanics of Degradation at the Bagdad Mine, Arizona
P. Moreira Coutinho¹, J. Kemeny¹, I. Barton¹ and S. Castro Reino¹; ¹Department of Mining and Geological Engineering, University of Arizona, Tucson, AZ and ²Geomechanics, Freeport-McMoRan, Oro Valley, AZ

The topic of this study is how mineralization, hydrothermal alteration, and weathering affect slope stability in porphyry systems using samples from Freeport-McMoRan’s Bagdad Mine. We investigated fresh and hydrothermally altered rock pairs (sericite and argillic) through geotechnical tests, petrography, cathodoluminescence microscopy, SWIR, INSAR, and ground radar analysis. Comparison of these data yielded a model for geomechanical degradation by alteration and weathering. Continuum Finite Element and Time Dependent Damage Models predicted how the excavation stability shifted through time due to changes in the rock mass associated with its degradation. Overall the results show that alteration decreases rock mass stability due to changes in rock texture and subsequent crystallization of weak mineral phases especially clays, but also oxides, carbonates, and sulfates.
in a field of view, for mapping clays at mines. Our test site was a geotechnically weak highwall at Asarco’s Ray open-pit copper mine, Arizona. The results showed that montmorillonite, a swelling clay, is abundant in the unstable area. This indicates that hyperspectral remote sensing can help map clay distribution and geotechnically weak zones at mines.

10:05 AM

**A Method for Calculating the Capacity of Shipping Containers to Resist Rockfall Impacts**

*B. Haugen and M. Raffaldi; Mining & Energy, RESPEC, Inc., Rapid City, SD*

Shipping containers are inexpensive, modular and widely available. They are thus desirable for creating rockfall barriers where low-cost, impermanent, and/or immediate installations are required. Unlike rockfall barrier systems such as dynamic catch fences, few if any data demonstrating how effective shipping containers are for absorbing rockfall energy are available in the literature. As a result, quantifying performance of shipping containers as rockfall barriers to is challenging. As part of a rockfall risk assessment project, a first-principles approach to estimating the rockfall velocity required to both tip and slide a shipping container was developed. To validate the approach, back-analysis of a rockfall event that caused an empty shipping container to tip over and slide was compared to 2D probabilistic rockfall simulations of the same event. To evaluate the influence of adding fill to the containers, velocity versus container percent-ﬁll curves were developed for different ballast materials. The relationships established in this work are useful for engineers attempting to design and construct reliable, effective, and low-cost rockfall barriers.

10:25 AM

**Integrating the Ground-Based Synthetic Aperture Radar with Interferometric Aperture Radar to Identify Impeding Slope Instability**

*M. Rajaeebaygi; FreePort-McMoRan, Phoenix, AZ*

Using appropriate and comprehensive monitoring procedures as the early warning for potential movement can eliminate the risk of injuries and equipment damage. The study will evaluate the ability of combining data from the monitoring systems to forecast pit slope instability and the size of the impacted area in a surface mine. To achieve the objective of the study, the acquired data from ground-based radar and InSAR were analyzed six months before the instability. The ground based radar was used as a primary monitoring system and detected the accelerating trend over time. However, the InSAR technology is able to provide the movement information at an early stage about developing deformation in the areas not readily visible by the ground-based radar. The conglomerate section at the top of the unstable wall in the case study was located outside the ground-based radar coverage section. The InSAR satellite with a 33-day cycle time, with ascending direction, measured displacement extension over the area of concern. The current study confirmed the benefit of integrated ground-based radar and InSAR data as a reliable precursor for pit wall movement and identification of the unstable area.

10:45 AM

**Identification and Characterization of Historic Underground Workings to Ensure Safe Mining Practices at the Bingham Canyon Mine**

*N. Vetz, J. Morkeh, J. Cefalo and J. Gibbs; Rio Tinto, Salt Lake City, UT*

Bingham Canyon Mine has a vast mining history with known underground (UG) mining dating back to as early as the 1860s. Geologists have estimated that approximately 1,600 miles of UG tunnels exist around the open pit. Size, condition, and exact location of some of these tunnels are poorly understood, with uncertainty increasing with their age. To alleviate this problem, multiple teams have come together to create an efficient process to identify and characterize UG workings before they pose a hazard to equipment or personnel. This process identifies their location by drilling from a safe location and then videoing and/or scanning the holes to characterize their condition. This data ensures a minimum crown pillar of 2500 exists or Geology establishes a 1500 exclusion standoff to eliminate interactions with the UG hazard. The process requires close coordination and clear communication between the Geotechnical, Geology, Planning, Survey, Blasting, and Ops teams to ensure quick and efficient execution. As the Bingham Canyon Mine continues to expand into larger UG working networks, precise knowledge about these tunnels is imperative to ensure the continuation of safe and efficient mining.

Tuesday, February 25

**Morning**

9:00 AM • North 222C

**Mining & Exploration: Innovation & Technology: Data Science and Machine Learning Applications in Mining**

*Chairs: A. Soofastaei, The University of Queensland, Chapel Hill, QLD, Australia and E. Tarshizi, Michigan Technological University, Houghton, MI*

9:00 AM

**Introductions**

9:05 AM

**Five Principles of Successful Implementation of Digital Technologies (AI/IoT)**

*A. Agarwal; Industrial Analytics, Uptake Technologies, Chicago, IL*

Even as commodity prices begin to rally, the mining industry faces challenges as big as the minerals it excavates and hauls from the earth. Productivity still struggles to match satisfactory levels and excess capacity remains. This has accelerated the mining industry’s unprecedented pursuit of cost efficiency across the value chain. Digital solutions (AI and IoT) promise exceptional results to the operational efficiencies of the Mining operations that have never been possible with the earlier solutions. By leveraging the data from the operations, AI can unlock significant value across entire value chain. However, mining companies encounter tough questions: where to start, what to solve, do-it ourselves or buy or hybrid, how to handle change management etc. These questions, if not understood, may lead to failed Digital implementation. In this presentation, Ashutosh Agarwal, will discuss five principles mine operators should consider when choosing a Digital (AI/IoT) solution. Following these five principles will help operators find the best digital solution to optimized resources, increased productivity, maximize process recoveries and get the most out of mobile and fixed assets.

9:25 AM

**On-Machine Learning: Taking AI out of the Lab and into the Dirt**

*E. Loelliger; Surface Mining & Technology, Caterpillar, Huntington Beach, CA*

These days, many companies are starting to use Artificial Intelligence and Machine Learning to solve complex business problems. While much of this work is done on existing data, it is significantly harder to complete the full lifecycle from new idea to finished product. Caterpillar has developed a process for creating, testing, and deploying Machine Learning models from ideation to the pit, which is now being used by mining companies every day to measure, manage, and maximize their operations.

9:45 AM

**Application of Text Analytics in MSHA Metal and Nonmetal Fatality Reports**

*E. Tarshizi and K. Raj; CDC NIOSH, Spokane, WA and Data Science, National University, San Diego, CA*

Advanced data science techniques have been applied in a variety of fields to improve health and safety and reduce accident and fatality rates. Mining similar to other industries requires to adopt and implement modern research methods to continue boosting safety in operations. Text analytics, in general, is one of the essential methods to analyze unstructured data, which is in text format. Using text mining and Natural Language Processing (NLP) techniques to extract interesting patterns and identify insightful information from contents and reports is extremely valuable to produce actionable recommendations and strategies. In this research investigation, advanced text mining techniques were applied to the U.S. Mine Safety and Health Administration (MSHA) final fatality reports in metal and nonmetal operations (surface and underground) to perform pre-processing, Exploratory Data Analysis, and various statistics to discover insightful word relation patterns in the reports. For this purpose, the fatality reports from to 2010 to 2017 were collected and cleaned. In addition, a classifier to identify and predict the report categories was developed using supervised machine learning methods.
A Portable AI-Based Solution for Fragmentation Analysis in Mining

M. Risso1, J. Park2, and J. Lundin3; 1Mining and Geological Engineering, The University of Arizona, Tucson, AZ, 2Electrical and Electronics Engineering, Universidad del Bio Bio, Concepcion, Chile and 3LPR Technologies, Vancouver, BC, Canada

Recent advances in computer vision techniques, along with the development of advanced artificial intelligence (AI) algorithms are allowing machines to outperform human pattern recognition abilities. The impact of these technologies are yet to be seen in industrial applications and they promise to lead to more accurate, robust and reliable sensors. Although many applications in mining and mineral processing can benefit from AI-integrated computer vision, there is no doubt that particle size analysis is a key one. While the image processing-based algorithms currently available provide acceptable accuracy for mineral processing, the challenge of applying this technology in an underground environment remains. This work presents a novel deep learning-based algorithm for fragmentation analysis that imitates the operation of the human vision system. The proposed technique provides robustness towards environmental conditions, which makes it suitable to be implemented in operations with dust, motion, and variable illumination conditions, such as underground blasting and shovel cameras.

Machine Learning Models for Progression Tracking of Impulse Force During High Impact Shovel Loading Operation

D. Ali and S. Frimpong; Mining & Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO

Large impact force is generated as the large capacity shovel load 100 tons of material into the dump truck, which in-turn generates high-frequency shockwaves that travels through the truck body, chassis and exposes the operator to whole body vibrations (WBV). Real-time tracking is required for this dynamic impulse force on the truck body which is the sole cause for these vibrations. Therefore, in current work, state-of-the-art machine learning algorithms Artificial Neural Network (ANN) and Support Vector Machine (SVM) have been implemented to track the generation and progression of this dynamic force during a shovel dumping operation. With efficient and real-time tracking, appropriate steps will be taken for minimizing the resulting vibrations and thus improving the operator’s health and safety.

Meaningful Operator Performance Data and Analytics - North American Mine achieves 36% Reduction in Truck Events through Big Data Analysis and Focused Training Intervention

R. Beesley; Immersive Technologies, Sandy, UT

Vast amounts of data have become available to decision makers to the extent that distinguishing the noise from the right signal, has become very problematic. Analytics can be used to improve the performance of heavy equipment operators in any mine site. This study will showcase a successful case study to explore further details of how various data sets from the mine were queried and run through an analytic engine. This is how a tailored training program was initiated addressing the impact on cost savings, productivity improvement and data-driven decision making. While most data analysis is conducted by mining companies on productivity and maintenance, this analytics tool uses operational data to identify operator performance variability and training needs analysis.

Artificial Intelligence in Mineral Deposit Models Real-time Updating: A Self-learning Actor-Critic Framework

A. Kumar and R. Dimitrakopoulos; Mining and Materials Engineering, McGill University, Montreal, QC, Canada

Production data is easily and abundantly available in a mining operation through smart digital technologies, advanced sensors, and monitoring devices. Sensors can now measure in real-time the quality and quantity of material extracted, hauled, crushed, conveyed, processed, refined, smelted, blended, and sold to different customers. However, existing methods cannot integrate such production sensor data to update mineral deposit models while preserving spatial connectivity and statistics. This work proposes an artificial intelligence (AI) algorithm inspired by Google continuous control framework to update mineral deposit models with real-time digital production data. The AI has two different convolution neural networks (actor and critic) that are trained using actor-critic reinforcement learning for continuous action space. Three different case studies show that the AI can update in real-time (30 seconds) the mineral deposit models with incoming production data while preserving spatial statistics and connectivity.

Tuesday, February 25

9:00 AM • North 132B

Mining & Exploration: Management: Accessing Capital in Mining and Exploration Today - Key Trends

Chair: T. Alch, Vice Chair NY Section of SME and Co Chair of SME’s Mining Finance Conference, Edgewater, NJ

9:05 AM

The Role of Disclosure Requirements in Accessing Capital: A Case Study of Mine Safety Disclosures

K. Awuah-Offei1, B. Olsen2 and D. Bumbalaukas2; 1Mining & Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO and 2College of Business Administration, University of Northern Iowa, Cedar Falls, IA

Securities regulators require that registrants make certain disclosures to promote fair and efficient markets and protect investors. The benefits of such disclosure requirements to investors and market participants should outweigh their regulatory burden. The US Securities & Exchange Commission, in 2011, adopted rules that require mining registrants to disclose, in their periodic reports, information regarding specified health and safety violations, orders and citations, related assessments and legal actions, and mining-related fatalities. To the best of our knowledge, no prior work in the literature has examined the usefulness of mandatory safety disclosures to investors. This work uses a case study of one mining registrant to examine whether investors respond to periodic mine safety disclosures. We accomplish this by comparing the stock price of the mining firm to that of a peer at the time of the mine safety disclosures to see if there are “abnormal” returns. Our preliminary results suggest that there is no significant difference in the returns due to mine safety disclosures. Further research with a larger set of disclosure events is necessary to confirm this result.

9:25 AM

The Case for Transparency in Seeking Capital

A. Stagg; Stagg Resource Consultants, Inc., Cross Lanes, WV

Financing mining projects is a difficult and highly competitive activity, with opportunities typically exceeding available capital in all but the best (or craziest) of times. Valuation models are fertile ground for creative thinking and the level of sophistication often has no relationship to the degree of accuracy. It is the writer’s thesis that increased transparency in valuation modeling can result in increased success in acquiring capital, notably from the more sophisticated and stable investment sources. Recognizing and acknowledging a project’s uncertainties and addressing them in the valuation process often provides more assurance to the investor than glossing over them.
9:45 AM
Forward-Looking Investment Opportunities through Technical De-Risking
K. Olson Hoal; Cornell University, Ithaca, NY
Considerable de-risking of mineral and energy projects can be made through improved integration of technical data across the different stages of a project. Potential value is lost, for example, when subsurface knowledge is not utilized in operations or in prediction of potentially costly environmental scenarios. Technical de-risking is an opportunity for the investment community to drive industry transformation in return for potentially higher returns from more cost effective and sustainable projects. Minerals and energy will always be needed, however innovations in extraction can be driven by investors asking more from company leadership. It can be argued that companies that use integrated, technical de-risking methods are rewarded over those that do not.

10:05 AM
Current Trends in Alternative Mine Finance Structures
B. Stull; Duff & Phelps LLC, San Francisco, CA
As royalty financing has matured and streaming has become popular, new entrants looking to provide capital in the mining sector continue to create new methods of financing. While public equity markets continue to be tight and traditional debt financing is available only once projects have already achieved major milestones, miners are looking for any alternative to finance their projects. Over the past 10 years, private equity companies and specialized mine finance investors have helped bridge the gap between traditional debt and equity financing. These companies have provided billions in royalty and streaming financing and continue to innovate in developing financing methods attractive to investors and miners alike. Over the past couple of years, pre-pay agreements with related options have started to appear in the mine financing world. The pre-payments can take on various structures as can the associated options, but the goal remains similar to the goals associated with royalties and streaming: provide a financing arrangement that is not overly onerous to the mine developer while limiting downside and allowing for some upside exposure to the investor.

10:25 AM
The Application of Quantitative Risk Analysis Tools to Support Investment Decisions in Metals and Mining Transactions
R. Cole; Hatch, Mississauga, ON, Canada
The paper outlines the use of quantitative risk analysis techniques to determine risk adjusted cash flows and project returns in the context of capital intensive project valuation and development in the mining sector. Quantitative risk analysis allows owners and investors to quantify overall project risk and assign uncertainty to specific elements of cash flow, considering a broad range of impacts and variability over time. The analysis provides a powerful tool in investing (pricing) or lending decision making, and in evaluating, derisking and prioritizing capital projects over the course of the lifecycle. The discussion will be focused around a case study, designed to demonstrate the approach taken in developing a quantitative risk model in evaluating an investment. The techniques presented offer a better understanding of project value drivers for investors and support a more robust decision making process for investors and lenders alike, answering some of the key questions presented by credit/investment committees when seeking to close a deal.

10:45 AM
Hot Topics in Mine Finance
C. Urda Kassis; Shearman and Sterling LLP, New York, NY
The sources being tapped, and structures being used, by mining companies to finance their greenfield projects and brownfield expansions continue to evolve at a fairly rapid pace. This session will include a discussion of topics relevant to such evolution including (i) an update on efforts to implement financing plans which combine streaming and traditional project finance, (ii) a review of new structures being used by commodity traders to provide funding for projects, (iii) the consequences for financing plans of the increased equity holdings by private equity funds in the sector, and (iv) the special challenges when financing EV mineral projects -- as well as other recent developments in the sector.

9:00 AM • North 223
Mining & Exploration: Management: Managing the Complexities of Starting Up New Mines
Chair: X. Ochoa, Lundin Gold

9:05 AM
Development of Mining-Related Coursework Based on the Gained Experience in Space Exploration
V. Tenorio, J. Kemery and K. Galla; Mining and Geological Engineering, University of Arizona, Tucson, AZ
The University of Arizona has been involved in almost every mission by NASA since the dawn of the space program. Beginning with mapping charts for the Moon landing projects, telescope observations, the exploration of distant solar systems, tele-operation of landing probes and high resolution imaging of planetary bodies, all these efforts are contributing in developing the architecture of space missions. The construction of new habitats, data collection, remote monitoring, materials handling in low gravity environments, In-Situ Resource Utilization, are some of the key issues to be addressed. Motivated to this date, by the upcoming rock sample to be retrieved by the spacecraft Osiris-Rex from asteroid Bennu, the Mining and Geological Engineering Department is planning to produce a comprehensive set of pioneering courses incorporating the gained expertise. This production-oriented coursework will prepare our future graduates in ore production techniques at Off-The-Earth (OTE) sites, dealing with distance, gravity, equipment design, life sustaining facilities, transportation and mineral processing, among other technological challenges.

9:25 AM
Loss in Mining
M. Javier; EnviroMINE, Denver, CO
Understanding losses as result of mining practices is critical. Characterization of losses (economic, social & environmental) invites us to think differently about effects of mining. Minerals are exhaustible, finite & unsustainable resources in finite planet, extracted in disequilibrium from nature. Mining’s losses would force us to redesign the business using rational features. Transitionally, management by loss is a series-strategies that minimize loss instead of maximizing profits. Meeting the demand of increased population will have higher speed of depletion that will generationally reduce the inventory of minerals. How long will actual mining last? What is next step for mining? Vision of mining is displayed in the characterization of loss to articulate our role in time. What & why do we need technology that is friendly to nature? This study offers new thinking for solutions to mining in the future. As a driver of change, losses show the mindset of the industry has not changed (Monuments of imperfection). The study presents two parts: vision of mining & consumption minerals. Those would trigger new ideas & actions to mine in balanced nature. Also, it would open new avenues of research.

9:45 AM
Pumpkin Hollow Resurrected
D. Swisher; Nevada Copper, Inc., Yerington, NV
The Pumpkin Hollow property, located in the prolific Yerington Mining District of Nevada, has a rich history dating back to the 1960’s. This was initially due to its iron potential, however, after extensive exploration, focus shifted to a cluster of large magnetite-rich copper skarn deposits. Nevada Copper Inc. (NCI) plans to exploit two near-term copper producing mines both underground (U/G) and open pit (O/P). In addition to the considerable deposit size, several opportunities exist to expand the resource through exploration drilling. NCI’s primary focus is to produce saleable copper concentrate by the end of 2019. In order to do this, the company is focused on the U/G mine first. The U/G mine has been re-designed to streamline the stope extraction process while eliminating waste and re-work. Concurrently,
technical studies and exploration continue O/P resource with a corporate strategy of margin over tons. Upon full scale mining of the U/G resource, NCI will seek to advance the O/P mine. With a first-mover advantage in the region and, with both developments being contained on an 10,000-acre private land position, Nevada Copper possesses a significant competitive advantage.

10:05 AM
Maximizing LOM Profit at Start-up: Designing an Optimization Focus into Performance Metrics on Day 1
K. Sever; Optimiz Consulting LLC, Gilbert, AZ
Mines report actual production but not production losses... net revenue but not lost revenue... actual costs but not avoidable costs... net income but not invisible losses already subtracted out! These losses reduce profit by millions of dollars annually, making optimization impossible to achieve. You can track/Reduce hidden losses if you add loss metrics to KPIs for production, capacity, problems and costs BEFORE start-up. This data gives executives and site management expanded perspectives about what is possible to achieve, triggers new questions about performance, budgets, projects, capital/expansions and optimization, and creates urgency to fix overlooked problems once the cost is known.

10:25 AM
SPCC Toquepala Expansion – Designing a Reliable Grinding Circuit
M. Perrucci; ABB Switzerland, Baden-Daettwil, Aargau, Switzerland
During feasibility phase, mining companies face several uncertainties which impact the design of the process: ore price fluctuations, permits, financing, speculations in markets etc. Southern Peru Copper Corporation's (SPCC) Toquepala Expansion project was not different. However, since the early phases the project team specified a grinding circuit with a state-of-the-art technology for the mills. SPCC has chosen the variable speed gearless mill drives (GMD) technology for their Ball Mills, which brings multiple advantages in terms of efficiency and availability in comparison to standard ring-gear Mills. This paper will present the reasons why SPCC considered GMDs for their mills, even when the mill powers were as low as 11MW.

Tuesday, February 25

Morning

9:00 AM • North 225A
Mining & Exploration: Operations: Mine Planning and Optimization II
Chair: J. Kraft, Minemax, Highlands Ranch, CO

9:00 AM
Introductions

9:05 AM
Simultaneous Production Scheduling and Transportation Optimization from Mines to Port under Uncertain Material Supply
L. LauRoche-Bolzert¹, R. Dimitrakopoulos¹ and J. Ferland²; ¹COSMO Stochastic Mine Planning Laboratory, Montreal, QC, Canada and ²Université de Montréal, Montreal, QC, Canada
Advancements in simultaneous stochastic optimization for strategic mine planning have made it possible to: (a) Optimize multiple components of a mining complex at once, taking advantage of the synergies that exist within the operation, as well as (b) include various sources of uncertainty within the mining complex. Sources of uncertainty include both supply or geological with respect to the orebodies mined, and demand or commodity prices. The transportation from the mines to the port is an additional aspect considered in this presentation. A new formulation is presented integrating mines-to-port transportation of multiple ore products to the simultaneous stochastic optimization framework for long-term mine production scheduling of direct-shipping ore operations. The model produces production schedules for the mines included within the complex as well as the mines-to-port equipment and infrastructure use, all under uncertainty of the related ore product quality.

9:25 AM
Stockpile Planning- How Early is Too Early to Consider Stockpile Strategy?
J. Baar; Bingham Canyon, Rio Tinto, Salt Lake City, UT
Correct stockpile planning can make or break a small mine. But what about a larger mine? This discussion will revolve around stockpile practices and when planning for stockpiles should occur. The bigger the mine, the more potential there will be for stockpiling large amounts of material. The smaller the mine the more necessary precise stockpile planning is in order to maximize ore in all market values. How we should go about this and plan for stockpile material, sets the stage for the future of our mines.

9:45 AM
An Integrated Approach to Dump Planning Optimization
R. Vivas; Technical Services, Hexagon Mining, Tucson, AZ
The mining industry reports hundreds of billions of dollars in revenue every year. Mine planners evaluate and update several mine plans on a regular basis. This technical paper presents an integrated approach in which the extraction, the haul and the dump plan are solved as one optimization problem. A traditional mine plan in which the shovel plan and the dump plan are solved separately is compared against the same plan in which the shovel and dump plan are solve together. This case study presents the gains in project value and how this integrated approach to dump planning can be applied to most open pit truck and shovel operations.

10:05 AM
Towards Real-Time Mining: Using Reinforcement Learning to integrate Production Planning with Truck-Dispatching Decisions
J. de Carvalho and R. Dimitrakopoulos; Mining Engineering - COSMO Lab, McGill University, Montreal, QC, Canada
The abundance of new information collected during mine operations raises the possibility of a self-learning mining complex framework. The continuous acquisition and monitoring of the operation provide new sensor data that can be used to update the uncertainty models (orebody models, equipment performance, plant requirements), providing guidance for more informed and adaptive decision-making in real-time. This work proposes a method to optimize an adaptive truck-dispatching policy using the Q-Learning method in an environment characterized by uncertainty in geology and equipment performance. The case study shows improvements in terms of targets, metal production, and fleet management.

10:25 AM
Z. Baumgardner¹, J. Hutchison², M. Nahir³ and J. Ankersmit⁴; ¹SLR International Corp, Irvine, CA; ²Hutchison Engineering Inc., Irvine, CA; ³Contaminated Sites Program, Indigenous and Northern Affairs Canada, Ottawa, ON, Canada and ⁴Federal Science and Technology Infrastructure Initiative Office, Program Sponsor and Implementation Office, Gatineau, QC, Canada
The industry standard “single point” or determinate cost estimates for mine closures are commonly used but unreliable, provide little information on potential cost risks or savings opportunities and hence are not good budgeting or planning tools. This presentation will outline probabilistic-based methods of estimating closure costs and discuss how to use them for mine closure planning and improved budgeting. Tools include decision trees to track alternative outcomes, Monte Carlo simulations to capture cost variability, and risk and opportunity identification and management matrices. These tools will be described and examples provided of how these can be used to improve closure planning.
a new linear model is presented herein to optimize strategic production scheduling of an open-pit mine with multiple processing streams and accounting for investment decisions under mineral supply uncertainty. The solution approach consists in first solving the linear relaxation using an extension of the Bienstock-Zuckerberg algorithm to the stochastic optimization. Then, a rounding heuristic based on the topological sorting is applied followed by a parallel multineighborhood Tabu search. The proposed method is applied on a multi-product open pit mine deposit, with the possibility of investing in new shovels, trucks or crushers to increase related capacities. Numerical experiments show that the proposed method managed to solve the instance within an optimality gap less than 1.5% in reasonable time. Results also display an increased expected net present value of 6% compared to the formulation without investment options.
is conducted at a temperature about 1050 C and is a necessary process to transform the natural crystalline form of spodumene \( Q \) to a form \( Q_2 \) which can be leached at a high temperature. Such energy-intensive high-temperature roasting and leaching processes have been the bottle-neck of the lithium extraction process. This paper presents the results of an alternative approach which includes chemical fusion followed by a two-step leaching process.

10:45 AM  
First Industrial Demonstration of FLSmidth ROL Process for Leaching Enargite Concentrates, Combined with Novel Arsenic Precipitation Technology at the Buenaventura Rio Seco Plant  
G. Roy¹ and P. Ponce Beoutis²; ¹Process Line Management, FLSmidth Inc, Midvale, UT and ²Gerente de Plantas e Investigaciones Metalúrgicas, Compañía de Minas Buenaventura S.A.A., Lima, Peru  
The copper mining industry is increasingly facing challenges of decreasing ore grades and orebodies becoming more difficult to process. Further complicating many ore bodies is the increase of arsenic bearing minerals, such as Enargite, which incur high smelting costs and environmental issues related to treating arsenic laden concentrates. Buenaventura and FLSmidth have been working together to develop and demonstrate an atmospheric hydrometallurgical process technology to meet the challenge of processing high arsenic concentrates. The Rio Seco demonstration plant in Peru is the site of the first continuous industrial trials of the combined technologies. The plant consists of an FLSmidth Rapid Oxidative Leach (ROL) process, complete with SMRt reactors, to enable the efficient dissolution of Copper and Arsenic from the Enargite concentrate. The arsenic is precipitated in a Scordite precipitation circuit developed by Buenaventura, with minimal losses of copper, prior to the production of copper cathode in the solvent extraction and electrowinning circuit. Results of the continuous testing at the Rio Seco demonstration plant will be presented.

Tuesday, February 25  
Morning  
9:00 AM • North 228B  
MPD: Comminution  
Chairs: H. Ghaffari, Tetra Tech B. Zhang, Derrick Corporation, Buffalo, NY

9:05 AM  
Coarser Grinding: Economic Benefits and Enabling Technologies  
D. Cirulis¹, R. Maron¹, J. Sepulveda², A. Jordens¹ and H. Walqui¹; ¹CiDRA Minerals Processing, Salt Lake City, UT and ²Gerente de Plantas e Investigaciones Metalúrgicas, Compañía de Minas Buenaventura S.A.A., Lima, Peru  
Coarser grinding and coarse particle recovery are receiving increased attention as a potential strategy for overcoming the multiple challenges that face the mining industry now and into the foreseeable future. First limitation - Adequately controlling the final product size to more closely approaching process barriers in a safe manner. This requires an advanced process control system that can achieve the desired target size with low size variability. Lack of reliable online, real-time particle size measurement has been a key limiting factor to achieving this goal. A new measurement technology developed by CiDRA overcomes this, making the grinding circuit better suited to implement a coarser grinding strategy. Second limitation - potentially lower metal recovery in conventional froth flotation due to its limited ability to recover coarse particles. CiDRA is in the final stages of development of a radically innovative separation technology. This paper presents a methodology for estimating the benefits of coarser grinding by using advanced process control enabled by a reliable real time online particle size measurement. Case studies and high-level control strategy are presented.
Microwave Assisted in Grinding Process for Metallurgical Coke  
L. Colorado-Arango and A. Osorio; Chemistry Engineering, Universidad de Antioquia, Medellin, Colombia
In steel and cement industry the elevated energy consumption is mainly due to grinding process, reaching up 70% approximately of costs of raw materials. The effect of microwave assisted to reduce the energy consumption for metallurgical coke grinding in a ball mill and its grindability was investigated using microwave oven of 2.45 GHz of frequency. A reduction in the Bond index of 15% was observed and the specific rate of breakage (Sj) increased in 12% during 3 minutes of exposure of electromagnetic radiation. This strategy improves the grindability of minerals and its kinetics condition.

High Fidelity Simulation Enabled by Geometrically Simple Charge: A Discrete Element Method Based Multi-Mode Breakage Model  
T. Boundy¹, R. Rajamani² and P. Taylor¹; ¹Colorado School of Mines, Golden, CO and ²University of Utah, Salt Lake City, UT
The discrete element method (DEM) has been applied with increasing utility to comminution unit operations by coupling DEM collision energy distributions to total mass population balance models. The present investigation utilizes total mass and indium particle size distributions in conjunction with single particle breakage studies to estimate the contributions of various breakage modes to the comminution of shredded liquid crystal display screen during attrition scrubbing. By including models for four breakage modes, prediction of grade and recovery of indium in the -50 mesh fraction is found to be accurate to within 10%. Comparison of pilot and production scale units reveals differing collision energy distributions across scales that suggest possible opportunity for improved design of pilot test equipment.

Introductions

9:00 AM • North 227C
MPD: Flotation- Operational Aspects & Equipment  
Chairs: O. Bascur, OSIsoft, LLC., Houston, TX R. LaDouceur, Montana Tech, Butte, MT

9:05 AM  
Impact of Water Quality/Management in Cu flotation — Morenci and Metcalf Concentrators  
F. Bernal, F. Mansilla and D. Ochi; Tech Services, Freeport McMoran, Morenci, AZ
In the Morenci and Metcalf concentrators, copper recovery is impacted by the quality of water. Recovery has a cyclical trend where recovery decreases considerably during the winter months. Lab flotation indicated the issue was process water related and not ore related. Water chemical organic characterization indicated the presence of surfactants, amines of organic residue origin and residues from flotation reagents. Inorganic characterization indicated the presence of a high concentration of ions such as chlorides, sulfates and metal ions in the water. A collaboration between the metallurgy group and operations applied the lab results to real fieldwork with successful results in the overall copper recoveries. Strategies included: oxidation of organics in tailings by increasing the residence time in tailing ponds (size increase), precipitation of ions using milk of lime, increasing the rate of organic oxidation by the addition of hydrogen peroxide, decreasing the organic discharge of waste water treatment facility discharge into tailings, better reagent management for the winter season, and leading efforts for a pilot treatment plant in Morenci tailings and wastewater facilities.

9:25 AM  
Online Gold Analysis Using X-ray Fluorescence  
E. Sharifi; Outotec Canada Ltd., Burlington, ON, Canada
Accurate real-time elemental analysis is one of the most important online measurements to enable efficient flotation circuit control and to achieve optimal metal recovery. In base metals concentrators, online elemental analysers have been utilized for process control since the 1960s, contributing to improved process performance and greater understanding of the process itself, in real time. In gold concentrators, typically the valuable metal content in most process streams is so low that direct measurement of gold has only been possible in product concentrate streams. Traditionally, gold content within flotation feed has been estimated according to direct measurement of elements such as iron, copper and arsenic. These indirect measurement models have proven useful in some applications. However, there are many applications where indirect measurement models are not feasible due to changes in ore properties or due to the presence of free gold that cannot be estimated according to other elements. This paper presents results of direct gold measurement using an online X-ray fluorescence (XRF) elemental analyser optimized for gold measurement.

10:05 AM  
Optimization of the Rougher Flotation Cell Mechanical Energy at the Morenci Mill  
F. Bernal, S. Ennis and E. Blanco; Technical Services, Freeport McMoran, Morenci, AZ
The Phelps Dodge Company began construction of the Morenci Concentrator in 1937 and began operating the plant in 1942. The mill still contains some of the original equipment from the 1940s. During an investigation into mass pull rates of the Morenci Mill flotation cells, it was discovered that cell impeller speeds were highly variable. Over the years, different motor types and different sheave sizes were installed throughout the circuit. Three Yasakawa variable frequency drives (VFDs) were used to change the cell motor speeds, so that the cells could be sampled at different impeller speeds on the same day. A cell by cell analysis was performed, along with hydrodynamic testing to determine the optimal agitator RPMs. A 1.3 percent increase in recovery was seen at 193 compared with the “as is” speed (~180 RPM) and the highest speed (200 RPM). Sheave installations began last year to standardize the internal energy to a range between 190-195 RPMs.

10:25 AM  
Optimization of Copper Flotation Circuit Using Advanced Mineral Identification and Characterization System (AMICS)  
P. Miranda; Eagle Engineering, Butte, MT
Most flotation circuits, especially copper, are constantly being observed for increases of overall recovery along with final concentration grade. Lately, automated mineralogy software, such as Mineral Liberations Analysis (MLA) and QEMSCAN, have assisted in increasing grade and recovery in these circuits. Recently, a new software called AMICS, Advanced Mineral Identification and Characterization System, has been utilized for optimization of a copper flotation circuit. Samples, including feed, concentrate, and tailings, were analyzed over three-month period to determine potential variables required for increasing concentration grade along with increasing overall recovery. The presentation will discuss the technology along with AMICS results and recommendations to the current flotation circuit.
Development and Validation of a Multi-Compartment Model for the Performance Prediction of Flotation Circuits
S. Amini¹, R. Silva² and A. Noble³; ¹Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA and ²FLSmidth, Midvale, UT
The detailed modeling and simulation of flotation circuits can support process design by reducing scale-up risk, improving performance estimates, and optimizing resource utilization. Altogether, these outcomes provide a more rigorous approach to plant design and a better value proposition to the plant operator. Over the last century, various modeling strategies have been developed; however, kinetic-based sub-processes models have largely prevailed as the industry standard for the adequate prediction of ultimate flotation circuit performance. In the current study, a multi-compartment flotation model was developed incorporating a rate-based pulp recovery, partition-based entrainment recovery, and physical carrying capacity limitations. The proposed modeling paradigm is capable of predicting the performance of flotation circuits while integrating feed and equipment characteristics as the primary input parameters. The capabilities of this multi-compartment model were ultimately validated through a systematic experimental program.

Optimization of the Haile Gold Mine Flash Flotation Circuit using Expert System Supervisory Logic
W. Friesinger¹, W. Gough² and B. Schug³; ¹Processing, Oceanagold, Charlotte, NC and ²Andritz Automation, Richmond, BC, Canada
This paper describes the operational challenges overcome using expert system supervisory logic for the Haile Process plant flash flotation circuit. With an original design to recover 65% of the gold coming in, uniform operation of the Flash Cell from shift to shift through automation was a major goal. Despite having automatic controls already in place, prior to installation of this expert system, control room operators battled the time consuming task of constant manual adjustment in order to keep parameters within tight ranges. Once target ranges were established, through manual trial and error by the Haile Process Team, the expert control was able to get the Flash Cell within these parameters and keep it there, ensuring consistent mass pull and better recovery from the cell. Areas of focus for the logic included: 1) eliminating variability in top valve density in order to increase recovery; 2) maximizing the amount of feed going to the cell; and 3) working with other automation control in the grinding circuit to not upset the water balance. The ultimate goal of recovering more gold by consistent operation was achieved using this supervisory logic placed around the Flash Flotation Cell.

Digital Transformation in Mineral Industry
O. Bascou, OSB Digital, The Woodlands, TX
The mining and metallurgical industries face many pressures, such as meeting production targets, minimizing costs, and maximizing product quality. In addition, manufacturers must adhere to increasing government safety and environmental compliance regulations. Many of these issues can be addressed through intelligent use of real time operating data continuously collected from their production facilities. A data-driven strategy is needed to enable operations, maintenance, and business personnel to quickly and easily take corrective action when abnormal conditions occur. A Digital Plant Template transforms data into operational insights in real-time. It uncovers the hidden, idle and downtime losses. By measuring, managing these unproductive times, people find new ways of avoiding them improving the profitability of the plant. The inFORMation created by the real time analytics is visualized and analyzed using PI Vision, PowerBI and ML Tools. The creation of new workflows and collaboration at the plant, at the enterprise and via services providers are enabled.

Floatation Circuit Evaluation Using Simulation Approach
R. Rodrigues Silva; FLSmidth, Midvale, UT
The evaluation of an existing flotation circuit comes with several challenges, some due to the number of variables involved. Feed variables include composition of ore and feed mass and volumetric flow variability. In conjunction with equipment and process variables such as froth depths, air flow rates, reagents, and pH, the complexity of this work significantly increases. Those variables may be independent, making the search for the optimal process conditions challenging. FLSmidth has developed a unique and robust floatation circuit evaluation using its own models that reflect the unique characteristics of each type of floatation equipment. These models can be used in steady state and/or dynamic simulations to reflect the variations at the plant and the expected outcome. The model uses historical data and compares all variables measured by the process plant and lab testing to map their interdependence and effect on metallurgical response as recoveries, grades, efficiency, selectivity, etc may be impacted. This paper presents the theory, development, and limitations of the methodology along with industrial examples which highlight the tools applicability to industrial circuits.

Gangue Rejection Analysis for Gravity Preconcentration of Low-Grade Sulfide Ore by X-Ray Computed Tomography
S. Bacchuar², N. Mkandawire¹, T. McGrath¹, C. Lin¹ and J. Miller¹; ¹Metallurgical Engineering, University of Utah, Salt Lake City, UT; ²Freeport McMoRan, Bagdad, AZ and ³Curtin University, Perth, WA, Australia
Inspired by the success in determining washability curves for the coal industry by X-ray computed tomography analysis, a similar attempt has been made to evaluate the gravity preconcentration efficiency for processing operations in the metal mining industry. This is possible with the theoretical metal recovery/gangue rejection curves, which help establish the maximum in gravity separation efficiency. With high-resolution X-ray computed tomography (HRXCT), and 3D image analysis, these theoretical metal recovery/gangue rejection curves can be established. In this way, the traditional sink-float analysis using heavy liquid fractionation can be replaced, and the tedious, time-consuming, toxic use of heavy liquids for laboratory sink-float analysis is avoided. Experimental HRXCT results for low grade sulfide ores are presented and compared to the results from dense media cyclone experiments in order to evaluate the efficiency of gangue mineral rejection for a low grade sulfidic gold ore.
9:45 AM
Victories and Lessons Learned at Ma'aden: the Largest Sensor Based Sorting Plant in the World
J. Rutledge, C. Robben and J. Bergmann; Mining, Tomra Sorting Solutions, Denver, CO
As sensor-based sorting becomes a recognized technology within the mining industry, there are an increasing number of large-scale installations that impact the industry beyond what was once thought possible. The Saudi Arabian mining company Ma'aden operates the largest sorting plant in the world and processes 13.5 millions tons of ore per year. Sensor based sorting technology rejects silica from the phosphate ore, prior to further crushing, milling and flotation steps. The implementation of sensor based sorting at Ma'aden resulted in significantly less crushing and grinding costs and a smaller flotation plant saving substantial amounts of water and reagents. The successes and challenges of the Ma'aden plant will be discussed.

10:05 AM
Characterising the Amenability of Gold Ore for Gravity Pre-Concentration Using DST Fluidization in the REFLUX™ Classifier
C. Lowes¹, J. Zhou¹, T. McGrath², J. Eksteen² and K. Galvin¹; ¹Chemical Engineering, Centre for Advanced Particle Processing and Transport, Newcastle, NSW, Australia and ²WA School of Mines: Minerals, Energy and Chemical Engineering, Curtin University, Perth, WA, Australia.
For increasingly lower grade ores, it has become widely recognised that pre-concentration prior to the milling circuit is a strategy for managing the rising dominance of the gangue. High recovery, upgrade and mass rejection are necessary to justify implementation, so one of the main challenges is assessing ore specific amenability to pre-concentration. For gravity separation, the sink/float test has traditionally provided the necessary information, though the technique is undesirable due to high costs and safety issues associated with heavy liquids. This paper describes an alternative technique for assessing gravity pre-concentration amenability based on hydrodynamic fractionation in a semi-batch REFLUX™ Classifier. Recent work has established excellent agreement with the sink/float test for dense minerals using an aqueous solution of lithium heteropolytungstates (LST) as the fluidizing medium. Here, the technique is extended to develop a methodology for quantifying gravity separation potential. A case study is presented on an Australian gold ore which analyses the potential for gravity pre-concentration and models separation performance based on the partition surface.

10:25 AM
Rejecting Fine Gangue Minerals from Weakly Magnetic Ores by Vibrating High Gradient Magnetic Separation in Pulsating Fluid
L. Chen¹, T. Kong¹ and M. Xie¹; ¹Kunming University of Science and Technology, Kunming, China and ²Sلون Magnetic Separator Ltd, Ganzhou, Jiangxi province, China.
Pulsating high gradient magnetic separation (HGMS) is mostly used to treat weakly magnetic ores, such as oxide iron and ilmenite ores to reject non-magnetic gangue minerals so that a rougher concentrate is produced for subsequent cleaning processes such as gravity and flotation. However, for fine weakly magnetic ores HGMS is sometimes limited due to the entrainment of gangue minerals. In this study, vibrating HGMS in pulsating fluid (VPHGMS) was developed to process fine weakly magnetic ores and its separation performance was governed by the vibrating and pulsating intensities. In the case study using a pilot-scale VPHGMS separator, a high-grade hematite concentrate assaying 55.4% Fe with 85.0% recovery was produced from a fine hematite ore assaying 32.0% Fe, and a high-grade ilmenite concentrate assaying 30.1% TiO2 with 75.0% recovery was produced from a fine ilmenite ore assaying 13.0% TiO2, which were both superior to the pulsating HGMS process. This study demonstrated that VPHGMS would be a potential technology to treat fine weakly magnetic ores with a high efficiency.

10:45 AM
Development and Reconciliation of a Value Chain Model Enabling Mass Simulations of Grade Engineering to Facilitate Scale-Up Analysis and Strategic Planning
E. Amini¹, M. Becerra², T. Bachmann³, N. Beaton¹ and G. Shapland¹; ¹IDG, CRCORE, Pullenvale, QLD, Australia; ²Anglo American, Santiago, Chile, Chile; ³Anglo American, Santiago, Chile and ⁴CRCORE, Pullenvale, QLD, Australia.
Several methodologies to manage low grade and often competent portion of the ore have been proposed and tested at lab, pilot and operational scales. CRCORE has developed Grade Engineering (GE) concepts to modify feed streams by rejecting low grade and possibly hard components in the stream at early stages of a value chain. Application of GE requires an understanding of the associated processing impacts on the value chain, as they are value modifiers on in-situ opportunities. Traditional modelling approaches and software tools do not have the ability to run the analysis at a block model scale with high fidelity in an integrated value chain. The Integrated Extraction Simulator (IES) in conjunction with sophisticated analytical tools such as Neural Networks (NN) were used to develop and reconcile a fully integrated value chain. The value chain model makes it possible to run all available blocks in the geometallurgical block model, which could be several million, and conduct scenario analysis suitable for Grade Engineering economic evaluation and strategic mine planning.

11:05 AM
Development of a Protocol to Assess Grade by Size and Particle Sorting Potential – Interim Outcomes
L. Dyer¹, L. Rojas Mendoza, F. Harach and A. Gupta; ST Equipment & Technology, Needham, MA
The ST Equipment & Technology LLC (STET) tribo-electrostatic belt separator is ideally suited for beneficiating very fine (<1µm) to moderately coarse (500µm) mineral particles, with high throughput. Testing demonstrated the capability of the STET separator to beneficiate bauxite samples by increasing available alumina while reducing reactive and total silica. STET technology is presented as a method to upgrade and pre-concentrate bauxite deposits for use in alumina production. Dry processing with the STET separator will result in a reduction in operating costs of refinery due to lower consumption of caustic soda, savings in energy due to lower volume of inert oxides and a reduction in volume of alumina refinery residues (ARR or red mud). The STET technology may offer alumina refiners other benefits including increased quarry reserves, extension of red mud disposal site life, and extended operating life of existing bauxite mines by improving quarry utilization and maximizing recovery. The dry and chemical-free by-product produced by the STET process is usable for manufacture of cement in high volumes without pre-treatment, in contrast to red mud which has limited beneficial reuse.

11:25 AM
Dry Beneficiation Of Bauxite Minerals Using a Tribo-Electrostatic Belt Separator
K. Flynn, L. Rojas Mendoza, F. Harach and A. Gupta; ST Equipment & Technology, Needham, MA
The ST Equipment & Technology LLC (STET) tribo-electrostatic belt separator is ideally suited for beneficiating very fine (<1µm) to moderately coarse (500µm) mineral particles, with high throughput. Testing demonstrated the capability of the STET separator to beneficiate bauxite samples by increasing available alumina while reducing reactive and total silica. STET technology is presented as a method to upgrade and pre-concentrate bauxite deposits for use in alumina production. Dry processing with the STET separator will result in a reduction in operating costs of refinery due to lower consumption of caustic soda, savings in energy due to lower volume of inert oxides and a reduction in volume of alumina refinery residues (ARR or red mud). The STET technology may offer alumina refiners other benefits including increased quarry reserves, extension of red mud disposal site life, and extended operating life of existing bauxite mines by improving quarry utilization and maximizing recovery. The dry and chemical-free by-product produced by the STET process is usable for manufacture of cement in high volumes without pre-treatment, in contrast to red mud which has limited beneficial reuse.
Tuesday, February 25

Morning

9:00 AM • North 125A

SME Young Leaders: Best Practices in Environmental Management: Case Studies

Chairs: D. Torres, Arcadis, Phoenix, AZ Y. Casasbuenas Cabezas, Colorado School of Mines, Golden, CO

9:05 AM

Introductions

9:05 AM

Delimitation of areas for a Sustainable Development in the Case of Artisanal and Small-Scale Gold Mining (ASGM) in Andes, Antioquia, Colombia

J. Velasquez² and O. Restrepo Baena¹; ¹Materials and Minerals, Universidad Nacional de Colombia, Medellín, Antioquia, Colombia and ²Civil Engineering, University of Texas at Arlington, Arlington, TX

Andes is the first municipality in Colombia with zero mercury mining activities. Through the Territorial Ordering Basic Plan the Town Hall plans to create a legal basis considering the social, economic, mining and agricultural aspects in order to help ASGM to formalize. The result of this study is the presentation of a map where the mining activities would be feasible, considering that these activities have been of great importance for the development of Andes. The study is based under the constrains presented above (socio-economical aspects). The main factors taken into account were: Social: in this category was studied the urban development, risk management and hazards. Mining and environment: mining activities development, processing plants, soil and water usage. Geologic and economic: topics related to metalloids, geological risks and floods. From a sustainable development perspective, this work is focused and will present the actions required for better practices based on “Zero Mercury Activities” creating solid basis for people in these communities to develop mining, understanding the importance of change, formalization and good practices.

9:25 AM

Discern Potential Environmental Impacts

Using the Integrated Biodiversity Assessment Tool (IBAT) to

B. Teschner and E. Holley; Mining Engineering, Colorado School of Mines, Golden, CO

The IBAT Report can help frame the biodiversity scoping or baseline studies and can be used in early project planning to proactively avoid or minimize impacts to sensitive species or protected areas. This presentation exhibits the use of the IBAT report in a case study and how the results were used in project permitting, design, and mitigation.

10:05 AM

The Little Critters that Stop Projects: Strategies to Address the Threat of Potential Listings Under the Endangered Species Act on Permitting Processes

D. Cerasale, WestLand Resources, Inc., Tucson, AZ

There is an increasing trend by mining opponents to use cryptic and relatively unknown species to prevent or delay the development of mining projects, particularly in the western United States. This presentation will discuss cases studies and explore techniques and strategies developed to address the potential impact of such a listing on mine operations and permitting. The Mohave shoulderband (Helminthoglypta [Coyote] greggi), a small brown-shelled desert snail known to occur on three mountains near Mojave, California, is one such species. Based in part on the restricted known range and potential threats to the snail from the development of the Golden Queen Mine, the Center for Biological Diversity (CBD) submitted a petition to the U.S. Fish and Wildlife Service (USFWS) for an emergency listing of the Mohave shoulderband as threatened or endangered under the Endangered Species Act. The strategies used during this instance included, to our knowledge, the first instance of a cooperative effort between a mining entity, CBD, and the USFWS to provide novel research to address explicitly the uncertainties associated with listing a cryptic and unknown species.

10:25 AM

Bigger than the Sum of its Parts: How Collaboration and Integration of Multidisciplinary Methods are an Invaluable Benefit to Projects

S. Ulrich and J. Gillow; Arcadis, Broomfield, CO

Recent work at a former uranium milling facility to characterize background soil and groundwater conditions has required the application of a wide variety of multidisciplinary technical methods and collaboration between multiple consultants and regulatory agencies to drive data-based decision making. The contributions of each entity were necessary to maximize the application of technical tools, to guide investigation planning, and to develop a robust site conceptual model. This concerted effort has optimized investigation funding and increased efficiency by bringing interrelated data into a common working environment to prevent duplicated efforts and aid development of big-picture interpretations in a complex geologic, geochemical, and regulatory environment. In this work, a consulting team led by Arcadis collaborated with two regulatory agencies (United States Environmental Protection Agency and New Mexico Environment Department) to plan and execute a subsurface investigation.

10:45 AM

Managing Environmental Significant Risks through Critical Controls

S. Wilson and S. Siemoneit; Freeport-McMoRan Inc, Phoenix, AZ

Freeport-McMoRan Inc. (FCX) is dedicated to managing Environmental Significant Risks (ESRs) with critical controls and employee engagement. ESRs exist globally across the minerals industry and exhibit substantial hazards to both natural and communal resources. These risks may affect a company’s ability to bring products to market and social license to operate. ESRs include catastrophic or chronic releases to surface water and/or groundwater, air releases, improper material/waste management, and wildlife mortalities. FCX manages these risks by creating a strict focus on critical controls and employee commitment. FCX uses Critical Control Inventories (CCIs) and employee training programs to outline the key physical and administrative mechanisms for preventing environmental upsets at each operation. The CCI framework acts as an instrument for teaching our workforce the most important environmental aspects of the business and has simplified the focus on what matters most. Critical environmental controls can minimize environmental impacts and help the minerals industry maintain positive stakeholder relations for long-term success.
Tuesday, February 25

Morning

9:00 AM • North 131B/C

Tailings – Perspectives for a Changing World: State of Practice

**Chairs:** G. Lysay, Freeport A. Adams, Stantec

9:00 AM

**Introductions**

9:05 AM

Cerro Verde Mine, Quebrada Linga TSF, Partnership between Owner and EoR to Achieve Robust Design and Construction of Starter Dam and Subsequent Operational Excellence

A. Adams¹, J. Obermeyer¹, T. Speigi¹ and T. Johndrow²; *Stantec, Denver, CO and *Freeport-McMoRan, Inc., Phoenix, AZ

In 2007, Cerro Verde began work with Stantec, as Engineer of Record (EoR), to conduct engineering studies for the Linga TSF near Arequipa, Peru. Throughout the design /construction process, the SMCV External Technical Review Board (ETRB) provided expert review and recommendations, which were incorporated into the design and execution of the project. The TSF stores tailings from a new 240,000 tonne per day (tpd) concentrator, an expansion of the existing concentrator and TSF. The expansion began in 2013 and was completed in 2015. Deposition of first tailings occurred in September 2015. The TSF consists of a 170-meter-high zoned rockfill starter dam with a central core designed to impound start-up water and contain approximately the first two years of tailings deposition. The TSF embankment subsequently has been raised continually by centerline method using compacted cyclone sand. This presentation summarizes the collaborative design and construction process and demonstrates how this process facilitated the desire for a robust design and efficient project execution. SMCV and Stantec continue to partner on the operational construction to rigorously achieve design expectations.

9:25 AM

Construction and Operation of Tailings Storage Facilities – Freeport-McMoRan Perspective

M. Waldron; Tailings, Freeport-McMoRan, Inc., Morenci, AZ

This paper presents the state-of-the-practice for construction of tailings storage facilities (TSFs) owned and operated by subsidiaries of Freeport-McMoRan Inc. (FM). The case studies presented will reference centerline and upstream constructed TSFs at the Bagdad and Morenci mine sites in Arizona. These dams are constructed and operated by these operations through rigorous collaboration among various FM internal teams (including site operations, site engineers, and corporate support) and external teams including the Engineer of Record (EoR) for the investigation and site characterization, design, construction, operation and monitoring of the TSFs. Successful operation requires an ongoing series of checks and balances including construction quality assurance and quality control, key performance indicator monitoring and regular site inspections that allow for quality construction and help identify opportunities for improvement. The challenges of managing the TSF construction and operation as these facilities undergo continual changes over their lifecycle and a consistent approach to promote structural stability and safe operations also are discussed.

9:45 AM

Newmont Goldcorp Penasquito Mine – How Technology has Enhanced Tailings Planning

R. Hunsaker and R. Arnaudez; Newmont Goldcorp, Guadalupe, Mexico

The oil sand industry operates large, complex TSFs. The industry takes advantage of tools generated for mining and uses them for planning and scheduling TSFs. Several different software packages are needed to handle this planning due to beach slope changes, MFT and water management. Mining lags behind the oil sand industry when it comes to tools for tailings planning. At the Penasquito mine the TSF dam spans 11 kilometers, is a centerline raise for three sides and a downstream raise for the fourth side. It is being constructed using a mine fleet 930E for a buttress, a fleet of 777 haul trucks for a sliver fill, 20-ton dump trucks for rock fill, and cycloned sand. The Penasquito team is implementing planning software to integrate all construction activities into one plan. Scenario planning is enhanced by software to optimize resources, activity duration and constraint identification. The overall software implementation is a work in progress with the overall goal of a safe, stable and well planned TSF.

10:05 AM

Case Study - Pre-Closure Tailings Management

C. Strachan, Stantec, Fort Collins, CO

This presentation outlines the closure planning and pre-closure work conducted at a precious-metal mine. Mine operations included open-pit and underground mining and tailings disposal with both conventional slurry and pressure filter plant operations. Tailings storage facility closure was aided by closure planning and pre-closure construction and operation. This included construction of a spillway designed for tailings and water management during the final years of operation as well as the capability to discharge extreme-storm runoff during operations and post-closure. The final years of slurry tailings deposition followed plans developed to create a draining tailings surface amenable for cover placement and establishment of vegetation. The open-pit mine was partially backfilled with filtered tailings to enhance slope stability and provide geochemical isolation. Reclamation cover materials, selected plant species, and vegetation establishment techniques were chosen and tested at various locations on site while conducting concurrent reclamation during operations. This presentation presents lessons learned as well as the successes in this pre-closure and closure process.

10:25 AM

Panel Discussion: State of the Tailings Dam Practice

A. Adams¹ and G. Lysay¹; *Stantec, Denver, CO and *Freeport-McMoRan, Phoenix, AZ

The final time slot for the session will be a panel discussion focusing on the current State of Practice with respect to TSFs. The State of Practice will be demonstrated through presentation of case studies with the objective to highlight key features from each selected project or operation. Panelists will share how challenges were overcome and innovative approaches were developed to address the various disciplines related to tailings and showcase applications throughout the TSF lifecycle. The discussion will include time for audience questions and participation.

Panel moderator: Georgia Lysay and/or Amanda Adams

Tuesday, February 25

Morning

9:00 AM • North 221C

UCA of SME: Shaft and Tunnel Construction

**Chair:** J. Schneider, Kelley Engineered Equipment, LLC

9:00 AM

**Introductions**

9:05 AM

Lockbourne Intermodal Subtrunk: Microtunnel Case Study

S. Saki; Aldea Services LLC, Columbus, OH

Lockbourne Intermodal Subtrunk is a sanitary sewer project intended to service the intermodal facility at Rickenbacker International Airport and developing areas in the vicinity. The project included the installation of 7,016+ linear feet of 60-inch sanitary sewer pipe utilizing a combination of pipe-in-trench and jack-and-bore construction methods along with installation of 21 manhole structures for the 60-inch sanitary sewer pipe. The microtunnel section of project included the installation of 10,218+ linear feet of 78-inch sanitary sewer tunnel using direct jacked microtunneling method and installation of 5 manhole structures along the microtunnel pipe length. This paper provides a critical review of the design and construction of the microtunnel section at Lockbourne Intermodal Subtrunk Project. The paper discusses the problems encountered during shafts and microtunnel construction, problems which were anticipated and mitigated, the problems which occurred during construction, as well as the approaches which were adopted to
handle these issues.

9:25 AM
Hydration Reaction and Strength Development of Calcium Sulfaloaluminate Cement Mortar used for Rock Support in Permafrost Region
G. Huang1, D. Pudtsaaine2, R. Gupta3 and W. Lu4; 1School of Mining and Petroleum Engineering, University of Alberta, Edmonton, AB, Canada and 2Department of Chemical and Materials Engineering, University of Alberta, Edmonton, AB, Canada
Cement-based materials (e.g. shotcrete) are widely used in mining industry for rock support. However, in permafrost regions, the strength development of Ordinary Portland cement-based materials is very slow due to the slow hydration reaction at cold temperatures. Calcium sulfaloaluminate (CSA) cement, as a high hydration heat and rapid set cement, has the potential to achieve fast strength development in permafrost regions. In this study, the hydration reaction and strength development of CSA cement mortar have been investigated at cold temperatures (e.g., 5, 0, -5, and -10 °C). The results indicate that CSA cement mortar achieved fast hydration and rapid strength development when cured at cold temperatures.

9:45 AM
An Engineered Tunneling Approach for Mine Access Tunnels
T. O'Brien1, N. Syrtios1, D. Hara1, V. Gall1 and K. Wooton2; 1Gall Zeidler Consultants, Ashburn, VA and 2Frontier-Kemper Constructors, Evesarville, IN
The use of engineered tunneling approaches for mine access tunnels and facilities has become more commonplace within the industry, with such an approach providing extended lifespans over 50 years and allowing risk management for critical mining infrastructure tunnels. Herein we discuss examples of new tunnels (via Conventional and TBM methods) and rehabilitation of existing tunnels. Examples include recently completed Luck Stone Inter-Quarry tunnel in Leesburg, VA, which employed the Sequential Excavation Method for an access tunnel connecting a newly opened pit to existing quarry and processing facilities, the Soto Norte Gold Mine in Colombia, with proposed TBM access tunnels, and Bingham Canyon Mine in Utah, where yielding steel sets were utilized in the rehabilitation of existing tunnels.

10:05 AM
Sirius Minerals North Yorkshire Polyhalite Project
S. Carter; Project Development, Sirius Minerals Plc, Scarborough, North Yorkshire, UK
Sirius Minerals Plc is currently developing the large North Yorkshire Polyhalite Project in the UK. The Project consists of the Woodsmith Mine, a 23 mile tunnel, a processing facility and a bulk port delivering 13Mtpa of multi-nutrient fertiliser to markets around the world. The two mine shafts are each approximately 5300ft deep and slightly over 22ft inside diameter. Headframes are set into 145ft deep shafts and utilises. The subject was previously explored by core drilling and prospect highwall cuts and retains a permit for quarrying, and has 3.8 million tons of resource has no monetary value, the active permit and exploration drilling on and utilities. The subject was previously explored by core drilling and prospect highwall cuts and retains a permit for quarrying, and has 3.8 million tons of limestone resource. Although SEC and JORC reporting criteria stipulate a mineral resource has no monetary value, the active permit and exploration drilling on the subject imparts a modest investment value to the property. Lacking mineral property sales data, fee simple land sales of similar undeveloped properties located adjacent to various operators of active limestone quarries were reviewed and selected for recent comparative sales to the subject. Adjustments for slope amount, highway access, and improved structures were made to derive a sales price per acre for the comps. The average fee simple sales price of the comps ($6,150 per acre) was reconciled by multiplying the amount of permitted acreage by the price per acre for the comps. The average fee simple sales price of the comps ($6,150 per acre) was reconciled by multiplying the amount of permitted acreage by the price per acre for the comps.

Tuesday, February 25
Morning

9:00 AM • North 128 B
Valuation: Case Studies and Methodologies
Chair: E. Mudd, Rock Associates, LLC, Overland Park, KS
9:05 AM
Introductions
9:09 AM
A direct, Project-Based Comparison of Commonly used Pre-Feasibility-Level Cost Estimating Methods
S. Stebbins; Aventurine Engineering, Inc., Elk, WA
Aventurine Engineering, Inc., was asked to evaluate and compare the reliability, pertinence, and utility of the different methods commonly used to estimate pre-feasibility-level costs. We examined five different approaches upon which evaluators typically rely to estimate mineral development project capital and operating costs at a pre-feasibility level. In addition to a ground-up approach, we also used Glacier Resource Innovation Group’s Evaluate, the U.S. Bureau of Mines Cost Estimating System (CES), an agglomerated, parametric approach centered around CIM’s Special Volume 47 CapCosts, and InfoMine USA’s Sherpa. Costs for three different mineral development and exploitation projects were estimated using each method. In addition to tabulating and comparing the estimated costs, all other information produced by each method is presented to provide insight into the utility of the overall results. As a consequence, much of the discussion in this presentation revolves around the overall suite of information provided by each cost-estimating system and the degree to which this information enhances the overall project evaluation process.

9:25 AM
Valuation of an Undeveloped Aggregate Property using the Sales Comparison Approach, West Virginia
D. Lunn; D.K. Lunn Geological Consulting, LLC, Lexington, KY
A vacant and undeveloped property located in West Virginia was the subject of a recent mineral valuation of aggregate deposits. The 121 acre subject property is located on a steep slope, has direct access to a highway, and lacks infrastructure and utilities. The subject was previously explored by core drilling and prospect highwall cuts and retains a permit for quarrying, and has 3.8 million tons of limestone resource. Although SEC and JORC reporting criteria stipulate a mineral resource has no monetary value, the active permit and exploration drilling on the subject imparts a modest investment value to the property. Lacking mineral property sales data, fee simple land sales of similar undeveloped properties located adjacent to various operators of active limestone quarries were reviewed and selected for recent comparative sales to the subject. Adjustments for slope amount, highway access, and improved structures were made to derive a sales price per acre for the comps. The average fee simple sales price of the comps ($6,150 per acre) was reconciled by multiplying the amount of permitted acreage (37.3 acres) of the subject to derive a value estimate ($230,000) for the limestone.

10:25 AM
Ventilation System Construction Challenges at the Blitz Project, Stillwater Mine
J. DEEN; Technical Services, SibanyeStillwater, Nye, MT
The Blitz Project is an expansion to the Stillwater Mine which represents a low initial capital and operating cost mining area with a 25-year mine life. The material from this project will add 530,000 ore tons and 350,000 mined ounces To the Stillwater Mine production annually. With this production increase for the Stillwater operation, the construction of a new ventilation circuit is essential for sustainable productivity. These ventilation changes and additions will ensure that the underground work environment presents minimal health & safety risks associated with common ventilation issues while providing a work environment that is conducive to hard work. The Blitz ventilation system construction required the addition of twin 2,600 foot Alimak raises to surface in a very remote location in the Beartooth Mountains. The driving of these raises required some very unique design to overcome the 2,600 foot length. Due to remoteness of the surface breakouts, helicopter support was necessary to facilitate construction activities. This paper will summarize these construction challenges and overall ventilation planning results.
9:45 AM
Using Paired Sales Data to Adjust Comparative Sales to Subject Property
J. Gustavson; Mineral Appraiser LLC, Boulder, CO
The Sales Comparison approach to valuation is applicable to all stages of Highest & Best Use when valuing mineral properties, be they exploratory or producing. When adjusting the value from a comparable sale to the Subject property, the availability of reliable data from Paired Sales lends support to this approach and increases its relevance. In a Paired Sales analysis, comparable sales are selected, which are similar in all parameters except for one, such as commodity price. The difference in the two sales prices can then be attributed to that one parameter. The author describes the fundamentals and illustrates the concept from market observations of his case studies of Paired Sales. The cases show that market value adjustments to Subject can be made proportional to findings from such Paired Sales. The examples relate to the proportionality between the fair market value of a mineral estate to commodity price, to geologic risk, to leasing activity, and to other parameters.

10:05 AM
Calculation of the Degree of Comparability for Historical Coal Property Transactions Used in the Determination of Fair Market Value for Coal Properties with High Grade Metallurgical Coal
D. Noll; Earthtech, Inc, Somerset, PA
In Pennsylvania the task of determining the fair market value for high grade, low volatile metallurgical coal is challenging because of the paucity of comparable sales transactions. In order to successfully evaluate a known coal property sales transaction for the purpose of using it to value another coal property one must consider numerous factors, both qualitative and quantitative in nature. This paper describes the examination of all five known coal property transactions in the entire Pennsylvania low volatile basin that took place over a five-year period, relative to the valuation date of coal properties that were taken by the Commonwealth. Discussed are the degree to which the known transaction value factors required quantitative adjustments to be considered to be comparable to the same value factors considered for the taken properties. For each transaction a “degree of comparability”, was calculated, which is the inverse of the quotient of the cumulative, adjusted value/clean ton (based on the quantitative adjustments) divided by the actual selling price per clean ton.

10:25 AM
Norming Data to Create a Comparable Sale

10:25 AM
Using Paired Sales Data to Adjust Comparative Sales to Subject Property

10:25 AM
Calculation of the Degree of Comparability for Historical Coal Property Transactions Used in the Determination of Fair Market Value for Coal Properties with High Grade Metallurgical Coal

10:25 AM
Appraisals of Oil and Gas Interests In Unconventional Resources- Norming Data to Create a Comparable Sale

9:45 AM
Using Paired Sales Data to Adjust Comparative Sales to Subject Property

9:45 AM
Calculation of the Degree of Comparability for Historical Coal Property Transactions Used in the Determination of Fair Market Value for Coal Properties with High Grade Metallurgical Coal

9:45 AM
Appraisals of Oil and Gas Interests In Unconventional Resources- Norming Data to Create a Comparable Sale

Tuesday, February 25
Afternoon

2:00 PM • North 226B
Coal & Energy: Coal Preparation and Advances in Clean Coal Technologies
Chairs: T. Ghosh, University of Alaska Fairbanks, Fairbanks, AK T. Gupta, Graduate Student, Fairbanks, AK

2:05 PM
Improving the Flotation of Oxidized Coals Based on the Degree of Coal Surface Oxidation on Site
X. Chen and Y. Peng; Univ of Queensland, Brisbane, QLD, Australia
Flotation of oxidized coals is a great challenge confronting the coal industry worldwide. To improve the flotation of oxidized coals, in this study a new technique to determine the degree of coal surface oxidation was developed first. It was found that overly oxidized coals exhibited only about 20% surface oxidation. This explains the inefficiency of oily collectors (such as diesel and kerosene) targeting unoxidized coal surfaces and polar collectors targeting oxidized coal surfaces in the flotation of oxidized coals. A new approach was then developed to efficiently float oxidized coals using a composite collector consisting of an oily collector and a polar collector targeting both unoxidized and oxidized coal surfaces simultaneously with the ratio of oily collector to polar collector being determined from the degree of coal surface oxidation. The measurement technique was tested in a number of coal preparation plants and it was able to quickly quantify the degrees of coal samples taken from different streams. The new strategy was tested in a coal preparation plant treating oxidized coals and demonstrated an increase of 20% combustible recovery.

2:25 PM
Double Emulsion Flotation of Fine Oxidized Coal
Y. Lu, X. Wang and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT
Flotation recovery of fine oxidized coal is frequently inefficient when using conventional oily collectors. To solve the problem of high oil consumption and low efficiency associated with traditional flotation, research efforts have been focused on the use of oil-in-water emulsion to reduce oil consumption. Few studies concerning water-in-oil emulsion, especially the high internal phase water-in-oil (HIP W/O) emulsion, have been conducted. Our microflotation results showed a significant oil dosage reduction when a HIP W/O emulsion was used as a collector for coal flotation. The state of the HIP W/O emulsion dispersion in water and the emulsion droplets attachment at the coal surface, which are vital issues associated with achieving efficient flotation, were studied. The HIP W/O emulsion could be a potential economical and efficient replacement for the traditional oily collectors as a promising collector for the flotation of fine oxidized coal.

2:45 PM
Recovery of Clean Coal from Low-Grade Coal through Combination of Gravity and Flotation Beneficiation Process
Z. Yang, Y. Xia, Y. Xing and X. Gui; China University of Mining and Technology, Xuzhou, China
Abstract: Beneficiation of cleaning coal from low-grade coal with high intergrown ash content is gaining attention in China. It not only improves the utilization rate of coal resources but also reduces environmental pollution. In this study, qualified clean coal was recovered from high-ash content and high intergrown low-grade coal separately through tailing discarding by gravity, intergrown liberation by grinding and column flotation. It finds that gravity separation process prepares suitable feed for grinding, rapid selective grinding process is needed for gravity concentrate in order to realize the liberation of intergrowth and selective flotation reagents are necessary for the separation of fine graded products to ensure the clean coal ash content below 12.5 %. Lastly, a novel gravity–grinding– flotation flowsheet is proposed and the suggested separation flowsheet is successfully applied in the KaiLuan (Group) Limited Liability Corporation, which is able to handle...
Approximately 400,000 metric tons low-grade coal every year. It is anticipated that the results of this work can provide a new effective management for low-grade coal.

3:05 PM
Research, Development and Application of an X-Ray Based Dry Coal Sorter
S. Zhou¹, T. Li² and C. Zhao³; ¹DADI ENGINEERING USA, Kellogg, ID;
²Tianjin MeiTeng Technology Co., Ltd., Tianjin, China and ³DADI Engineering Development Group Corp., Beijing, China
An X-ray based dry coal sorter named the TDS has been developed and successfully applied in different coal preparation applications including underground mining. The features of the technology such as design principle, structure and technical characteristics are introduced. Performance data from various TDS industrial applications shown in the paper indicate that this technology can provide an effective separation on ROM coal over a wide size range (120 to 150). Latest development of the TDS including the three-product sorter, underground sorter and mobile TDS system are also discussed in the paper.

3:25 PM
Modeling the Bubble Loading Based on Force Balance on the Particles Attached to the Bubble
A. ESKANLOU and Q. Huang; Mining Engineering, West Virginia University, Morgantown, WV
Particles loading on a bubble is the result of a successful collision, attachment, and balancing of the forces between particles and the bubble. In this study, a mathematical model to estimate the bubble loading has been developed based on the force balance on the lowest particle attached to the bubble. Gravity, buoyancy, hydrostatic pressure, viscous drag, capillary, and capillary pressure induced forces are taken into account in the model. The resultant force of the tangential components of the normal force applied by particles on top of the lowest particle and the viscous drag exerted on the attached particles by the surrounding fluid is balanced with other forces to predict whether detachment of the lowest particle occurs or not. The mathematical model was then validated by comparing the model prediction results with the experimental measurements using two minerals with different densities in a steady-state column flotation. Comparison results indicate a good agreement with a minor discrepancy that could be attributed to the irregularity of solid particles used for the flotation experiments.

3:45 PM
Bioleaching of Alaskan coal for REE extraction and concentration
T. Ghosh¹, A. Sachan¹, B. Briggs² and S. Aggarwal³; ¹Department of Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK; ²Department of Biological Sciences, University of Alaska Anchorage, Anchorage, AK and ³Department of Civil and Environmental Engineering, University of Alaska Fairbanks, Fairbanks, AK
Rare earth elements (REEs) are used in a variety of consumer goods and in defense purposes. Acquiring a domestic profitable source of REEs is a critical national need. Coal has been found to be one of the alternative sources of REEs. Alaskan coal from Wishbone Hill and Healy are known to contain REEs up to 286 ppm and 534 ppm, respectively, while having concentrations as high as 950 ppm on ash basis in some density fractions. Microbial leaching or bioleaching is a novel method that can be used for extraction of REEs from coal. A certain species of bacteria, Shewanella oneidensis MR-1, was used to separate the REEs from Wishbone Hill and Healy coal samples. The experiments were performed for various density fractions of both coals by varying solids percentage, temperature, size of coal, and bacterial concentration and recovery of REEs for these conditions was recorded. Highest individual recovery of neodymium, 75.3%, was obtained for Wishbone Hill 1.3 floats, while a maximum of 98.4% total REE recovery was obtained for Healy 1.3 sinks. Healy coal has the higher total recovery of REEs in comparison to Wishbone Hill coal.
3:05 PM
**Mining Geothermal Energy from Deep Abandoned Wells using Coaxial Borehole Heat Exchangers: A Case Study from Numerical Modeling**

X. Hu¹, Y. Guo¹, J. Banks² and W. Liu¹; ¹School of Mining and Petroleum Engineering, University of Alberta, Edmonton, AB, Canada and ²Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada

Mining geothermal energy from deep abandoned wells becomes a hot topic in recent years. This study aims to evaluate geothermal potential of deep abandoned wells by retrofitting them as coaxial borehole heat exchangers (BHEs). The coaxial BHE was modelled with COMSOL Multiphysics and verified by an analytical solution. The results of a case study show that deep abandoned wells have a great potential for geothermal exploitation using coaxial BHE. In addition to the operational parameters (i.e. well depth, injection temperature, injection flow rate, thermal conductivity of the insulating tube), this potential is also affected by properties that are temperature-dependent.

Tuesday, February 25
Afternoon

2:00 PM • North 225B
**Coal & Energy: Innovations, New Projects, and Improvements in Underground Coal Mining**

**Chairs:** G. Barclay, Contura Energy Services, Waynesburg, PA L. Stotts, Coal Source

2:05 PM
**Extending Mobile Roof Support Reach for Increased Coal Reserve Recovery**

T. Burgess¹ and C. Blanchard²; ¹Engineering, J H Fletcher and Co, Huntington, WV and ²Management, Ramaco Resources, LLC, Lexington, KY

Ramaco Resources, LLC and J.H. Fletcher recently collaborated to solve a unique geologic situation and safely increase the reserve extraction potential of Ramaco’s Rockhouse Eagle mine. The mine is located in Logan County, West Virginia and was developed as a room and pillar operation with expected normal operating heights between 6000 and 10800 (1.62M and 2.74M). As mining progressed into the reserve and while Fletcher mobile roof supports, (MRS), were being procured and built, actual mining conditions varied substantially from expectations. Due to the presence of a previously undetected third split of coal in the seam, cavity heights had increased up to 2283, (6.71M). The planned MRS’ being built even with traditional extensions that attach to the top of the MRS roof support plate would be incapable of reaching the mine roof. A taller reach MRS was not a viable option due to the increased collapsed height as the entrance to the mine was limited to 5001, (1.72M). This paper will explain the collaboration between MSHA, Ramaco and Fletcher to develop an MRS tilting, mid-chassis extension designed to be installed on the machine underground to increase the range of the MRS.

2:25 PM
**Advances in Conveyor Transfer Point Modeling using the DEM and 3D Laser Scanning**

A. Hustrulid; Shaw Almex Industries Limited, Bonita Springs, FL

The discrete element method was first applied to conveyor transfer points over 20 years ago. This paper reviews advances in the numerical modeling of transfer chutes and the collection of as built chute geometry using 3D scanning technology. Increases in computation speed, particularly with the GPU, results in significant improvements in the fidelity of the numerical model through including adhesion, increased number of particles, different particle shapes, greater range in the particle size distribution, particle breakage and coupling with fluid flow models.

One of the difficulties in upgrading existing chutes is obtaining the “as-built” geometry and identifying surrounding infrastructure that may impact a new chute design. With 3D laser scanning as built data can be collecting in the field and converted to cad models that can be considered in chute design.

2:45 PM
**Effect of Wetting Agent on Capture of Coal Dusts by Water Drops**

L. Pan and Y. Gao; Michigan Technological University, Houghton, MI

Capture of coal dusts in the underground coal mines is achieved using flooded bed scrubber, in which dust particles are collected by free water surfaces. This process involves collision and attachment of dust particles onto water surfaces, and dust-engulfed aggregates are then removed by a demister. In this work, the attachment process was fundamentally studied by measuring interactions between water drops and polished coal surfaces using a newly-developed synchronized tri-wavelength reflection interferometry microscope. The effect of wetting agents was examined. The result shows that the critical rupture thickness of air films on bituminous coals was 147 nm. The critical rupture thicknesses were increased with increasing the concentrations of wetting agents. It has also been found that the kinetics of thinning of air films was accelerated with increasing surfactant concentrations, which was in turn governed by electrostatic force. This attraction might be associated with a few layers of water molecules adsorbed on coal surfaces. The present result provides fundamental mechanisms involved in coal dust capture by water drops.

3:05 PM
**A Laboratory Investigation of Underside Shield Sprays to Improve Dust Control of Longwall Water Spray Systems**

S. Klima, R. Reed and T. Beck; CDC NIOSH, Pittsburgh, PA

Researchers at the National Institute for Occupational Safety and Health (NIOSH) performed laboratory testing to improve longwall dust control by examining the use of underside shield sprays in conjunction with the longwall directional spray system. In a field survey of longwall operations, NIOSH researchers observed dust clouds created by the fracturing and spalling of coal immediately upwind of the headgate drum that migrated into the walkway, exposing mine workers to respirable coal dust. The goal of this research was to create an effective traveling water curtain to prevent this dust from reaching the walkway by redirecting it toward the face. The location, orientation, and pressure of the sprays were the primary testing parameters examined for minimizing dust exposure in the walkway. Laboratory testing indicates that use of underside shield sprays on the longwall face may lower respirable dust exposure for mine workers.

3:25 PM
**Using a Digital Camera to Monitor the Concentration of Mine Dust – A Preliminary Trial**

L. Wu¹, C. Miranda² and W. Liu¹; ¹School of Mining and Petroleum Engineering, University of Alberta, Edmonton, AB, Canada and ²Teck Metals Ltd, Trail, BC, Canada

The monitoring of dust concentration is of great importance for dust management at mine sites and process plants. However, conventional monitoring instruments cannot be installed at some locations. Thus, this study aims to develop a new technique to monitor the dust concentration using a digital camera at laboratory scale. A batch of photos were taken at a fixed scene with various dust concentrations. After that, through Matlab coding, six image features were first extracted and then correlated with dust concentration using machine learning method. The results show that dust concentration can be successfully monitored by the proposed technique.

3:45 PM
**Dust Control at a Belt Conveyor Transfer Point Using Water Sprays and a Wetting Agent**

T. Beck, S. Klima and C. Seaman; CDC NIOSH, Pittsburgh, PA

Coal conveying and transfer can release significant amounts of dust into the mining environment, causing a health and safety risk to mine workers. Efforts to control emissions during coal transport could reduce exposures to both airborne respirable dust and accumulations of combustible float dust. The National Institute for Occupational Safety and Health (NIOSH) evaluated the ability of a water spray system at an underground belt-to-belt transfer point to reduce concentrations of airborne coal mine dust. Experiments conducted by NIOSH researchers compared...
the base condition of no water application to treatments with plain water and a plain water solution with a 0.2% wetting agent concentration. Airborne measurements showed that applying plain water reduced dust levels by 26%. Plain water reduced the observed respirable dust concentrations by 28%. The addition of an anionic wetting agent reduced dust levels around the transfer point by 49% and respirable dust by 46%. These results suggest that while plain water applications may alleviate some dust liberation, the use of wetting agents can provide much more effective dust control during material transfer.

Tuesday, February 25
Afternoon

2:00 PM • North 227B
Coal & Energy: Mine Rescue and Emergency Preparedness

Chairs: E. Zeglen, Alpha Natural Resources, Clarksville, PA
T. Rauch, Kappes Cassidy & Associates, Reno, NV

2:00 PM
Introductions

2:05 PM
Why Do We Need Risk Assessment? - Everything is Going Great!
W. York-Feirn; Colorado Department of Natural Resources, Colorado Division of Reclamation Mining & Safety, Denver, CO

People often ask: “Why Do We Need To Do a Risk Assessment?” Organizations and their management are often lulled into a false sense of security due to complacency, and a feeling that “Everything is Going Great” and ask “what could possibly go wrong here?” This presentation will illustrate where some things have gone terribly wrong at some mines, leading to several major disasters in the past. Risk Assessments for major mine emergencies could have helped mitigate potentially dangerous situations. Preparedness and readiness assessments are necessary to assure proper responses can be made in the event of an emergency. These assessments pinpoint individual mine risk and readiness deficiencies for mine emergencies and help mine management prioritize the gaps and devise action plans to quickly address them. We will provide an update on our assessment program and describe where future work will be done.

2:25 PM
Mine Fire Location Model: A Field Verification
D. Bahrami, L. Yuan and L. Zhou; CDC NIOSH, Pittsburgh, PA

Underground mine fires remain a concern for mine operators, posing a health and safety risk to the miners. In the last decade the number of mine fires has decreased significantly, however, dealing with an unknown fire in underground mines can be a challenging task, creating a hazardous condition for miners during an evacuation and rescue operation. A timely detection of mine fire and monitoring its characteristics, namely size and location, is of great importance in reducing the risk of injuries. A new fire location algorithm has been developed and integrated into an Atmospheric Monitoring System (AMS) program. This paper describes the location model and presents the results of verification fire tests conducted by NIOSH researchers at the Safety Research Coal Mine facility using the collected AMS data. NIOSH is endeavoring to develop workplace solutions to improve detection of and reduce the risk of hazardous conditions. The results demonstrate successful application of the improved fire location model and provide a useful tool for solving the problem of unknown fire location and reducing the risk of hazardous conditions.

2:45 PM
Large-Scale Explosion Propagation Testing of Treated and Non-Treated Rock Dust when Deposited with a Thin Layer Coal Dust
I. Perera and M. Harris; Fires & Explosions, CDC/NIOSH, Pittsburgh, PA

To prevent coal dust explosion propagations, rock dust needs to be lifted and suspended in the air with the coal dust during an explosion. All rock dusts cake in the presence of moisture but addition of anti-caking agents prevent rock dust from caking. Mining and rock dusting frequently create layers of rock dust and float coal dust. In order to simulate this scenario, a thin layer of coal dust was distributed on top of a layer of either treated or non-treated rock dust in the Experimental Mine Barbara, Poland and large-scale explosion tests were conducted to evaluate the flame propagation characteristics. The experimental results compare the effectiveness of the treated and untreated rock dusts using strong and weak methane ignitions.

3:05 PM
Deployment of FLIR Thermal Imaging Cameras on Bulldozers
Vision Enhancement through Steam for Spent Sand Reclamation and Distribution
K. Winfield and B. MacDonald; Provix, Alliston, ON, Canada

Surface Mining extraction & separation methods include the use of heated water that can result in significant steam rising from the spent sand. Visibility for mining operators is significantly reduced leading to potentially unsafe operating conditions & affecting productivity due to reduced operational speeds. The problem with steam rising from the spent sand has impacted on trip times as the operators could not see properly through the steam & therefore could not maintain expected speeds. Deployment of thermal imaging cameras has increased visibility for the Operators and provide for enhanced vision in steam, fog, smoke, and dark. Providing the operators with visual acuity in dense steam, allows them to confidently move their large equipment, knowing that anything with a heat signature will be clearly defined on the in-cab design. Both personnel and other operating equipment are clearly detected and operators are able to maintain an effective pace through the distribution process. Dual FLIR thermal imaging cameras are automatically activated based on the direction of travel and requiring no operator input to display an enhanced image of what is in front or behind the bulldozer.

3:25 PM
Evaluation of Carbon Monoxide and Smoke Sensors at a Low Ventilation Velocity
J. Rowland, L. Yuan and R. Thomas; Fires & Explosions Branch, NIOSH, Pittsburgh, PA

This paper presents the results of large-scale fire experiments on evaluating the performances of carbon monoxide (CO) and smoke sensors at low ventilation velocity. Experiments were conducted using three different combustibles: conveyor belt, coal, and diesel fuel, and were conducted in the Experimental Research Coal Mine at the NIOSH Bruceton Research Facility. A total of eight sensor stations was located downstream of the test fire with each station containing a CO, smoke, carbon dioxide, oxygen, humidity, barometer, temperature and two airflow sensors. The air flow velocity ranged from 44 to 108 fpm in the tests. The response times were recorded for the CO and smoke sensors at each sensor station when smoke and gaseous combustion products of the burning combustible reached the station. The response times of CO sensors were used to determine the appropriate sensor spacing in the belt entry with a low air velocity. The performance of the smoke sensor was found to be affected significantly by the high humidity in the experiments. The results showed through proper selection of sensors and can provide sufficient early fire warning times and improve health and safety of miners.

3:45 PM
Determination of a Mine Fire Intensity Using Atmospheric Monitoring System in a Ventilation Network
L. Zhou, L. Yuan, R. Thomas, D. Bahrami and J. Rowland; NIOSH, CDC, Pittsburgh, PA

Continuous monitoring of carbon monoxide and other fire related parameters by means of atmospheric monitoring system (AMS) has been widely applied by mine operators to detect fires at very early stage. Researchers at the National Institute for Occupational Safety and Health (NIOSH) have devoted great efforts to the study of integrating real-time AMS sensor data with mine fire simulation program to simulate and predict the spread of smoke to provide assistance to mine fire emergency response. The determination of fire intensity using the monitored
sensor data is the most critical component to the successful application of this integration. Direct calculation of fire intensities using AMS sensor data has been achieved by NIOSH researchers, which has proven to be very promising when a fire is within a close range of sensors. This paper presents a methodology for determining fire intensities for the complicated scenarios that a fire is distant from sensors with occurrence of airflow splits and merges. The method was validated using full-scale mine fire tests, and can help mine operators and safety personnel make informed decisions in a fire emergency.

Tuesday, February 25

2:00 PM • North 221C

Drilling and Blasting

Chairs: N. Rouse, DynoConsult, Lexington, KY N. Schaefer, University of Kentucky, Lexington, KY

2:00 PM

Introductions

2:05 PM

Reduce Dilution/Overbreak from Heading Rounds at Underground Gold Mine

N. Rouse; Respec, Lexington, KY

This case study discusses a project completed at an underground gold mine in Nevada. The purpose of the project was to reduce dilution and overbreak by adjusting the blast design while incurring little additional cost. The authors spent two weeks on site using various drill and blast instrumentation tools to collect baseline data on the current blast design/operations, develop an alternative design, test the alternative design, and evaluate the cost differences between the current design and the proposed design. This presentation covers the scope of the project, tools and methods used in the project, results of the data collection, and final recommendations.

2:25 PM

Data Analytics and Better Blast Reporting

M. Slezak; RESPEC, Lexington, KY

Blast Reports have been a necessary part of the drilling and blasting process for decades. Through the years, there have been incredible advancements in technology and data analytics. The data collected in blast reports has a ton of potential to be used, but even with all the technology at our fingertips we don’t capture the data in efficient ways. Many operations collect mass amounts of data on blasting, and simply let them sit on a shelf, to be forgotten. This paper will explore the new technologies we can leverage in blast reporting. From easy data collection to exploring the insights data science can bring to blast report analysis. We will explore mobile data collection systems, cloud data storage, and blast data science. We will look into the details of a data-set with over 200 blasts to identify trends/patterns, key performance indicators and cost savings. Through the use of some advanced statistical methods we hope to uncover new ways of thinking about efficient blasting. Use of the technology results in a streamlined approach to blasting regulation and blasting best practices. Blasting doesn’t have to fall behind the many other industries adopting these new technologies.

2:45 PM

The Impacts of Delay Sequence on Fragmentation

T. Worsey¹ and J. Silva²; DynoConsult, Dyno Nobel, Lexington, KY and Mining Engineering, University of Kentucky, Lexington, KY

Charge sequence and charge timing are adopted as very important variables when it comes to fragmentation size and shape of the muck pile. Charge sequence is defined as the order in which explosive charges are fired, and charge timing is defined as the time between each explosive detonation. This paper includes preliminary results of full scale tests at a limestone quarry designed to evaluate the influence of the charge sequence on the fragmentation results when this variable is drastically changed. For the collection of the information, the quarry requires that five years prior, a major geotechnical event had occurred, which subsequently changed the optimum mining method. The assessment identified that with just a few simple steps the operation could significantly improve the mine productivity and economics. Sometimes a problem must be solved with a different mindset from which it was created. Mining Plus’s practical industry experience allows our team to bring a global perspective to local problems, ultimately helping operations extract maximum value.”

3:05 PM

How Can We Measure Blast-Induced Ore Loss and Dilution?

W. Hunt; OreControl Blasting Consultants, Denver, CO

In nearly every hard-rock surface mine around the world, in-situ ore tonnes and grade are reconciled with material logged by dispatch systems and mill sampling. However, an un-deniable truth exists that we have all known: What is achievable pre-blast is not always achievable post-blast. Blast-induced movement changes the shape, volume, and in many cases, dip of the ore structures. Why has this fact been ignored in reconciliation processes for so long? The answer is simple: because the solution is extremely complex. Presented here is a solution any mine operator can use to answer the question “How much ore loss and dilution is caused by my blast?” Several different blasts are examined from different types of ore bodies, single and multi-flitch operations, with high and low powder-factors.

3:25 PM

“Value Unextracted” - How an outside Perspective Helps Capture Value

J. Reinhard; Underground, Mining Plus, Vancouver, BC, Canada

“We have tried everything”, “Our mine is more complex than other mines”, or “This is how we have always done it”. All mining industry professionals have heard at least two of these catchphrases at some point in their career. In essence, these statements often represent lost opportunities, ineffective practices and unrealized revenue. This presentation examines a case study in which Mining Plus was engaged by a North American diamond mine to review and improve underground drill and blast practices. Over the course of the onsite review, it was discovered that five years prior, a major geotechnical event had occurred, which subsequently changed the optimum mining method. The assessment identified that with just a few simple steps the operation could significantly improve the mine productivity and economics. Sometimes a problem must be solved with a different mindset from which it was created. Mining Plus’s practical industry experience allows our team to bring a global perspective to local problems, ultimately helping operations extract maximum value.”

3:45 PM

Drilling Consumables: How To Choose The Best Products For Your Mine

D. Rosenbach; Epiroc, Eveleth, MN

Every mine wants to drill their holes for the lowest cost possible, but what is the best way to go about doing so? Do you go with the lowest cost product and focus on purchase price, the highest cost product and hope for the best quality, or somewhere in between? Once you decide which product to go with, the real dilemma comes with how to track those products to make sure you are drilling the most cost effectively. We will examine different methods for testing drilling consumables, tracking their consumption, and examining their performance to help you ensure you are getting the best “bang for your buck”.

4:05 PM

Artificial Intelligence Approach to Predict Rock Fragmentation Based on Random Forest Algorithm and a Novel Hybrid Differential Evolution-Extreme Gradient Boosting Machine

P. Duah¹, B. Kansake², G. Barakos¹ and H. Mischo¹; Institute of Mining and Special Civil Engineering, Technische Universität Bergakademie Freiberg, Freiberg, Saxony, Germany and Department of Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, Missouri, MO

Fragmentation of rock after bench blasting is an imperative determinant of the cost associated with downstream processes such as loading, hauling and crushing. The ability to predict rock fragmentation could aid optimize drilling and blasting patterns that produces the most suitable fragmentation of blasted ore, thereby minimizing the overall cost of production. The objective of this paper is to evaluate
the performance of two artificial intelligence algorithms, Random Forest and a novel hybrid Differential Evolution-Extreme Gradient Boosting Machine (DE-XGBoost) for prediction of rock fragmentation for two mining projects. This study seeks to advance real-time fragmentation analysis in the mining industry.

4:25 PM  
**Improvement of Drilling Penetration Rate in Open Pit Mines Using Hybrid Algorithms**  
E. Moosavi; Department of Petroleum and Mining Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran, Tehran, Iran (the Islamic Republic of)  
The prediction of penetration rate helps to select the best input parameters to get the highest drilling rate with the least cost. Thus, it has been the focus of many researchers and mining companies. Several approaches, including mathematical models and artificial intelligence, have been proposed to predict the penetration rate. On the other hand, many complicated analytical models have also been developed during recent years that can predict drilling rate with a high degree of accuracy. Hybrid algorithms, as one of the most important data mining technologies, has been successfully used in different fields with their capability to identify complex relationships when sufficient data exist. The proposed methodology was used to develop mathematical programming between penetration rate and effective parameters. Next, Hybrid algorithms as a meta-heuristic method were used for prediction and optimization of drilling penetration rate. Results indicate that the proposed model provides an efficient tool for estimation of penetration rate and determining optimum drilling conditions.

Tuesday, February 25  
Afternoon  

2:00 PM • North 126B  
**Environmental: Hard Hats, Boots and Suits: A Panel Discussion**  
*Chairs: L. Watson, Merjent, Minneapolis, MN H. Halderman, Haley & Aldrich, Inc., Greenwood Village, CO*  

2:00 PM  
**Introductions**  

2:05 PM  
**Hardhats, Boots, and Suits Panel Session**  
H. Halderman; Haley & Aldrich, Inc., Denver, CO  
This session will only include three to four (15-minute) presentations on the topics: (1) communication and engagement between generations within the mines and different levels and responsibilities within the workforce; and (2) innovative technologies that help transmit information across different levels of the organization and provide an additional tool for information dissemination. The remainder of the session will include a panel of various members of the mining community who will exchange ideas and answer questions on the challenges faced in the mining industry regarding these focus areas. Panel members will include a range of roles at the mine site, from implementation to operations and management. We are hoping to foster open discussion on the challenges faced in the mining industry disseminating information and ideas from the top down as well as the bottom up. We are also hoping that individuals can share successes they have achieved with different communication approaches. This panel discussion will be a critical format for collaborative sharing of ideas and a better way for us to come up with true solutions to these challenges, versus only using presentations.

2:25 PM  
**Implementation of New Technology into a Multigenerational Workforce**  
D. Garcia; Celeritas Consulere, Tucson, AZ  
New technology implementation will need to be considered in the context of a workforce composed of four generations working side by side as managers, employees and colleagues. Rolling out a new technology will require that companies identify obstacles to communication and to develop techniques to avoid miscommunication. Communication and learning styles are a product of multiple factors, including the employee’s generation, culture, gender and individual preferences. A generation gap in communication can lead to employees who feel ignored and unheard, which in consequence weakens a company. The differences in generational backgrounds, values and styles will be highlighted to help companies find methods to fully engage their workforce.

2:45 PM  
**Organizational Design at Sibanye-Stillwater**  
M. Knight; Human Resources, Sibanye-Stillwater, Columbus, MT  
Organizational Design at Sibanye-Stillwater’s US Region Operations Following the acquisition of Stillwater Mining by South African based Sibanye Gold in May of 2017, Sibanye-Stillwater’s US Region’s operations undertook a review and redesign of their organization as part of executing a large scale expansion. The process involved an assessment of the Region’s current organization and capabilities and development of detailed role descriptions for levels of responsibility within the organization. This was followed by review and development of the role descriptions through a series of facilitated workshops addressing role responsibilities and accountabilities and identifying any obstacles or tools required to achieve role expectations and communicating those expectations across the company. Once this data was assembled and analyzed, multi-site, multi-disciplinary teams were formed to produce the tools for communication and reduce the obstacles that were identified in the workshop process. At this time, the development phase is coming to a close and implementation has begun.

3:05 PM  
**Coeur Rochester - We Pursue a Higher Standard**  
J. Bilant and G. Robinson; Process, SME, Lovelock, NV  
Coeur Mining’s vision is to Pursue a Higher Standard by Protecting our people, places and planet; develop our resources and operations for the future; and deliver results through innovation and consistency. At the Rochester Mine in Northern Nevada this framework facilitates alignment from executive management through the hourly work force and drives industry-leading safety and environmental performance, permitting, major development, production increases, lower costs and greater efficiencies. These successes are attributable to a world-class workforce, a culture of innovation and intense focus on life of mine planning. This presentation will discuss these major accomplishments, communication throughout the workforce and how lessons learned set Rochester up for future success.

3:25 PM  
**Panel Discussion**  
B. Nielsen; Environmental and Sustainable Development, Freeport-McMoRan Inc, Phoenix, AZ  
I will be attending this session as a panel member, who will exchange ideas and answer questions on the challenges faced in the mining industry regarding communications between various generations within the mining workforce, and innovative technologies that help disseminate information across different levels of the organization. As a panel member, I will represent the remediation and management side of the operation. This panel hopes to foster open discussion on the challenges faced in the mining industry relaying information and ideas across the various functioning levels of our organization. Panel members are critical to sharing ideas and finding solutions to these challenges.
Mary Poulton, a recognized expert in the use of neural networks for geophysical data analysis, will exchange ideas and answer questions on the challenges faced in the mining industry related to continuous education for professionals and workforce diversity. This panel discussion will foster open discussion on the challenges faced in the mining industry, relaying information and ideas across the various functioning levels of our organization. Panel members are critical to sharing ideas and finding solutions to these challenges.

Tuesday, February 25
Afternoon

2:00 PM • North 127B
Environmental: Managing the Social License to Operate for Today and Tomorrow: Multidisciplinary Approaches

Chairs: B. Teschner, Colorado School of Mines, Golden, CO
N. Smith, Colorado School of Mines, Golden, CO

2:05 PM
Innovations to Drive Sustainable Business Value in Mining

A. Trippel; ERM, Minneapolis, MN

As mining companies grow in our increasingly competitive world, they need to effectively juggle changing economic, social, environmental, and political stakeholder expectations. This session will look at how leading companies are pulling ahead of the curve by incorporating new approaches and innovative technologies into their environmental, health, safety and social business practices. It will further reveal how they are priming their people, processes and facilities to gain business value - - through mindful risk and opportunity management.

2:25 PM
An Evaluation of the Use of Sustainability Indicators in the Mining Industry

C. Perdeli Demirkan¹, A. Waclawski², N. Smith² and S. Duzgun³; ¹Earth Resources Development Engineering, Colorado School of Mines, Lakewood, CO; ²Mining Engineering, Colorado School of Mines, Golden, CO; and ³Mining Engineering, Colorado School of Mines, Golden, CO

Mining companies have long embraced sustainability, yet despite their efforts to quantify contributions to sustainability, current indicator-based assessments are far from standard. This research examines the state of mining companies’ sustainability reporting by comparing a set of sustainability indicators compiled from the literature to the indicators used in company reports over the last six years. It reveals trends in reported indicators and gaps between the literature and company reports. Based on the initial findings, we show that more (~40%) social indicators are reported by companies than are environmental (~32%) and economic (~28%) indicators. Furthermore, current reporting approaches do not capture the different temporal and spatial scales at which mining operations take place, providing a two-dimensional view of a company’s contributions to sustainable development. This research is the initial step in determining how mining companies can more accurately and consistently assess their contributions to sustainability without sacrificing the temporal and spatial nuances of their different operations.

2:45 PM
How Early Social Performance adds Value to Capital Investment Projects

A. Coppel; Sustainability and External Relations, Newmont Goldcorp, Greenwood Village, CO

There are many mining project that are first technically designed, with senior social and environmental staff later incorporated to obtain permits and convince stakeholders that the project is a good idea. Stakeholders are seen as risks to manage, with environmental and social baseline information perceived as only essential for the environmental permit. Project delays are common, often due to technical redesigns, permitting delays, and social protests. This presentation will focus on how front-end loading environmental and social performance in the scoping phase adds value to projects, enabling baseline information, permitting planning, and stakeholder input to improve project design and create conditions for best practices in underground mine planning.

3:05 PM
Multifuse Mine: the More Sustainable Mine Practice?!

A. Binder and O. Langefeld; Department of Underground Mining Methods and Machinery, Clausthal University of Technology, Clausthal-Zellerfeld, Germany

Different approaches from various fields provide a variety of possibilities to increase the sustainability of a mining operation. The Blue Mining approach considers additional energy-related usages of a mine during and after production to support the local creation of value beyond the lifetime of the mine. By integrating early planning stages, synergetic effects of both uses are maximized while avoiding conflicts between them. The presentation focusses on the possibilities of multiple uses and defines requirements and impacts for the different options. To assess if the multiple-use is more sustainable than common operations, available assessment approaches for sustainability aspects are reviewed and an approach for the decision-making process in underground mine planning is developed.

3:25 PM
A New Approach to Native American Engagement on National Forest System Lands

V. Peacey; Rio Tinto - Resolution Copper, Gold Canyon, AZ

A shift in meaningful engagement with Native American tribes has occurred as a result of the USFS lead Consultation process on Resolution Copper’s EIS. A Tribal Monitor program comprising job training and direct employment was developed by the USFS and Resolution Copper to be responsive of Tribes requests for increased participation with job training and employment. Tribal Monitors gain knowledge about cultural and natural resources working alongside trained professionals and at the same time, they record their own perspectives on the landscape. The information is communicated to Tribal community elders and the USFS to inform decisions on the Resolution Copper EIS. The program has resulted in improved information exchange, understanding and informed decision-making.

3:45 PM
Using Discrete Choice Theory to Elicit Individual Preferences and Managing Social License to Operate

K. Awasu-Ofere¹ and S. Que²; ¹Mining & Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO and ²College of River and Ocean Engineering, Changjiang University, Wuhan, China

Discrete choice theory is a technique used in economics to model individual preferences in choice situations. It is widely used in market research and other arenas to understand consumer preferences. Some researchers have recently used this approach to study the preferences of individuals in mining communities. This body of work shows that discrete choice theory, used with theories and practices from other disciplines, is a useful way to understand individual preferences and manage social license to operate. This presentation provides an overview, based on the experience of the authors and the published literature, of the challenges and best practices in using discrete choice to elicit individual preferences in mining communities. The presentation discusses challenges related to design of discrete choice experiments (survey instruments) and those related to modeling. It also discusses how discrete choice models, developed from data obtained from discrete choice experiments, can be used to manage social license to operate.
4:25 PM  
Using Sustainability Tools to Certify Renewable Energy Projects at a Mining Operation  
R. Walker; Barr Engineering Co., Minneapolis, MN  

Mining operations, and the utilities that serve them, are increasingly exploring microgrid solutions and sustainability metrics to evaluate the options for power supply at mines. Grid connected mining operations have an opportunity to work with utilities to determine the best mix of energy that maximizes cost savings, increases resiliency and contributes to sustainability goals. Just as buildings can be evaluated and receive green building certification such as LEED, more tools and processes are available to similarly evaluate large and complex infrastructure projects, such as large mining operations, to include and plan for renewable energy options. There are several types of tools and metrics. We examine a case study of a mining operation in Minnesota and consider a range of options regarding a mix of energy supply including microgrid, solar, wind, pump-storage and battery solutions. We present information regarding how these tools are designed, the criteria they evaluate and measure, and some of the details regarding how projects receive certification. Finally, we discuss how to effectively communicate results to a range of stakeholders.
handbook of techniques, state-of-the-art serious gaming software, tabletop card game, a training clinic, a supervisor leadership workshop, and a forum for sharing critical controls for potentially fatal health risks. New modeling of health metrics and environmental exposure conditions, including dust and heat stress, are being developed as part of our serious games initiative to enhance worker awareness and improve training on those public health topics. Collectively these outcomes should result in fewer mining injuries and illnesses.

3:05 PM
Evaluating Mine Emergency Competency: Lessons Learned from Harry's Hard Choices

L. Brown¹, K. Noiva², B. Granillo² and J. Burgess²; ¹Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ and ²Mel & Enid Zuckerman College of Public Health, University of Arizona, Tucson, AZ

Synthetic learning environments present a unique opportunity to assess competency in a dynamic, interactive environment that replicates the complex situations that miners face in the real world. Extending a paper scenario by NIOSH, Harry’s Hard Choices (HHC) is a synthetic learning environment for mine emergency response and evacuation training. We have conducted a multi-year experiment with HHC, aggregating data from training sessions with hundreds of miners of different experience levels. We discuss the benefits and challenges of evaluating learners under simulated realistic conditions and offer novel computational techniques to reveal competency. Key findings are presented, including insights on novice and expert behavior.

3:25 PM
Developing an Interactive Virtual Reality Mine as a Training Tool

A. Abdelrazen, L. Daling, R. Suppes, Y. Feldtmann and F. Hees; ¹Cybernetics Lab IMA & IFU in RWTH Aachen University, Scientific Researcher, Aachen, Germany; ²Institute of Mineral Resources Engineering in RWTH Aachen University, Scientific Researcher, Aachen, Germany; ³Cybernetics Lab IMA & IFU in RWTH Aachen University, Research Group Leader, Aachen, Germany and ⁴Cybernetics Lab IMA & IFU in RWTH Aachen University, Deputy Head, Aachen, Germany

The emerging technology of Virtual Reality (VR) has been introduced to training of workforce in many domains. Due to its capability to visualize 3D worlds in an immersive way, many benefits have been foreseen for the training in mining engineering as well. This field is highly challenging due to the need of demonstrating complex processes with suitable visualizations. Yet, research on intuitive interactions for mining operations within VR worlds has not been sufficiently investigated. This paper presents a virtual reality mine (VR-Mine) that introduces various scenarios focusing on intuitive design techniques such as 3D modelling, navigation, gesture interaction, menu conception and operating heavy machinery. Within the VR-Mine users are able to explore and interact with simulated mining operations which can be a basis for a broad scope of training programs. The implemented scenarios vary from safety procedures to drilling and blasting techniques.

3:45 PM
Development of a Comprehensive Training Program for Workers Exposed to Excessive Heat

M. Vieira De Moura, A. Rasti and P. Roghanchi; ¹Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ and ²Mel & Enid Zuckerman College of Public Health, University of Arizona, Tucson, AZ

Excessive heat exposure is, among the health and safety hazards, the one that has adverse effects on the health of mine workers. Indoor and outdoor work environments are prone to heat hazards, the outdoor work due to the direct exposure to the sun and indoor work due to humidity or improper air conditioning. Development and adoption of training programs at workplaces can significantly reduce the rate of heat-induced accidents. An accurately designed training program advances the ability of workers to perform their activities in the hot environment safely. The training program also reduces the risk of heat-related illnesses and safety hazards associated with heat. This study demonstrates a comprehensive training program to address excessive heat exposure in workplaces. The training program was evaluated by training 65 workers in various industries, including mining, oil & gas, and construction. New learning techniques such as interactive, self-learning, adult learning, and blended-learning techniques were compared. Finally, the effectiveness and lesson-learned from the training program were discussed.

4:05 PM
Lifelong Practical Training for Mining Industry Professionals; What do the Stakeholders Want?

M. Bueno², G. Barakos¹, K. Luolavirta¹, P. Santur³, S. Luukkanen² and H. Mischo¹; ¹Institute of Mining, TU Bergakademie Freiberg, Freiberg, Germany and ²Oulu Mining School, University of Oulu, Oulu, Finland

Training and lifelong learning of mining industry professionals over the value chain of critical raw materials has been recognised worldwide as a challenge for the development of a strong raw materials mining sector. Nevertheless, the number of available mining sites for continuous practical education is limited, while also the specifications for practical training are not clearly defined. As part of the ongoing MINETRAIN research project, a stakeholders’ survey has been launched to determine the type of trainees and their needs for practical training. The results are used to develop an on-site multidisciplinary course at the Pyhäsalmi underground mine, in Finland.

4:25 PM
Designing and Administering Workplace Surveys—Notes from the Field

A. Richins, H. Wallin and M. Nelson; Mining Engineering, University of Utah, Salt Lake City, UT

Many mining companies have adopted safety and health management systems (SHMS), to reduce accidents and fatalities. Good management systems always include a version of the Shewhart Cycle: “Plan, do, check, and act.” This ensures that all aspects of the system are continually evaluated and improved. Obviously, this approach should also be applied to the SHMS as a whole. One way to evaluate the effectiveness of a social/behavioral system is to give surveys to the system participants. Such “surveys are widely used to determine individual and group perceptions in politics and ; they can also be used to assess safety management and culture. Because opinion surveys have been widely used in the social sciences, many references hat describe how to design a survey that provide meaningful and statistically significant results. The authors gave such a survey a total of 18 times at 10 U.S. mines. The survey design did provide “good” data, but the mechanics of giving the survey were more challenging than expected, and varied widely from site to site. This paper draws on that experience to provide suggestions for future assessments of the effectiveness of safety and health management systems.
2:25 PM A Preliminary Approach to Occupational Diseases in Colombian Mining Industry
J. Monsalve¹, A. Silva¹, M. Monsalve² and G. Soto¹; ¹Universidad Nacoiar de Colombia, Medellin, Antioquia, Colombia and ²Hospital Minel Uribe Angel, Envigado, Colombia

Nowadays, the development of important and large-scale mining projects in Colombia is giving relevance to this industry in the country's economy. Despite Colombia's mining tradition, its evolution in areas such as occupational health and safety hasn't been that fortunate. Today, Colombia reports a large number of emergencies and fatalities in the mining industry; on average 85 emergencies and 101 fatalities are officially reported each year. On the other hand, even though, accidents and fatalities are regularly reported, this doesn't occur with occupational diseases in mining. This could be due to that Colombian health care system presents difficulties during a timely diagnosis of this kind of illnesses. The aim of this work is to review possible health effects on workers considering different types of mineral associations in different mineral deposits throughout the country; and establish a series of medical screening tests to trace and control possible occupational diseases. As a result, it is expected to contribute to the prevention of the occurrence of occupational diseases in mining.

2:45 PM Application of Optical Microscopy for Semi-Continuous Coal Mine Dust Monitoring
N. Santa¹, E. Sarver¹, C. Keles¹ and J. Taylor²; ¹Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and ²Clemson University, Clemson, SC

Respirable coal mine dust exposures still represent a major occupational health hazard, especially in central Appalachia. In this region, the prevalence of progressive massive fibrosis has risen dramatically over the past two decades. Current monitoring technologies are not enough to allow quick counting and classifying of coal mine dust particles. As a novel approach to this problem, we are investigating the efficacy of optical light microscopy (OLM) as the basis of a new semi-continuous dust monitoring concept. The goal of this study is to demonstrate that OLM can be used with image analysis to count and classify typical coal mine dust particles.

3:05 PM Modification of the PHS Model to Predict Heat Stress
P. Lazaro and M. Momaye; Mining and Geological Engineer, University of Arizona, Tucson, AZ

Exposure to heat stress is one of the main environmental stressors in hot climates. The damaging effects of heat stress can lead to major heat related injuries such as heat stroke, heat exhaustion, or even death. The Predicted Heat Strain (PHS) model is the latest attempt by mining companies to aid in the evaluation and management of occupational heat exposures. The adopted algorithm relies on scientific formulae and the supply of working environmental data and anthropometric characteristics of an average mine worker. In this study, we present a modification of the PHS model based on an expression that relates the core body temperature as a function of the skin temperature and stored heat. To validate the results, we compared the predictions made by the modified PHS model with direct physiological measurements obtained from ingeestible pills and heat stress monitors under different environmental and working conditions.

3:25 PM The Effects of Cooling Technologies on Core Body Temperature Monitored During Mining Activity
V. Cordova and M. Momaye; University of Arizona, Bagdad, AZ

A large number of miners remain under the shadow of heat stress risk due the requirement to complete job tasks in environments that combine high ambient temperatures and relative humidity with radiant and conductive loading, leading to an increased potential for inducing exertional heat-illnesses. We present the results of a study conducted to evaluate the performance of cooling vests by monitoring miners’ core body temperature in real time. The comfort levels attained by miners using different cooling vests are assessed. The effect of hardhats’ color on the comfort level and core body temperature is also examined. The study was performed on several workers during a hot summer at one of major mining operations in Arizona.

3:45 PM Field Practices and Recommendations for Real-time Diesel Particulate Matter Monitoring in Underground Mines
M. Khan², K. Homan¹ and A. Ut Rehman¹; ¹Mining and Nuclear Engineering, Missouri S&T, Rolla, MO and ²Mining Engineering Department, University of Engineering & Technology, Lahore., Lahore, Pakistan

Miners’ exposure to diesel exhaust is harmful. The standard Diesel Particulate Matter (DPM) monitoring method (NIOSH 5040 method) has limitations that preclude rapid DPM estimation and detailed understanding of DPM variations over time. However, real-time DPM monitors do not inherit these limitations. DPM regulations, endorsed in the United States by MSHA triggered development of instruments that can estimate DPM in real-time. Several real-time DPM monitors have been used by many researchers and efforts still continue to improve their measuring techniques and understanding. Common challenges that real-time DPM monitors include their applicability in different mining conditions and the lack of a standard/ unified calibration. FLIR Airtec is a real-time DPM monitor that has been used widely by various researchers and its performance was reported satisfactory. This study suggests several practices that can eliminate some errors/ problems encountered while using the Airtec monitor in underground mines and interpreting its results. These good work practices have been identified after extensively using Airtec in several underground US metal mines and conducting tests in a laboratory.

4:05 PM Evaluation of a Canopy Air Curtain for Reducing Diesel Particulate Matter Exposures
J. Noll, R. Reed and S. Vanderslice; NIOSH, Pittsburgh, PA, United States Mine Outlying Islands

Mine workers are one of the highest exposed occupations to diesel particulate matter (DPM) which is considered a carcinogen to humans by the International Agency on Research on Cancer. Those who work outside of cabs can be the highest exposed working groups. One potential control technology to help reduce these exposures is to use a canopy air curtain (CAC). The CAC can be attached to the canopy of certain types of equipment such as ANFO loaders and roof bolters and delivers clean air over the operator’s breathing zone. A fan draws in air through a filter to capture particles and then supplies clean air beneath the canopy where a mine worker is working. It was first designed for reducing exposures to respirable dust in roof bolters and later shuttle car operators. This study modified the design to enable the technology to capture DPM instead of dust and tested the efficiency of the CAC to reduce DPM concentration. With a 3 inch lip, the CAC reduced DPM exposures by over 90% in the center and around 80% when approaching the front edge of the CAC. The CAC could provide some protection to DPM for blasters and other types of miners working under a canopy and outside of cabs.

4:25 PM Outlining the Future of Coal Mine Dust Monitoring
D. Dyer and D. Kallam; Airtec, Boston, MA

Coal mine dust monitoring includes their applicability in different mining conditions and the lack of a standard/ unified calibration. FLIR Airtec is a real-time DPM monitor that has been used widely by various researchers and its performance was reported satisfactory. This study suggests several practices that can eliminate some errors/ problems encountered while using the Airtec monitor in underground mines and interpreting its results. These good work practices have been identified after extensively using Airtec in several underground US metal mines and conducting tests in a laboratory.

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5:05 PM Evaluation of a Canopy Air Curtain for Reducing Diesel Particulate Matter Exposures
J. Noll, R. Reed and S. Vanderslice; NIOSH, Pittsburgh, PA, United States Mine Outlying Islands

Mine workers are one of the highest exposed occupations to diesel particulate matter (DPM) which is considered a carcinogen to humans by the International Agency on Research on Cancer. Those who work outside of cabs can be the highest exposed working groups. One potential control technology to help reduce these exposures is to use a canopy air curtain (CAC). The CAC can be attached to the canopy of certain types of equipment such as ANFO loaders and roof bolters and delivers clean air over the operator’s breathing zone. A fan draws in air through a filter to capture particles and then supplies clean air beneath the canopy where a mine worker is working. It was first designed for reducing exposures to respirable dust in roof bolters and later shuttle car operators. This study modified the design to enable the technology to capture DPM instead of dust and tested the efficiency of the CAC to reduce DPM concentration. With a 3 inch lip, the CAC reduced DPM exposures by over 90% in the center and around 80% when approaching the front edge of the CAC. The CAC could provide some protection to DPM for blasters and other types of miners working under a canopy and outside of cabs.
coercivity required for a hard magnet. This effort has rapidly identified both properties as well as quickly identifying those systems that can develop extrinsic for materials discovery allows for rapid screening of both intrinsic magnetization advanced manufacturing methods and substitution at the system level to improve substitutes for permanent magnets including materials discovery, application of

Accelerated Development of Substitutes for Critical Rare-Earth Permanent Magnets
T. Lograsso; Critical Materials Institute, Ames Laboratory, Ames, IA
The Critical Materials Institute has developed a multi-pronged approach to finding substitutes for permanent magnets including materials discovery, application of advanced manufacturing methods and substitution at the system level to improve overall motor performance. An integrated computational experimental methodology for materials discovery allows for rapid screening of both intrinsic magnetization properties as well as quickly identifying those systems that can develop extrinsic coercity required for a hard magnet. This effort has rapidly identified both high performance magnets with reduced RE content and RE-free magnets that exceed the performance of existing non-RE magnets. Alternatively, application of advance manufacturing methods such additive manufacturing, magnets can be fabricated into unique configurations that can concentrate flux not possible with conventionally processed magnets. When coupled with advanced motor design, overall motor performance can be improved with reduced magnet sizes and with significant less manufacturing scrap losses.

Improved Methods for the Separation of Cobalt, Manganese, Nickel, Lithium from Waste Lithiumion Battery Scrap
M. Strauss, J. Klaehn, J. McNally, L. Diaz Aldana and T. Lister; Idaho National Laboratory, Idaho Falls, ID
Lithium and cobalt are critical materials essential to energy storage and renewable energy. The increase in demand for electric vehicles has led to a search for alternative sources for lithium and cobalt and corresponding methods for separating them from lithium battery scrap. The current methods for the separation of Co, Mn, Ni, Li require leaching solutions to have a pH between 2-4 in order to use the Cyanex series Solvay extractants. Through an innovative electrochemical leaching process for lithium batteries, a Co/Ni separation is possible without direct pH modification using only buffer solutions with the reagent. This research demonstrates this process can be more environmentally sustainable because less reagent is consumed. The corresponding McCabe-Thiele diagrams and number of theoretical stages were determined to achieve an 80-90% purity of cobalt, manganese, nickel, and lithium.

Recovery of Critical Minerals from Li-ion Batteries using Mineral Processing Technologies
L. Pan, R. Zhu, T. Payne, M. Schienke, M. McGee, T. Folayan and L. Nunneley; Michigan Technological University, Houghton, MI
Li-ion batteries use critical minerals including graphite, cobalt, and lithium in their chemistry. When reaching the end of life cycles, these spent batteries are valuable resources to be recycled. Upcycling of critical minerals from these secondary resources requires a series of separation processes so that the purified products meet market needs. In this work, we have investigated the separation of various components from spent Li-ion batteries using mineral processing technologies including froth flotation and gravity separation. We have developed a process that enables the production of high-purity battery materials, which has the potential to close the loop of material used in Li-ion batteries. In addition, the recovery of other valuable materials will also be discussed.

Characterization of Rare Earth Elements in Acid Mine Drainage Precipitates
Y. Wang; Department of Mining and Mineral Engineering, Virginia Tech, Blacksburg, VA
Recent efforts have shown that acid mine drainage precipitates (AMDp) may be a promising source of rare earth elements and critical materials (REE/CM). To better understand this resource, several particle characterization studies were conducted on AMDp samples from three AMD treatment sites in Northern and Central Appalachia. This work included the determination of particle size, size distribution, morphology, mineralogy, chemical speciation, and rare earth content. In all cases, the REEs in AMDp showed positive enrichment of heavy rare earths and yttrium relative to surrounding host rock. While the particle characteristics and gangue mineralogy varied considerably from site to site, sequential extraction tests showed that most of rare earths in AMDp were bound to carbonates and iron and manganese oxides. Results from this characterization study will be presented along with implications for process development.
Our solar system is full of critical raw materials. Asteroids such as “Ryugu” or i.e. “Davida” have mineral resources worth about $27 quintillion. Their exploitation could mean a “sustainable” solution for mankind and the end of fear of supply for these resources. But, who would be the owner of these valuable resources?

United States and Luxembourg have begun to create a legislative framework for the exploration and commercial use of the Moon’s resources and the so-called “celestial bodies”. This paper aims to analyze the current situation in space mining of critical raw materials and its forecast for the year 2025.

Growing global demand for rare earth elements (REE) has led to increased interest in improved REE production methods. One active research area has been in the development of new selective extraction chemistries. Because raffinates contain trace amounts of residual organics and metals may be discharged to wastewater treatment plants, it is important to understand whether these wastes may have detrimental impact on wastewater treatment function. We will present results of experiments exposing a bacterial culture representative of microorganisms responsible for nitrogen removal to solvent extraction components. To date the organic components appear to be more problematic than residual REE.

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Mineral resource estimation is an assessment of the quantity and quality of a mineral deposit. While traditional estimation techniques can be a very useful tool, some geologic situations may prohibit its use. A change due to folding or faulting can skew the estimation a great deal. By using Dynamic Anisotropy Interpolation (DAI), a geostatistical method, which considers local variations of the domain orientations into the mineral resource estimation, bias can be minimized. In this research, the resource model was developed using DAI; a trend surface was created to reflect the dip and dip direction. The dip and the dip directions were then interpolated to get these two parameters for every block within the deposit. A comparative study of DAI to traditional geostatistical interpolation on an iron deposit shows that the volume and tonnage were constant at twenty six million eight hundred eighty thousand cubic meters and one billion six hundred eighty million tons, respectively. It was observed that the grade had a small difference of .1%. The higher grade was calculated using DAI; however, no significant difference in the model was observed when using dynamic anisotropy interpolation.

MPS algorithms are specifically advantageous when dealing with complexity, and heterogeneity of geological data. This study presents a novel pixel-based MPS method for modeling spatial data. The developed computationally efficient methodology is based on mapping database of training image patterns using t-Distributed Stochastic Neighbor Embedding (t-SNE) algorithm for dimensionality reduction, and clustering the data samples by applying Density-based Spatial Clustering of Applications with Noise (DBSCAN) algorithm as an efficient unsupervised classification technique. For automation and input parameters tuning, and to ensure high-quality realizations, we have implemented multiple optimization stages in our methodology, including Kullback-Leibler divergence, genetic algorithms, k-nearest neighbors algorithm and history matching using pseudo-histograms, in addition to an entropy-based template size determination technique. The model was tested using synthetic data sets and applied on stochastic geological modeling.

Spatial variability and uncertainty of continuous variables (grade) and categorical variables (rock types) in mineral evaluation greatly impact the economics of mining projects. The common approach of simulating grades using deterministic rock types is problematic since spatial variability and uncertainty of grades at rock type contacts are not well captured in all types of contacts. Therefore, jointly simulating these variables can improve confidence in a resource model. Computer algorithms are used, and the idea behind the algorithms is to transform continuous variables into a Gaussian random field and categorical variables into indicator data through a truncation rule to Gaussian vector random fields. The experimental and cross variograms of the Gaussian variables, and the truncation rules were iterated optimized. Eventually, a joint model of these random fields via theoretical variograms is achieved through a correlogramized model with various parameters (coefficients) depending on the model inputs. Equi-probable images of rock types and grades are generated through a co-simulation of these variables. The simulation model was validated using a real case study data set.

For a mining operation, the considerable economic gain can be achieved by determining the optimal cutoff grade for each period. The cutoff grade is influenced by the economic parameters, mining operation capacities, and the grade distribution in the deposit. Thus, the extraction sequence and the cutoff grade should be optimized simultaneously, and the material between the lowest (breakeven) and optimal cutoff grade is stored in the stockpile for the later periods when it becomes economical. In this study, two models are proposed for the...
simultaneous optimization of extraction sequence and cutoff grade. Two case studies are presented, to illustrate the applicability of the developed models.

3:45 PM
How the New SEC Rules for Disclosure of Exploration Results, Mineral Resources and Mineral Reserves Affects the Aggregates and Industrial Minerals Sector
K. Awuah-Offei; Mining & Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO
New Securities and Exchange Commission (SEC) rules on how mining firms registered in U.S. markets are to disclose exploration results, mineral resources and mineral reserves go fully into effect in 2021. With these rules (Regulation S-K 1300), the SEC sought to better align U.S. rules with global best practices. The rules will have specific impacts on the aggregates and industrial minerals mining sector. This presentation discusses the major changes introduced by the new rules and their impact on how the aggregates and industrial minerals sector estimates and discloses exploration results, resources and reserves. The paper reviews the major differences between S-K 1300 and Industry Guide 7 and the implications for aggregates and industrial minerals producers.

4:05 PM
Strategic Scheduling for Thin Seam Mining Using Smart Equipment
D. Palomino and V. Tenorio; Mining, Student, Tucson, AZ
The extraction of thin seam deposits faces several challenges due to the level of accuracy needed in order to cut layers of reduced thickness, which has a direct impact on the reserves, dilution control, blending and therefore in the final economic results of the operation. These become more critical when seams are less than 40 cm. of thickness. A strategy based on the deployment of smart equipment, which includes autonomous scrapers, high precision continuous surfer mining, and drones for surveying, along with modern statistic tools, provides a range of multiple scenarios with different levels of certainty. The proposed assembly can help to optimize the haulage route and diminish the dilution; therefore, it increases the control of operations, increases the reserves, maximizing the ore grade reliability. A case study presents the production system, the utilization of a stochastic model, a route optimization algorithm, and the results for optimization using actual field data.

4:25 PM
Grade Estimation of an Indian Copper Deposit using Spatial Pair Copula Model
S. Datta¹, B. Samanta² and S. Equeenuddin¹; ¹EARTH AND ATMOSPHERIC SCIENCES, NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA, New Barrackpur, WEST BENGAL, India and ²Mining Engineering, IIT, Kharagpur, Kharagpur, West Bengal, India
Pair copula models have been used in scientific domain for spatial data analysis particularly for non-Gaussian data. Many real life grade attributes of mineral deposit exhibit non-Gaussian behaviour akin to lognormal or highly skewed marginal distribution. The copper deposit investigated here is one of them. An attempt has been made in this study to use spatial copula model for Copper grade estimation. Although, various copula models are existent in the literature, a spatial pair copula namely C-Vine copula is investigated. The study results indicate that this pair copula model performs fairly well when compared with the ordinary kriging.

Tuesday, February 25
Afternoon

2:00 PM • North 222B
Mining & Exploration: Engineering Solutions to Safety and Health Technological Advancements

2:05 PM
Experience and Future of Mechanized Rock Bolting
R. Lyle and A. Machines; Cementation Americas, North Bay, ON, Canada
If mechanized rock bolting produces safer results without impairing performance – why isn’t all rock bolting mechanized? At Cementation Americas, we have wide experience with a wide variety of bolting methods over a diverse range of ground conditions. In our presentation we will examine both the safety and productivity implications of mechanized bolting methods, particularly the notable reduction of safety incidents. In spite of all the advantages, challenges remain to increasing the use of mechanized bolting methods. Greater adoption of mechanized bolting in North American mining leads to better safety outcomes, but further development is required to overcome some of the current challenges, such as efficiently installing dynamic ground support required in deep hard rock mining, to allow increased adoption.

2:25 PM
Machine Learning Model for Prediction of Core Body Temperature based on Wearable Non-Invasive Monitoring Devices
V. Cordova and M. Momayez; University of Arizona, Bagdad, AZ
The direct method to measure the body’s core temperature is to employ invasive monitoring techniques, such as ingestible thermostors. In this study, we developed a machine learning model to predict the core body temperature using physiological data obtained from wearable devices such as a dermal patch and a tympanic ear thermometer. This addresses the challenges associated with evaluating and monitoring heat stress in hot mining environments. The model evaluates the data collected from mineworkers at different Arizona mine sites providing a regression algorithm that estimates the core temperature. We validated the model and the performance of non-invasive devices based on data collected during several summer seasons.

2:45 PM
Driver Safety System Data Analysis and its Effect on Fleet Optimization
M. Yildirim; Global Mining, Caterpillar Inc, Chandler, AZ
Effective production, carrying the most tons with the least amount of cost, is an important goal for all mine operations. But, even more important, is achieving this goal safely. Technologies currently exist to reduce the risk of a major safety concern on mine sites: operator fatigue. Operator fatigue monitoring technologies prevent fatigued driving by monitoring the eye closure and head nodding of machine operators to prevent incidents from occurring. While it’s clear this technology improves the safety of mining operations, there is no metric that confirms the correlation between fatigue events and mining productivity. This study aims to find if there is any positive correlation between the implementation of fatigue monitoring technology and mine site productivity. A collection of data mining techniques were used to extract data to demonstrate the correlation between different data sets. This study includes data sets gathered from a hard rock surface mine captured through Cat® MineStar™ Fleet, MineStar Health, VMS data and MineStar Driver Safety System (DSS).
3:25 PM
**Monitoring of Multiple-Level Stress Interaction at Two Underground Limestone Mines**
B. Slater, M. Murphy, G. Rashed, V. Gangrade and M. Van Dyke; PMRD, NIOSH, Pittsburgh, PA

The National Institute for Occupational Safety and Health (NIOSH) has previously established pillar design guidelines for shallow, flat-lying mining, and single level operations. Little guidance exists for ground control design in multiple level stone mines, and understanding the interactions between levels would allow engineers to better select interburden thicknesses and the necessary amount pillar columnarization. To investigate these loading conditions in multiple-level environments, NIOSH has partnered with two multiple-level operations to study the stress interaction between the levels as undermining occurs. The first mine is located in Tennessee with an 800 ft (243 m) overburden and 20 ft (6 m) interburden thickness between levels. The second mine is located in Kentucky with a 1,000 ft (304 ft) overburden and 85 ft (26 m) interburden thickness between levels. The monitoring program at these sites includes stressmeters and LIDAR for tracking stress redistributions and rock displacement in response to undermining. Monitoring is ongoing, but preliminary results and numerical modeling results show the expected interaction between levels at instrument locations.

3:45 PM
**Increase Efficiency and Safety Improvement with Underground Positioning and Communication through Ultra-Wideband Radio Technology**
F. Uth, A. Kianfar, R. Baltes and E. Clausen; Institute for Advanced Mining Technologies (AMT), RWTH Aachen University, Aachen, Germany

The need to improve productivity, safety and profitability of mining operations is driving the widespread application of automation technologies in mines. Underground positioning and communication are essential technologies for the future of autonomous underground mining. In contrast to other positioning and communication technologies such as Wireless Local Area Network (WLAN) or Radio Frequency Identification (RFID), Ultra-Wideband (UWB) radio technology provides significant benefits like accurate and robust positioning of mobile machine equipment, which is indispensable for future autonomous systems in underground mining processes e.g. production, transportation and auxiliary operations. The application of UWB provides further technical solutions, such as emergency communication and high precision positioning with accuracies < 0.5 m, through sensor data fusion of UWB and e.g. inertial navigation to increase safety and efficiency. In this presentation, the Institute for Advanced Mining Technologies (AMT) of RWTH Aachen University presents an overview of the research activities and results in underground positioning and communication for mobile machine equipment using UWB.

4:05 PM
**Rise and Mine: An Evidence-Based Framework for Fatigue Management in Mining**
T. Bauerle; Health Evaluation, Assessment, and Monitoring Team, NIOSH/SMRD, Spokane, WA

Worker fatigue is especially prevalent in mining due to a combination of fatigue-related factors, such as dim lighting; heat; highly repetitive/monotonous tasks; and long shifts. In the US, miners work 10 more hours/week than the average worker and more than 17% work over 60 hours/week (vs. 7%). Nonetheless, mine managers can be hard-pressed to obtain information needed to identify and address the factors unique to their workplace because of the lack of an evidence-based US mining industry guidance and the multifaceted nature of the worker fatigue literature. One solution is to synthesize existing evidence from other industries and countries that focus on fatigue measurement and mitigation. Researchers at NIOSH Spokane launched a 5-year study in 2019 to develop evidence-based guidance for mines to tailor and manage specific worker fatigue issues. Part of this work includes a comprehensive review of effective fatigue measurement and management strategies. This presentation will be an overview of these and future efforts to synthesize research relevant to fatigue management in mining, including preliminary findings on existent recommendations for worker fatigue.

Tuesday, February 25

2:00 PM • North 222A
**Mining & Exploration: Geosciences: Underground Geotechnical**
* Chairs: S. Warren, NIOSH, Spokane, WA M. Raffaldi, NIOSH, Lexington, KY

2:05 PM
**Physical Properties of NOH2O® Polymer-Based Emulsion: A Flexible Grout Used for Water-Sealing in Mines and Underground Infrastructure**
W. Goodman, D. Van Dyk, N. Grotbie and A. Osborne; Sovereign Group of Companies, Leesburg, FL

NOH2O® is a Polymer-Based Emulsion (PBE) grout developed in the 1970s. PBE is a suspension of colloidal polymer emulsoids dispersed in a solution of additives promoting flow and adhesion. PBE is injected in a fluid state and remains fluid until activated either by simple shear or chemically with use of an activator. Some PBE properties and behaviors are - Particle size < 1 micron - Initial injection viscosity = 2.5 dp - Single part and miscible in water - Wash-out resistant under high flow/ high pressure conditions - Sets even after dilution in formation water at < 15-25% of original concentration - Controlled curing rates from 2 seconds to several days - Sets effectively in saline and hypersaline formation waters - Remains flexible after solidification. 350%+ elasticity - Curing is non-exothermic - Safe to handle and environmentally friendly; not classified as Dangerous Goods - Can be used effectively with ordinary Portland cement to reduce costs - Radiation tolerant - 120+ year design life Because of its low viscosity and small particle size, PBE penetrates and seals water in fine fractures. Rubber-like PBE grout has successfully sealed discrete inflows as high as 3000 gpm at pressures up to 2900 psi.

2:25 PM
**Optimization of Undercut Orientation for Grasberg Block Cave Mine**
C. Vanegas Palacio², U. Kothari¹, F. Sinaga¹, J. Nguz Tshiens¹, N. Mojtabai² and D. Saiang²; “Freeport McMoRan, Phoenix, AZ and 2Mineral Engineering, New Mexico Tech, Socorro, NM

The mechanisms by which block caving occurs depends on induced stresses, gravity, strength, and discontinuities of the rock mass. This paper develops a stress analysis for the Grasberg Block Cave (GBC) Mine in Indonesia to understand the optimal cave front orientation. In order to identify the ideal configuration, a model using the in-situ stresses and representative rock parameters was built. Several analyses were performed by rotating the model of the undercut level and a representative cave shape from zero to 360 degrees. Analytical derivations were based on situe stress conditions, discontinuities, Hoek–Brown rock failure criteria and 3D boundary element method (BEM). A distinction between optimal, acceptable, and critical orientations of the undercut face was obtained from the results of the numerical analysis. Four optimal ranges of the undercut orientation were derived from the results; the current undercut face coincides with one of the optimal orientations.

2:45 PM
**Application of Image Processing for Accurate Measurement of Extraction Ratio in Abandoned Underground Mines**
M. Sadeghiamirshahidi; Geological Engineering, Montana Technological University, Butte, MT

Extraction ratio in underground mines affects many aspects of mining operation (e.g. performance of hydraulic barriers in underground coal mines, dewatering, pillar stress distribution and pillar design). Especially, it is a key factor in Long term stability analyses of abandoned underground mines. The extraction ratio is not always the same all across the mine and it changes from one stage of mining to another or from place to place. In many abandoned mines, especially
the older ones, the extraction ratios used at different parts of the mine throughout their lifetime are not known to a desired level of accuracy (if known at all). This complicates the long-term stability analyses of such abandoned mines. In this paper an image processing method is introduced that uses the existing maps of mine working areas and calculates the precise and accurate extraction ratios of every stage of mining from those maps. The method was validated by comparing the results of the model with the known extraction ratios in an underground mine. The method is then used for long term stability analysis of an abandoned underground coal mine in Michigan which underlays a busy interstate.

3:05 PM
Monitoring Underground Rock Stability Using Finite Element Analysis
J. Jia¹ and V. Tenorio²; ¹Lanzhou Jiaotong University, Lanzhou, China and ²The University of Arizona, Tuscon, AZ

To ensure the stability of underground space, the stress and the strain/dispacement of surrounding rock needs systematic monitoring. This paper proposes a finite element analysis solution. In order to achieve this goal, the stability of rock requires a detailed analysis, and as a result, the excavation methods may require modifications or even changes if the existing conditions give evidence to be unstable. Taking one underground space at the San Xavier Mine Laboratory in Tucson, AZ as a case study, the mechanical and physical parameters were tested, and the simulation models built, then the stability of this mine site was calculated and analyzed. The obtained results can provide valuable advice for the design of future expansion projects, and contribute with key information for the safety for operators.

3:25 PM
Shotcrete Practical Improvements at Freeport Underground Mine
D. Hutabarat, M. Sihombing and B. Arun; South Tangerang, Indonesia

Shotcrete has been widely used for surface support system in underground mining excavations for years. As today’s, in Freeport underground mine, shotcrete remains a widely adopted component of a typical support system. The popularity of this ground support has lead to a steady increase in the volume of shotcrete used per annum over the last 10 years. Almost all of the shotcrete used is reinforced with fibers. The implementation from a safety and productivity perspective not only over the expected life-span of an underground opening, but also at a very early age. This paper summarizes shotcrete current practice at Freeport underground mine and concludes shotcrete improvement, efficiency and performance. A critical review such as increasing early-age strength, achieve final strength, toughness and durability requirements, enhancing spray ability, screening of the right mix design, reduce mine worker fatalities, injuries and assets damage resulting from rock fall accidents and cost savings are among the listed parameters discussed in detail.

3:45 PM
Effect of Substitution of Silica Fume on the Mechanical Properties of Cemented Paste Backfill
A. Bascetin¹, E. Eker², H. adiguzel³ and S. Tulay ¹; Istanbul Universitesiscerrahpasas, ISTANBUL, Turkey and ²gumushane university, GUMUSHANE, Turkey

The purpose of this study is improving the strength of the cemented paste backfill. Also, the effect of Silica Fume (SF) was investigated on mechanical properties of CPB. In this study, tailings were taken from the copper mine, Portland Cement (PC) (5%, 7% and 9% by weight), and water is mixed with taken from SD (5%, 10%, 15% and 20% by weight) substitute for PC, CPB samples were obtained. Thus, using SD instead of PC was investigated the effect of on the mechanical properties of CPB. Obtained CPB samples were subjected to uniaxial compressive strength (UCS) tests at curing times of 3, 7, 14 and 28 days. The maximum values of UCS at 28 curing period were obtained 10 wt. % SD 9% PC (6.28 MPa). This value showed a strength of 3 times in the 28 day cure period according to the reference cemented samples (9% PC). Consequently, an additive of 5% SD directly has affected the cost of CPB due to reduces the PC ratio (%10).

4:05 PM
A Multi-physics Coupling Study on Paste Filling in Deep Ground Environment
D. Wang; special mining and civil, Ph.D., Freiberg, Germany

The paste filling mining method is a filling technique with many advantages and maybe is the perfect way to solve the most challenging high tectonic stress issue that we have to face when we exploiting the resources under the deep ground. However, the paste is affected by many factors (the surrounding rock temperature, the surrounding rock pressure, backfill sequence, the paste components) after being pumped down to the underground. So it is a very complicated but also a preoccupation barrier need to be conquered from both the perspective of economy and safety operation. This article aims to challenge the frontier research. Firstly theoreticallly analyze be committed to figuring out the interaction between surrounding factor and the filling paste, then the established coupled model runs by using comsol (an extraordinary multiple physics simulating software). Finally the intuitive plots about the relationship between the multiple physics and filling paste provide a vivid approach to understand the paste backfilling method.

4:25 PM
Development of a Supervisory System for Monitoring Ventilation and Rock Displacement Data at San Xavier Mine Laboratory
V. Tenorio¹, A. Alsalhi², G. Heath³, M. Mornayez³ and J. Werner¹; ¹Mining and Geological Engineering, University of Arizona, Tucson, AZ and ²Geology, KAUST, Riyadh, Saudi Arabia

The ability to access data from a site to a distant control room is essential for mining operations. There are several sources of data that can be collected and utilized for real-time and near-real time monitoring, in order to perform further analysis as part of continuous improvement efforts. Some of these include: point cloud imaging/augmented reality, topographic calculations, temperature variations, air quality assessment, rock displacement measurements. The benefit of accessing and studying these data is to provide safe conditions for human workers and production equipment, while finding the opportunity of increasing productivity. A prototype dashboard deployed in an in-campus control room displays anemometer data and crack gauge displacements from the San Xavier Mine Laboratory to show the potential benefit of remote access of such readings.

Tuesday, February 25
Afternoon

2:00 PM • North 222C
Mining & Exploration: Innovation & Technology: Operational Benefits from In-shift Planning and Short Interval Control

2:00 PM
Introductions

2:05 PM
Scheduling Optimization of Trackless Equipment in an Underground Mine Based on Genetic Algorithm
H. Wang¹, V. Tenorio², J. Hou¹, G. Li¹ and N. Hu¹; ¹School of Civil and Resource Engineering, University of Science and Technology Beijing, Beijing, China and ²Department of Mining and Geological Engineering, University of Arizona, Tucson, AZ

This paper presents an algorithm for optimizing the scheduling of trackless equipment in underground mines. The input of this method is the number and capacity of the trackless equipment, the production process, ore amount in stopes, and the distance between stopes. With the shortest combination of working time and interval as the goal, the genetic algorithm obtains the optimal working sequence and optimal equipment configuration sequence. The algorithm is verified
in four scenarios with phases ranging from 5 to 10, and cycles ranging from 5 to 30. The solution time of the algorithm is less than 20 minutes, which is acceptable in practical application, showing that the 10 phases-30 cycles scenario is closer to an actual mine production situation, thus the optimization model can effectively improve the operation efficiency. Simulated equipment failure conditions helped testing the robustness of the optimization. At an 8% failure rate, the operation time extends less than 1%-12% over what was expected. The algorithm can quickly provide a feasible and effective solution for production scheduling decision of trackless equipment in underground mines.

2:25 PM
Closing the Loop between Mine Short Term Planning and Real-Time Mine Operation Takes Ability
M. Serres and E. Lima; Industrial Automation - Process Industries, ABB Inc., St-Laurent, QC, Canada
In open-pit and underground mining operations, the weekly production schedule is divided into days, shifts and hours for detailed planning and scheduling of resources. Although seemingly simple at first, the coordination between weekly production schedule and production execution is one of the top challenges in mines and has a direct impact on operational efficiency and costs. This presentation is a practical demonstration of how an innovative Operations Management System integrates Short Interval Control and Closed Loop Scheduling into the same digital platform and effectively closes the loop between mine short term planning and real-time mine operation.

2:45 PM
Integrated Short Interval Control Solution for Task Management in Underground Mining
D. Meisburger; Hexagon, Tucson, AZ
Closing the gap between planning and operations is a challenge for underground miners. When plans go awry, decisions must be made quickly using the latest information to keep on track and achieve longer-term targets. As a leader in mine planning and fleet management systems (FMS), Hexagon developed an integrated solution to close this gap. Mine plans are seamlessly pushed to the FMS system and results are returned to planning. The feedback loop ensures plan compliance is monitored in near real-time, allowing miners to quickly pivot when plans derail.

3:05 PM
Digital Stockpile Modeling, Monitoring and Control
A. Young¹ and W. Rogers²; ¹Student Member, Porto Alegre, Rio Grande do Sul, Brazil and ²Mining Engineering, University of Utah, Salt Lake City, UT
Optimizing stockpile usage is challenging for many mining companies. This difficulty comes from a lack of both their digital capacity and their understanding of stockpile characteristics. These gaps cause a high amount of uncertainty over the true material composition of the stockpile, which can lead to substantial impacts for downstream processes, hinder production forecasting, and cause operational delays. Few software agnostic solutions to this problem exist. Therefore, stockpile control represents a generally unsolved mining engineering challenge. It also appears to lack an operational standard for best practice, which causes many mining companies to use a “best-guess” approach. Since the specific needs related to stockpile management vary greatly from one mining company to another, we do not propose a “one-size-fits-all” solution. Instead, we propose a roadmap to reduce stockpile uncertainty through the convergence of innovation and emerging technologies. The Internet of Things (IoT) provides the fundamental starting point of this roadmap which leads in the direction of sensors, operational data management systems, robotics, and cloud computing.

3:25 PM
Development of a Short Interval Control System for Reduction of Operational Variance Through Workforce Engagement
H. Amador de Oliveira and W. Rogers; Mining Engineering, University of Utah, Salt Lake City, UT
Reducing operational uncertainty stands as one of the ultimate challenges of the mining industry. Efforts on improving equipment reliability are broadly discussed by the scientific community. However, this paper will focus on the workforce interactions that could reduce throughput variability in surface truck-and-shovel operations. Correcting deviations from planned activities, misbehaviors, or communication errors at the time they occur is very challenging. Short Interval Control (SIC) is a process with the ability of increasing productivity through faster decision making. In this paper we look at a use case for improving workforce engagement and professional development through SIC. For the use case, a mobile application was developed to connect operational data systems with front-line supervisors. Deviations from plan are automatically calculated, filtered, and provided to FLs through notifications on wearable device. In this way, decision makers were aware of operators’ performance in near real-time. The app reduced time between controllable deviation and supervisor correction. In addition, it also served as a training and professional development tool.

3:45 PM
Impacts of Downtimes Mitigation Related to Face Drilling Rigs in Mining Development Cycles
S. Arenas Bermúdez, J. Molina Escobar and C. Zapata Otalora; Mining, SME, Medellin, Antioquia, Colombia
The development in underground mining is directly related to the performance of face drilling rigs. Reducing operating costs and improving productivity are current and crucial topics for mining projects around the world within the development phase. To assess the influence of these parameters, daily field data was taken in order to identify major downtimes in normal cycles and apply adequate correctives to mitigate them. In addition, this article presents the reader graphic illustration with the correlation between utilization and development, including historical data. This paper was elaborated from October 2017 to March 2018. The result of this study seeks to identify when projects generate profits by comparing four situations with constant productivity, but varying variables such as the possession rate, maintenance fee, production, and utilization. Finally, it is demonstrated that successful in mining projects, related to equipment is proportional to the utilization of the fleet, but with the right manage of productivities.

4:05 PM
Challenges and Best Practices in Transitioning from Pass Down Sheets to Digital Short Interval Control Systems in Underground Mines
S. Pennetsa and G. Fellows; SME, Milpitas, CA
Short Interval Control Systems yield significant benefits in terms of extending effective shift length, face utilization, and tons moved from face to stockpiles. The GMG group has also released guidelines around SIC and its implementation. While a SIC system can be implemented with off-the-shelf hardware, it will also need reliable underground networks to maximize the effectiveness of the system. This paper examines the challenges faced when introducing this new system to operators, shifters, supervisors and old-school dispatch operators, and recommends best practices to transition from a paper-based pass-down-sheet system with radio dispatch to a tablet-based Short Interval Control System that works in mines with little to no underground network support in conjunction with a Dispatch / Digital OpsCenter through to a well networked mine with automated dispatch. Successful transitions also involve process change, training and change management.

4:45PM
Design Considerations for Stiff Soil Slopes on the Carlin Trend With Planned Heights in Excess of 270 Meters
B. Maur; Mining Engineering, Nevada Gold Mines, Elko, NV
The Carlin Formation of northeastern Nevada has historically presented challenges both during the design and implementation of open pit slopes at several mines along the Carlin Trend. The sequencing and interbedding of lacustrine sediments, paleo-landslides, and altered volcanic ashes are known geotechnical challenges within the Carlin Formation making them difficult to model three-dimensionally. The back analysis of historic slope failure and laboratory testing of the Carlin Formation gives a wide range of material properties and when coupled with perched and compartmentalized groundwater affects slope design decisions. Historically on the Carlin Trend maximum continuous slope heights of 120-150m of Carlin Formation have presented major stability concerns. The Arturo Phase III open pit will have continuous Carlin Formation slope heights upwards of 270m in height. The proposed Arturo Phase III open pit will be a single access ramp system through the Carlin Formation. A synopsis of geological and hydrogeological modeling inputs for slope design will be presented.
initiatives, including examples of best practices and potential areas for growth.

The preliminary results can provide insights into the current state of diversity and inclusion programs in the North American mineral resources industry. This study characterizes the current state of progress, and what successes and challenges they have experienced. Therefore, what exactly companies are doing in this space, how they are measuring their progress, and fostering an inclusive atmosphere; however, there is a lack of coherent data on workforce diversity and a more inclusive working environment. Conventional wisdom holds that a more diverse workforce and leadership structure leads to greater business returns and more equitable and sustainable practices. Within the last decade, some companies have taken steps to increase workforce diversity and mining impacted communities. MTMA will make policy and training recommendations for safe, inclusive and respectful workplaces and provide training courses on active bystander intervention strategies (DIGGER Program).

Susan Lomas has been a Professional Geologist in mining and mineral exploration for over 30 years. She has worked in mines and remote exploration camps in the jungles of South America, the remote wilds of Canada and 30 other countries. Susan’s career has been an incredible adventure, but she has, at times, been physically unsafe, sexually harassed, harassed, intimidated and discriminated against while at work. Experiences that are too common for women and men in mining. Susan will share stories, show statistics on inappropriate workplace behaviours in mining, offer solutions so women can keep moving their careers forward and steps women and men can take when inappropriate workplace behaviours happen to them or in their presence.

Gain insights into the macro and micro trends driving hiring in the mining industry in 2020 to help plan your career or refine your hiring strategy. Learn which skills are in demand, which sites are ramping up and down, and what is happening through specific geographies, materials, and job roles. This session will draw heavily on data from Careermine, the leading job site for the mining industry, and Edumine, the leading education and training provider for the mining industry to provide a unique perspective on the global mining industry.

There is a rising demand in the mining and earth resources industries for greater workforce diversity and a more inclusive working environment. Conventional wisdom holds that a more diverse workforce and leadership structure leads to greater business returns and more equitable and sustainable practices. Within the last decade, some companies have taken steps to increase workforce diversity and foster an inclusive atmosphere; however, there is a lack of coherent data on what exactly companies are doing in this space, how they are measuring their progress, and what successes and challenges they have experienced. Therefore, this study characterizes the current state of diversity and inclusion programs in the North American mineral resources industry. The preliminary results can provide the industry with a critical understanding of the current state of diversity and inclusion initiatives, including examples of best practices and potential areas for growth.

The next generation of field mappers will push the science of geologic field mapping through technological innovations and enhancements. However, they may have less exposure to practical field mapping techniques. This poses a huge risk for the future of quality field maps. Discover how to bridge this growing gap by leveraging both traditional mapping methods and innovative technology to ensure the involvement and ownership by all experience levels of field mappers. Diverse instructional methods will be discussed to accommodate for skill gap, knowledge retention, and to set the foundation for critical thinking and skill adaptability.

Gain insights into the macro and micro trends driving hiring in the mining industry in 2020 to help plan your career or refine your hiring strategy. Learn which skills are in demand, which sites are ramping up and down, and what is happening specific geographies, materials, and job roles. This session will draw heavily on data from Careermine, the leading job site for the mining industry, and Edumine, the leading education and training provider for the mining industry to provide a unique perspective on the global mining industry.

As autonomy gains traction within the mining industry, it is transforming the nature of work performed by people within the mine site. This means miners are required to redefine roles and retrain people to use new technology. While the economic, social and environmental benefits of automation are clear, there are some bottlenecks that can significantly impact on these benefits if they are NOT considered upfront and managed properly. Automation often fails because the importance of the role of the person working within autonomous operations is underestimated, particularly their ability to compensate for the unexpected. Therefore, selecting the right people, effective training and suitable upskilling strategies are key to ensuring a highly proficient workforce within autonomous operations. A recent simulator-based training initiative by an Iron Ore mine in Australia aimed at improving productivity of Excavator Operators interacting with autonomous trucks led to significant improvement in the efficient use of autonomous system to maximize productivity.
2:25 PM Integrated Command and Control Platform for Autonomous Mining Vehicles
J. Ferrin; Autonomous Solutions, Inc., Petersboro, UT
Autonomous mining can lead to significant decreases in operating costs and improvements in utilization rates, production rates, fuel consumption and safety. However, there are practical challenges to implementing a fully-autonomous system including change management, capital requirements, and both technical and operational risks of disrupting production. Such challenges can be too daunting for operations to overcome in a single system, resulting in a piecemeal approach to implementation with isolated solutions that cannot be integrated. This approach often leads to a failure to realize the benefits of a unified autonomous mining solution. The solution to this fractured approach is a single, OEM-agnostic command and control system, built as a modular platform, that connects each vehicle, while allowing them to still function independently. This approach facilitates scalable autonomy, allowing sites to adopt automation practices at an incremental pace, better suited to their unique circumstances.

2:45 PM Implementation of an Autonomous Haulage System on Retrofitted Haul Trucks at Nevada Gold Mines Goldstrike Operations
J. Oxborrow; Open Pit Mine Engineering, Nevada Gold Mines, Elko, NV
In mid-2017 Barrick Gold in partnership with Premiere Gold Mines contracted Autonomous Solutions Incorporated (ASI) to complete an autonomous operation Proof-of-Concept (POC) at Nevada Gold Mines (NGM), Goldstrike — Arturo Operation. The POC directed ASI to supply a successful retrofit of 5 Komatsu 930E-2 haul trucks for fully autonomous operation and to provide and implement their proprietary control software. By June of 2018, the first truck began testing. This presentation highlights the collaboration efforts between NGM and ASI in retrofitting 15+ year old haul trucks for autonomous operation, the optimization of the system — people, processes, and technology, and completion of the Proof-of-Concept. The presentation will include planning and execution methodology for integrating Autonomous Surface Haulage technology in an operational mine, and the evaluation tools and criteria used to evaluate the holistic system. It will also offer insight into the considerations and pitfalls associated with green-field and brown-field implementations.

3:05 PM Autonomous Solutions for Open Pit Mining
C. Aupperle and C. Gilbert; Caterpillar Inc., Tucson, AZ
The sun beats down on the red dirt of the Pilbara in Western Australia. Massive 250-ton mining trucks traverse haul roads at speeds up to 40 mph. One glimpse inside the cab and it’s apparent that no operator is present. On the bench above, blast hole drills execute patterns with no human interaction. Dozers are climbing steep cuts with empty seats. Where are the people? How is this possible? Autonomy is changing the way we mine. The ability for computers to execute complex decision making and navigate roads with centimeter accuracy is shaping a futuristic mining environment that has become the present. In the most remote areas of the world, mining companies are learning how to extract minerals more efficiently in safer environments. From semi-autonomous dozers to fully autonomous mining trucks, manufacturers are providing the solutions needed to improve the quality of life for mining personnel and extend mine lives due to increased efficiency.

3:25 PM Practical Implementation of Semi and Full Autonomous Systems in Mining
P. Dormehlt; Sedna, Elko, NV
As adoption of automation within the mining industry increases, it has become clear that the selection and implementation of the technology exposes both opportunities and risks to the operation. This paper covers what a successful automation implementation could look like, through the different phases of the project: 1. Business Case – does the benefit out-way the risk and disruption to the business? What are the key financial and operational drivers for a success? 2. Understand Technologies – the team should understand the key technologies inherent in autonomy to be able to identify the correct product for your mining conditions and business case. 3. Vendor Selection – understand how unique operational and environmental conditions impact vendor selection. 4. Risk Assessment – review the vendor’s product risk assessment, identify new controls, while being mindful of achieving the business case. 5. Operational Readiness Plan – how does a mine site properly prepare for implementation? 6. Identification of KPI’s – what should be measured? Does this align back to the business case? How will they be measured? 7. Execution – measure KPI’s and ensuring new controls are properly managed.

Tuesday, February 25
Afternoon

2:00 PM • North 132A
Mining History
Chair: G. Luxbacher, NIOSH, Prosper, TX

2:05 PM
Irish Miners in 19th Century America
E. McCarthy; Performance Minerals LLC, Morgan Hill, CA
The common perception is that the Cornish and to a lesser extent, Germans were the artisan immigrant miners of 19th century America; the Irish involvement was limited to unskilled labor and was clouded by frequent episodes of alcohol fueled violence, strikes, poor work habits and mismanagement of technology. All of these perceptions are demonstrably untrue; the accomplishments of the Bonanza Firm on the Comstock, Myles O’Connor in Grass Valley, Marcus Daly in Butte, Thomas Cruse in Marysville, the Portland Company in Cripple Creek and Thomas Walsh in Ouray are the most outstanding, but there are hundreds more prospecting, mine development, processing, transportation and management contributions made by the Irish. Despite their reputation for alcohol and violence, the Irish were demonstrably the most civilized on the frontier, with strong family values, social organizations and building of the first churches in every community they frequented. The Molly Maguire violence in Pennsylvania and the anti-Chinese behaviour of the Irish led labor organizations in the west were ugly and reprehensible but also sadly characteristic of a very violent and discriminatory 19th century society.

2:25 PM
100 Years and Counting, Two Mining-Related Hydroelectric Projects that Continue to Generate Power Long After Mining is Over
T. Braun; SRK Consulting (U.S.), Inc., Denver, CO
In 1915, engineers charged with generating 10,000 horsepower to run the large mining and milling facilities in Southeast Alaska designed and built two hydroelectric projects in the Juneau-Douglas area. The Salmon Creek Dam Project required state-of-the-art engineering in terms of innovative concrete dam design and the Annex Lake Project relied on precision underground engineering to install a lake tap that did not drain the natural lake. Both projects delivered reliable power throughout the planned operating period between 1915 and 1941. When mining stopped, the hydroelectric projects remained operational and delivered power to the local community. Today, the Salmon Creek and Annex Lake projects provide 15% of the electrical power demand for the same community. The story of how this mining infrastructure transitioned from the mining period to an electrical utility in the 21st century offers insight into the design criteria for the operating life of a facility and the unique role of utility-related regulations.

2:45 PM
AIME in Arizona — the 113rd Meeting of 1916
G. Luxbacher; OMSHR, NIOSH, Prosper, TX
In September 1916, the then American Institute of Mining Engineers convened its one-hundred and thirteenth meeting in Arizona, the first meeting held in the State aside from a brief visit to the Arizona Territory in 1889 as part of a California meeting. Preceded by train stops to visit El Paso, TX (ASARCO smelter) and Santa Rita, NM (Chino copper and Empire Zinc), the meeting was held in Douglas, Lowell, and Globe, and included mine visits as well as numerous technical sessions. Occurring shortly after Arizona achieved statehood (1912), the program was rich
in detail about those operations that provided the foundation for the Arizona mining industry. This paper reviews that meeting, the first of many that AIME and later SME have held within the State.

3:05 PM
Mining Camp Kid
T. McNulty; T. P. McNulty and Associates, Inc., Tucson, AZ
In the late-1930s, we lived in Oatman, AZ, and the neighboring camp of Gold Road. When War Production Board Order L-208 closed the domestic precious metal mines in October 1942, Dad joined the USSR&M Bullfrog lead/zinc project at Vanadium, NM. After the War, we lived in a remote gold exploration camp in the South Amazon Basin of Brazil, then resided in two camps in the interior of British Guiana before it became Guyana. Our homes were 12-foot by 24-foot elevated platforms fitted with a 10 by 10 screened US Army tent and a thatched roof. The camps were tiny, typically inhabited by 3-5 expat couples, 5-15 expat bachelors, and a small indigenous workforce. There were plenty of snakes, big spiders and aggressive insects. Mom taught me parts of four years of schooling through the Calvert Correspondence System. Our last camp, about 10 miles north of Grants, NM, was built during the uranium boom, had modern houses and indoor plumbing, and all proper company towns that appeared throughout the western US during the 1950s. What a change, but the comforts and conveniences probably were enjoyed more by parents than by us kids!

3:25 PM
The Law in Arizona Mining Camps; Mining Law and a Whole Lot More
J. Lacy; Law, University of Arizona, Tucson, AZ
A federal mining law was passed by Congress in 1866, but miners in Arizona had already been organizing into mining camps and passing laws to define how mineral rights were acquired and maintained. Many camps didn’t stop there however, and included laws for keeping the peace, settlement of disputes and other issues important to the organization of society before the “official” semblance of law arrived. This presentation will take a look at some of the common elements of these “mining district regulations” in Arizona during the period from approximately 1862 to 1895.

3:45 PM
Mid-Tertiary IOCG Deposits in Arizona and a “Lost” Mining District
D. Welch; Mining, SME, Gilbert, AZ
The Molly Marie Prospect is a group of 20 contiguous mining claims located just north of the western end of the Superstition Mountains. The geologic features of the Prospect include a mid-Tertiary IOCG ore deposit located in a previously unrecognized submarine caldera. Accompanying the IOCG deposit, located near the foot of the Superstition Mountains, is a subject that must be breached: A “Lost” mining district. The location of these legendary and often notorious mines has been thought to be deep inside the Superstition Wilderness area, but it’s just outside its boundaries. By using modern methods, including seismic and mercury vapor surveys, lithium and gold assays, geology, and historical evidence, the locations of many back-filled pits, a processing area, and caved stopes were found. In this paper, an overview of the geology and history of the area and physical evidence of previous mining will be presented. The correlation between the geology, history and physical evidence of the area will be expanded on to demonstrate the existence of a rich historic mining district and an opportunity for an exceptional exploration target.

Tuesday, February 25
2:00 PM • North 228A
MPD: Chemical Processing II - Leaching & Modeling
Chair: J. Lee, University of Arizona, Tucson, AZ

2:05 PM
Imaging Adverse Hydraulic Conditions in a Leach Pad with Electrical Resistivity Geophysics
D. Rucker, S. Calendine and C. Baldyga, HydroGeophysics Inc, Tucson, AZ
Ore densification is a common problem in lower parts of thick heap leach pads, which in turn leads to permeability reduction and ultimately a decreased drainage flux. When this occurs, storage of leach solution increases closer to the surface, which may eventually lead to a perched water table. Unless a robust drilling program is in place to characterize the leach pad, many of these adverse hydraulic conditions may go unnoticed until a catastrophic failure occurs. In lieu of a large drilling program that can take months to complete, a reconnaissance geophysical survey could be completed quickly to gather similar information and at scales that are more intuitive to comprehend. Electrical resistivity is one of the most popular methods for characterizing leach pads, which can be deployed strictly from the surface, conducted on side slopes, with results often turned around the following day. In this talk, we show examples of leach pad characterization projects for gold and copper heaps, some validating data, and hypothetical scenarios where the adverse hydraulic conditions can be alleviated.

2:25 PM
Investigation of Chalcopyrite Leaching by Alternative Oxidants, Cr₂O₇²⁻ and NO₃⁻ In Methanesulfonic Acid (MSA)
J. Ahn and J. Lee; University of Arizona, Tucson, AZ
Chalcopyrite leaching has been studied in many different ways. Conventional sulfuric acid leaching shows the surface passivation during the leaching process. Methanesulfonic acid (MSA) has shown a promising extractions with hydrogen peroxide as an oxidant. This paper used dichromate (Cr₂O₇²⁻) and nitrate (NO₃⁻) as two alternative oxidants to investigate the copper leaching kinetics from chalcopyrite concentrate. Different concentrations of MSA and the oxidants were tested for the leaching chalcopyrite which received from a copper mine in southern Arizona. Copper extraction exceeded 90% with these two oxidants. Acid concentrations, oxidant concentration, and temperature were parameters for leaching study and detailed results will be discussed. The calculated activation energy of the reaction was 25.93 kJ/mol in dichromate system and 43 kJ/mol in nitrate system indicating the reaction was controlled by the mass transport and chemical reaction, respectively.

2:45 PM
Thermodynamic Modeling of Pregnant Leaching Solution Generated During Heap Leaching For Copper Production from 5°C to 45°C
J. Xu and G. Yue; Material Engineering, Metallurgical Engineering and Biomedical Engineering, The University of Texas at El Paso, El Paso, TX
Heap leaching plays a more important role for copper production with increasing low grade ores by hydrometallurgical route. Current heap leaching is operated at about 10-32°C. However, the temperature distribution in the heaps under different geographic locations or in the same heap but under different seasons is varying, and so does the temperature of pregnant leaching solution (PLS, typically contains 1-7 g/L Cu and 1-5 g/L Fe). To better understand the iron and copper distribution in the PLS, a detailed speciation study is required. In the present study, by virtue of our previous modeling work, thermodynamic modeling of the PLS under industrial conditions is carried out to quantify the distribution of iron, copper and sulfuric acid. The developed model provides a mathematical tool capable of quantifying the concentrations of free ions and complexes in terms of temperature (5°C to 45°C) and solution composition. Finally, oxidation-reduction potential measurements are
employed to validate the model. 

**KEYWORDS** Speciation, iron, copper, sulfic acid, pregnant leaching solution, heap leaching, oxidation-redox potential.

3:05 PM

**Hydrometallurgical Removal of Mg Impurities in Hydrogen Assisted Magnesiothermic Reduction of TiO2**

M. Free and S. Sarkar; University of Utah, Salt Lake City, UT

Low cost titanium production from TiO2 can be performed using a combination of manganesium, magnesium chloride, and hydrogen gas. The by-product magnesium oxide and residual magnesium metal can be removed from the resulting mix of TiH2, magnesium chloride through leaching. The titanium can be recovered from the purified TiH2 by dehydrogenation. This presentation discusses an evaluation of leaching kinetics for Mg removal from the TiH2/MgO/MgCl2 that results from this titanium production process.

3:25 PM

**Leaching Kinetics of Rare Earth Element Associated with an Illinois No. 6 Coal**

X. Yang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

Studies were conducted to investigate the potential of extracting rare earth elements (REEs) from Illinois No. 6 coal using hydrometallurgical processes. Leaching tests were conducted using 1 M sulfuric acid while varying solution temperature. The kinetic data suggested that the leaching process followed the shrinking core model. The activation energy was 14.6 kJ/mol using the diffusion-controlled model for the data collected from the first 10 minutes leaching and 35.9 kJ/mol using the reaction model for the period between 10 and 120 minutes of leaching. BET analysis data suggest that the reaction products formed on the solid-liquid interface caused pore blockage as well as a barrier between the reactants and bulk solution. The elemental analyses showed that Fe and Ca were major contaminations in the leachate solution which potentially formed precipitates due to localized pH and Eh variations or near the particle surfaces during leaching reaction. XPS results showed the formation of CaSO4 on the solid surfaces. Test results indicate that the light REEs appear to be more likely to co-precipitate with CaSO4 compared to heavy REEs.

3:45 PM

**Forecasting and Optimization of Recovery from Heap Leach Facilities (HLF)**

B. Fetter and R. Gow; Forte Dynamics, Windsor, CO

When operating an HLF, it is important to track KPIs to optimize operations. Best practices for successful operations include tracking of ore placement, PSD, leaching operations, and collaboration between mine planning and process operations. This discussion will focus on best practices for data collection, HLF operation, planning, and forecasting. Discretized heap leach models have been developed for several sites around the world. These models incorporate metallurgical data including tons and grade, PSD, ore stacking, pad geometry, kinetics, and hydrodynamics. The HLF is represented as a discretized matrix with vertical separation to form spatially discrete cells. Activation is based on the loading and leaching plan to allow for simulated growth and compaction of the HLF over time. Each discretized cell is quantified with ore properties and metals content. The model tracks solution movement and recovery of metals as a function of time based on unsaturated flow properties, kinetic dissolution and diffusion rates, and leaching dynamics. The model is used to provide forecasts and conduct trade-off studies to optimize HLF operations and evaluate PSD performance respecting recovery.

4:05 PM

**Alkaline Heap Leaching of Vanadium from Cement Agglomerated Ore**

J. Olson; McClelland Laboratories, Sparks, NV

A heap leaching process was developed for extracting vanadium using a high pH solution. The process includes crushing, agglomeration with cement, heap irrigation with sodium hydroxide solution, and vanadium recovery from solution by conventional methods. Relative to acid leaching, the alkaline process was more selective against impurities, while achieving a similar vanadium extraction (68.8%). Although calcium vanadate species are known to be poorly soluble, column leach tests conducted in this work demonstrated that the presence of cement did not impede vanadium extraction. This process may enable the heap leaching of ores with high clay content and high carbonate content (which would consume excessive acid in a low pH leaching system). Additional testing is required to optimize leaching conditions and determine reagent requirements, but this process has the potential to become a low-cost and low-risk vanadium extraction method. This work was conducted on a vanadium-bearing sample from the Gibellini Hill black-shale hosted deposit in Eureka County, Nevada.

4:25 PM

**Heap Leaching Acid Feed Control**

M. Fiera; REVA, West Bridgewater, MA

In the heap leaching process a key to success in producing high quality agglomerated ore is to have minimal process variation of the feed solutions entering the kiln. Tightly controlled acid feed rates can achieve stable and predictable agglomerated spheres. This will in turn lead to less acid consumption and improved leaching, which are critical for successful production at a mine. The problem at a large copper mine in Eastern Arizona, was the acid flow variation from a pneumatic actuator had to position a ball control valve. The pneumatic actuators lacked precision (2% movement) due to the compressibility of air and needed an increased pressure set point. The plant sought a solution and selected a REXA electro- hydraulic actuator that produces up to 2,000 pounds of thrust and reduced the valve movement to <0.5 degrees. Similarly, the REXA Actuator’s high stiffness and exact positioning enabled the feed set-point to be lowered, reduced consumption and worker exposure, and improved leaching to having a better quality of ore post agglomeration. Acid consumption savings is estimated to be $312K per year.

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**Tuesday, February 25**

**Afternoon**

2:00 PM • North 228B

**MPD: Physical Separation I**

**Chairs:** M. Rezaei, The Pennsylvania State University, University Park, PA J. McDonald

2:05 PM

**Introductions**

2:05 PM

**Advancements in Interstage Screening Using Thermoplastic Polyurethane Screen Surfaces to Improve Performance at Barrick’s Resin in Leach Facility**

E. Mortensen1, M. Badra2, J. Colgrove3 and A. Nicosia4; 1Process Machinery Associates, Reno, NV; 2Barrick Goldstrike Mines, Carlin, NV and 3Derrick, Buffalo, NY

As part of normal operations, Barrick Goldstrike continuously evaluates equipment for efficiency and reliability. Recently noticed were shorter than expected lifespans, loss of throughput, and excessive cleanings for their stainless steel Wedge Wire baskets. In a collaboration with Derrick, tests were conceived to assess the feasibility of using urethane screen surfaces to extend life and reduce cleaning. Tests began in January 2018 and continue through today. As of July 2019, there are several Interstage screens (baskets) with at least one year run time and all have shown very positive results. The New Urethane Interstage baskets require virtually no cleaning thereby reducing maintenance costs. The new media has met the required throughput, removed blinding issues, and have had zero (0) high levels reported during operations. In addition, the baskets have been shown to be more durable as documented with decreased resin breakthroughs compared to the stainless steel. The use of these screens has shown enough economic and process benefits that Barrick has started systematically replacing the existing stainless steel wedge wire baskets to Derrick Style G Vault Screens throughout.
2:25 PM
Using Sensor-Based Laser Sorting to Increase Grade and Recovery of Quartz at Elmore Sand & Gravel
H. Cline¹, T. Goodin², A. DeCenzo³ and J. Ruttledge⁴; ¹Tomra, Denver, CO; ²Elmore Sand & Gravel, Elmore, AL and ³Preferred Process Solutions, Rock Hill, SC
Elmore Sand & Gravel, located in central Alabama, creates a wide range of products for architectural, construction, metallurgical and filter media applications. In 2018, with the objective of creating a high purity metallurgical quartz product with iron content below 0.04% from various types and qualities of feed, Elmore conducted test work on a Laser Sorter at the Tomra Test Center in Hamburg, Germany. The test work confirmed the ability to create a low ferrous product out of both “brown” and “white” feed material and indicated an opportunity to increase the overall capacity and the life of the existing quarry. In 2019, Elmore installed a Tomra Laser Sorter at their operation, which was the first laser sorting operation of its kind in North America. This presentation will discuss the operational principles of laser sorting and its practical application in high quality quartz production and other applications such as detecting quartz associated gold. We will also present some further results that have been achieved now that this sorter has been in production for several months.

2:45 PM
Potential Applications for Dry Beneficiation of Iron Ore Fines Using a Tribo-Electrostatic Belt Separator
L. Rojas Mendoza¹, K. Flynn¹, A. Gupta¹, A. Berton² and D. Roy²; ¹ST Equipment & Technology, Needham, MA and ²Soutex, Quebec City, QC, Canada
ST Equipment & Technology LLC (STET) tribo-electrostatic belt separator technology allows for the beneficiation of fine mineral powders with an entirely dry technology at a high throughput. The STET separator is well suited for separation of very fine (<1µm) to moderately coarse (500µm) particles, in contrast to other electrostatic separation processes that are typically limited to particles >75µm in size. STET has successfully beneficiated iron ore samples including run-of-mine ores, tailings and ilabirite with iron feed contents ranging from 30-55%. Experimental findings indicate that low-grade iron ores can be upgraded to commercial grades (58-65% Fe) while simultaneously rejecting silica by using STET belt separator. Here, a compendium of experimental results and a preliminary study of potential applications for the STET technology for the iron industry are presented. The preliminary studies include high-level flowsheets and economic evaluations for selected applications. Challenges associated with the adoption of the technology and a comparison to currently available technologies for the processing of iron ore fines are also discussed.

3:05 PM
Dry Magnetic Separation for Iron Ore Concentration using Newly Developed High-Speed Low Intensity Magnetic Drum Separator
X. Jiang; Eriez Manufacturing Co., Fairview, PA
The dry low intensity magnetic separators are widely used for the tramp metal removal, magnetite pre-concentration, or steel mill slag recovery. It has been challenging to produce saleable magnetite concentrate using conventional dry low intensity magnetic separator. In this research, Eriez developed a high-speed low intensity magnetic separator to process fine magnetite feed. The conventional dry low intensity magnetic separator is not capable of discharging the entrained non-magnetic minerals and unbritallized particles. Therefore, the centrifugal force and pneumatic force must be applied to enhance the separation efficiency. The different drum speeds from 600 FPM to 1600 FPM were tested, and it has been found that the desired concentrate grade was only achieved when the drum speed reached 1600 FPM. A concentrate of 62.8% TFe was obtained with a Fe recovery of 66.4% at 1600 FPM. Further study indicates that pneumatic force can improve the magnetic separation significantly. The concentrate grade of 63.2% TFe with 70.2% Fe recovery was reached by one stage high-speed low intensity magnetic drum separator with the assistance of an airflow.

3:25 PM
The Value of Correct Sampling
B. Mahony; Engineers Australia, Burradoo, NSW, Australia
The utilisation of robust, reliable and accurate sampling systems is key to the successful management of any mineral processing plant or loading facility. The design of a sample station should take into account numerous considerations including applicable sampling standards, project specifications, process data and rheological information. Fundamentally, however, the value of the sample station should be measured by the accuracy of the data it produces, and this is directly impacted by the ability of the sampling equipment to repeatedly withdraw a statistically representative portion of material from the process stream, and if required, correctly reduce this to a manageable size. This paper will focus on how a number of operations around the world obtained value from the use of statistically correct, bias free sampling systems. This will include a review of the equipment that was used and how the value was enhanced throughout the life of the mine via regular mechanical and process audits.

3:45 PM
Techniques and Procedures to Recover Tailings
J. Ribeiro and C. Ribeiro; Chairman, Gaustec Magnetism, Nova Lima, Minas Gerais, Brazil
Techniques and Procedures to Recover Tailings This work discloses the features demanded for reliable tailings recovery, typically smaller than 37 microns. It presents theoretical aspects and is based on yearly reports from large scale Concentration Plants making use of Super-WHIMS Technique and specially designed BigFLUX magnetic matrix packs. A brand-new tailings-oriented WHIMS Magnetic Separator will be presented, designed for up to 1600 m3/h of feed. High volume capacity accommodates low % solids slurries, which is a must to achieve chemical quality requirements. Additionally, tailings reclaiming and low-cost tailings dewatering methods will be presented based on actual operation procedures.

4:05 PM
Physical Pre-Concentration of Coarse Coal Refuse for a Heap Leaching Approach to Rare Earth Element Extraction
M. Leake¹, A. Noble¹ and M. Free²; ¹Virginia Tech, Blacksburg, VA and ²University of Utah, Salt Lake City, UT
Recent efforts by the US Department of Energy have identified coal refuse as a potential source of rare earth elements. The extraction of these materials from coal refuse generally requires aggressive leaching conditions that are both costly and environmentally hazardous. Alternatively, bioleaching in an engineered heap possesses many advantages, including lower costs and reduced long-term environmental liability. Coal refuse is a unique feed source for a heap leach, containing a mixture of various mineralogical constituents that may improve or inhibit leaching performance if properly sorted prior to entering the heap. This paper describes the development of a unique physical concentration circuit that separately isolates acid-producing constituents and REE-enriched constituents using a combination of x-ray transmission sorting and density-based separations. Both laboratory evaluations and economic implications will be presented.

4:25 PM
The In-Tank Clarifier, an Alternative for CounterCurrent Processing
J. Werner; Mining, University of Kentucky, Sadieville, KY
Typical counter current processes such as leaching often require the use of an agitated vessel combined with a clarifier to separate solids and liquids to achieve counter current operation. To decrease the capital expense and footprint associated with counter current processes, a design is presented for an in-tank clarifier which simultaneously allows for the agitation and the separation of liquids from solids. A preliminary finite element model was constructed utilizing Euler-Euler methods to simulate liquid particle interactions and simulate performance. Various geometries are presented with the associated results. Further, physical vessels were constructed to validate the design and performance.
The Resolution Copper project is located near Superior, AZ. The Resolution deposit is a large, high-grade copper-molybdenum deposit that will be exploited by panel block caving methods. The deposit has been extensively drilled and metallurgical testwork has been completed to determine the ore response and assist in the design of the concentrator. The testwork has included establishing grinding parameters, flotation testing, reagent screening, dewatering testwork, tailings cyclone work and tailings humidity cell testing. The concentrator will employ SAG/Ball Mills, flotation cells/columns and thickeners. Copper and molybdenum concentrate products will be produced. Two tailings streams will also be created – SAG/Ball Mills, flotation cells/columns and thickeners. Copper and molybdenum concentrate products will be produced. Two tailings streams will also be created – SAG/Ball Mills, flotation cells/columns and thickeners.

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# Resolution Copper – Concentrator Design

A. Marks; Resolution Copper, Superior, AZ

The assessment of metallurgical performance risk is an important, but challenging, aspect of separation circuit design. Many current circuit design tools use advanced mathematical modeling; however, the simulation routines often specify static values for the various technical and economic input factors, such as feed grade, kinetic coefficients, processing costs, and product market price. In most cases, these input factors are subject to considerable uncertainty, and this static input approach introduces considerable design risk due to the propagation of uncertainty in the circuit performance calculations. The current study describes a method of predicting uncertainty propagation in separation circuits by integrating two unique circuit evaluation methods: linear circuit analysis and the functional unit evaluation concept. This fundamental approach leads to a series of simple design rules that describe how uncertainty propagation will change with specific modifications to the circuit design. The capabilities of this innovative approach are illustrated through a systematic separation experimental study using the electrostatic concentrator circuits for separating titanium from silica.

2:45 PM

# Analyzing Metallurgical Performance Risk in Separation Circuits Using Linear Circuit Analysis and Functional Unit Evaluation

S. Amini and A. Noble; Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA

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2:00 PM

**Introductions**

Tuesday, February 25
Afternoon

2:00 PM • North 227C

**MPD: Plant Design I**

**Chairs:** H. Akbari, Kinross Gold Corporation, Round Mountain, NV C. Churchman, Capstone, Miami, AZ

2:05 PM

# Pilot Plant Design and Operational Practices at the NC State Minerals Research Laboratory (MRL) for Industrial Minerals Beneficiation

R. Mensah-Biney; NC State Minerals Research Lab, Asheville, NC

The MRL has designed and operated several continuous pilot plants for the beneficiation of industrial minerals since its inception over 70 years ago. The MRL has found continuous pilot plant operation as a valuable scale-up tool from bench tests to commercial plant design. Pilot plant testing helps establish design criteria, operating parameters, process efficiency, and economic process feasibility. The pilot plant is often used to provide bulk samples for product evaluation in the marketplace. MRL has an excellent track record scaling up from pilot plant studies to commercial plant design. The design and operational practices for the beneficiation of three industrial minerals, feldspar, quartz and spodumene will be presented. Some of the common design and operational problems will be discussed and the future of pilot plant design and operation for the beneficiation of industrial minerals will be proposed.

2:25 PM

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S. Amini and A. Noble; Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA

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2:45 PM

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3:05 PM

**The Importance of Proper Slurry Pump Sizing and Selection**


Problems associated with improper slurry pump sizing can be significant. Bigger is not necessarily better, and often times can be extremely detrimental. An incorrectly sized slurry pump, together with the application in which it is operating, can lead to poor pump performance, accelerated wear rates, and overall reduced life of the internal pump components. In addition to the pump itself, equipment on both the suction and discharge sides can be negatively impacted. All of these effects ultimately result in a higher total cost of ownership to the end user. This paper discusses proper pump sizing criteria and specifications which are intended as guidelines to be considered when selecting a slurry pump.

3:25 PM

# Sibanye-Stillwater Smelter Production Simulation Study (Process Digital Twin)

G. Krebs², G. Skipton¹, J. Larson² and M. Franklin¹; ¹MOSIMTEC, LLC, Herndon, VA and ²Sibanye-Stillwater, Columbus, MT

Sibanye-Stillwater is engaged in the development, extraction, processing, smelting, refining and marketing of palladium, platinum and associated metals (platinum group metals or “PGMs”). Besides processing mine concentrates, SibanyeStillwater also recycles spent catalyst material acquired from third parties at the smelting and base metal refinery to recover the contained PGMs – palladium, platinum and rhodium. Sibanye-Stillwater smelts and refines the spent catalysts within the same process stream as the mine concentrates. Sibanye-Stillwater is undergoing major renovations and have planned upgrades at the metallurgical complex and intend to use modeling and simulation technology to provide insight on the smelter production capacity given different scenarios of process and capital improvements. MOSIMTEC LLC (“MOSIMTEC”), as modeling and simulation experts, have been contracted to support development of this dynamic simulation model. This presentation further describes the project, the system being modeled, the simulation model inputs and outputs, the modeling approach, and highlights some of the analysis completed.

3:45 PM

# Automation: Optimizing Mill Water Scale Control

L. Lacanette², J. Wrthlin¹ and N. Morrison¹; "Water Technologies and Solutions, Suez, Lebanon, United States Minor Outlying Islands and "KGHM, Ruth, NV.

Within the minerals processing operation for copper concentrators, ore chemistry has a direct impact on the resulting mill water chemistry and can cause significant fluctuations in scale potential. Changes in the flow rates and ratios can result in the sudden potential for scale formation from the mixing of these ‘incompatible’ streams. At KGHM Robinson Nevada Mining Company, prior work was completed to identify the mechanisms of scaling and to successfully mitigate the formation of scale in the supply water system. Even though this has improved the control of scaling on average, there are scenarios where scale potential fluctuates due to changing conditions. To curb the likelihood of plant scaling, the use of automated monitoring and control equipment has been applied to detect and respond to changes, resulting in a real-time continuous control system. The use of sensors and plant operations data into a control module network is now a fully automated control system for adjusting the scale conditions in real-time. The paper will discuss the impact of the automation system on plant operations, equipment maintenance cycles and treatment chemical usage for mill water scale control.

4:05 PM

# Gold Metallurgical Balancing-Know Your Errors

S. Romero², P. Hayes³ and R. Dunne¹; Robert Dunne Consulting, Perth, WA, Australia; ²Geostats Pty Ltd, Perth, WA, Australia and ³Geostats Pty Ltd, Perth, WA, Australia

Gold metallurgical accounting involves the measurement of all the gold containing components present in a metallurgical circuit. The task of metallurgical accounting is to essentially perform a simple ‘in and out’ mass balance, that includes inventory changes, over the processing plant. The balance might be perceived to be relatively straightforward. However, reliable metallurgical accounting relies on the measurement of crucial components in the processing circuit and difficulties and errors exist with each measurement. Understanding the potential variance that exists in measurements provides one with an estimate of the likely errors that will
appropriate process aids (polymeric depressants, inorganic salts, etc.) to increase that may be used to lower or eliminate entrainment. Based on the review, we as well as a summary of the main factors affecting entrainment and the techniques is one of the significant factors affecting concentrate grade. This paper provides a Entrainment is inevitable for both the hydrophobic and hydrophilic minerals, and entrainment can be considered as a two-step transfer process, one at the upper base of the flotation froth from the top of the pulp, and eventually discharge to the concentrate product, even when they are not attached to gas bubbles. Therefore, entrainment can be considered as a two-step transfer process, one at the upper layer of the pulp to the flotation froth, and the other from froth to the concentrate. Entrainment is inevitable for both the hydrophobic and hydrophilic minerals, and is one of the significant factors affecting concentrate grade. This paper provides a comprehensive review of the entrainment mechanisms and entrainment models, as well as a summary of the main factors affecting entrainment and the techniques that may be used to lower or eliminate entrainment. Based on the review, we point out that selective aggregation of fine and ultrafine gangue minerals using appropriate process aids (polymeric depressants, inorganic salts, etc.) to increase their particle sizes appears to be the most convenient and economical method. Directions of further research along this line are discussed.

Tuesday, February 25
Afternoon

2:00 PM • North 230
MPD MGM: Managing Non-sulfide Gangue (NSG) in Flotation

Chairs: R. Kappes, Newmont Mining Corp, Englewood, CO
Z. Gao, Central South University, Changsha, China

2:00 PM
Introductions

2:05 PM
New Approaches to Selectively Reject Naturally Hydrophobic Gangues in the Flotation of Base Metal Sulphide Minerals

Y. Peng and X. Chen; Univ of Queensland, Brisbane, QLD, Australia
Efficient separation of naturally hydrophobic gangue minerals, such as talc and carbonaceous materials, from sulphide minerals in flotation is becoming a significant challenge in many processing plants due to the need to process lower grade and more complex ores. Considering the hydrophobic nature of these gangue minerals, pre-floating them at the beginning of flotation circuit in the absence of collectors and reject the concentrates is a common practice to remove these gangue minerals. However, sulphide minerals, such as chalcopyrite, can become naturally floatable due to surface oxidation which generates hydrophobic species on the surface. As a result, sulphide minerals may be floated with the naturally hydrophobic gangue minerals during pre-float, leading to a significant loss of valuable minerals. In this study, new approaches were developed to maximize the pre-float of hydrophobic gangue minerals while minimizing the loss of sulphide minerals based on the control of surface species on sulphide minerals in flotation and a new flowsheet design.

2:25 PM
Fine and Ultrafine Entrainment: Mechanisms, Models, Controlling Factors and Abatement Techniques

C. Wang¹, C. Sun² and Q. Liu³; ¹University of Science and Technology Beijing, currently on a visiting study in University of Alberta, Edmonton, AB, Canada; ²University of Science and Technology Beijing, Beijing, China and ³University of Alberta, Edmonton, AB, Canada
Entrainment is a transfer process by which fine and ultrafine particles enter the base of the flotation froth from the top of the pulp, and eventually discharge to the concentrate product, even when they are not attached to gas bubbles. Therefore, entrainment can be considered as a two-step transfer process, one at the upper layer of the pulp to the flotation froth, and the other from froth to the concentrate. Entrainment is inevitable for both the hydrophobic and hydrophilic minerals, and is one of the significant factors affecting concentrate grade. This paper provides a comprehensive review of the entrainment mechanisms and entrainment models, as well as a summary of the main factors affecting entrainment and the techniques that may be used to lower or eliminate entrainment. Based on the review, we point out that selective aggregation of fine and ultrafine gangue minerals using appropriate process aids (polymeric depressants, inorganic salts, etc.) to increase their particle sizes appears to be the most convenient and economical method. Directions of further research along this line are discussed.

2:45 PM

J. Jankolovits, G. Sampayo and A. Santana Palomera; Mining Solutions, Solvay, Stamford, CT
Carbonaceous gangue must be appropriately managed in sulfide mineral flotation because it significantly impacts plant operations and metallurgical outcomes. Carbon readily dilutes concentrate grades, contributes to overfrothing, and reduces value recovery. These operational problems are caused by carbon material properties, including its natural hydrophobicity and floatability, association with value and gangue minerals, fine particle size, and adsorptive properties. Managing carbon requires a holistic approach where the processing strategies (preflotation, depression, bulk flotation), flowsheet, ore type and flotation behavior, and reagent scheme are all considered in the operation. This presentation will review key principles on carbon surface chemistry and mineralogy and link these fundamentals to the processing strategy and reagent selection. Examples will be highlighted where advanced metallurgical outcomes were achieved with a holistic carbon management approach.

3:05 PM
Functionalized Biopolymer for Enhanced Metal Recovery in Froth Flotation Processes

L. Kuri¹, C. Bruin², S. Vhora¹, W. Gibbs¹ and C. Landis³; ¹Integrity Mining and Industrial, Humble, TX; ²Base Met Labs, Kamloops, BC, Canada and ³Integrity Bio-Chem, Cresson, TX
Clay minerals decrease the efficiency of froth flotation processes used to recover precious/base metals during ore beneficiation. High viscosity and froth stability can lead to increased gangue recovery to the flotation concentrate, limiting mass and target metal recovery when circuit capacity limits exist, as well as diluting the final concentrate. Ionic interactions with pulp chemistry also lead to reduced collector attachment on the target mineral surfaces, leading to low recovery or high reagent dosages. By preventing the ionic interaction with the clays, the target minerals can be floated more effectively, and their overall recoveries are increased at a given concentrate mass recovery. This paper introduces new biopolymer technology that sequesters clays in the gangue/ore to reduce non-sulphide gangue recovery to the concentrate and improves collection and recovery of target minerals. Reproducible trends in representative flotation separation tests are correlated to increases in copper recovery and grade, at an equivalent mass recovery. These improvements permit higher rougher concentrate grades which may lead to improved cleaner circuit performance and recovery.

3:25 PM
Effect of Platy Gangue Minerals in Sulfide Flotation: Mechanisms

T. Bhambhani¹, R. Farinato¹, D. Nagaraju¹ and P. Somasundaran²; ¹Mining Solutions, Solvay, Stamford, CT and ²Columbia University, New York City, NY
Transport of gangue via entrainment is attributed to slurry drag due to the upward motion of air bubbles; the transport being advective. A significant increase in gangue transport rates to the froth zone was observed when platy mica was mixed with an ore as compared to silica. It was hypothesized that this increased transport was related to increased drag experienced by the platy particles. The hypothesis was tested by conducting froth sampling experiments under increased drag. A bias in transport of coarse particles was observed, and it was hypothesized to be related to confinement of the particles in the channels. This was proven by comparing advection/drag dominated experiments with advection/drag and drainage balanced experiments.

3:45 PM
Modifying Wheat Starch for the Selective Depression of Hydrophobic Gangue

B. Fletcher, W. Chimonyo and Y. Peng; School of Chemical Engineering, The University of Queensland, St Lucia, QLD, Australia
Starch and its derivatives offer possibilities for creating inexpensive and environmentally benign flotation depressants. Historically they have been used to depress hydrophobic gangue such as carbon and talc in base metal ores but can lack the selectivity required for efficient processing complex ores that are becoming more prevalent. Due to their own complexity, however, native starch polymers present considerable scope for modifications that appear to benefit their
Separation of Ultrafine Iron-bearing Silicate Gangue from Hematite by High Efficiency Flotation
W. Chen, Y. Zhou and H. Xu; Changsha Research Institute of Mining & Metallurgy Co, Changsha, Hunan, China
Iron-bearing silicate gangue minerals and hematite are hardly separated from each other by high intensity magnetic separation. Instead, they are enriched in concentrate during high intensity magnetic separation process. Although flotation is an effective method for separating iron-bearing silicate gangue minerals and hematite, the sliming nature and Fe ion crystal structure of iron-bearing silicate minerals result in the decreasing selectivity of flotation reagents. A new anionic collector of multi-polar group was developed for the high efficiency flotation of Yuanjiacun iron mine which is rich in chlorite. It improves separation efficiency of chlorite from hematite. Besides, it is applicable to the flotation of high-slime iron ore and micro-fine iron concentrate recovery, and it can achieve high efficiency flotation at room and low temperature. The result shows that this new collector with coronet ether-like structure characteristically absorbs on the chlorite surface, and it causes a strong chemical bonding with Mg and Al ion on chlorite surface. Thus, strong bonding between collector and chlorite realizes efficient flotation separation of micro-fine chlorite and hematite.

The Use of Chitosan as a Green Depressant of Silicates in Phosphate Flotation
A. Alsafasfeh and L. Alagha; Mining Engineering, Missouri University S&T, Rolla, MO
The application of green reagents as process aids in the froth flotation process is of crucial importance in order to reduce the environmental impacts. In this study, chitosan polymer was used as a green depressant of silicates in the direct flotation of phosphate minerals. Zeta potential measurements were used to examine the electrical properties of mineral surfaces in the presence and absence of chitosan polymer to understand the behavior of the flotation feed. Flotation recoveries and concentrates' grade of phosphates were studied as a function of chitosan's dosage, pulp's pH, and flotation time. The flotation recoveries of phosphate minerals in the presence of chitosan polymer were compared with the recovery values obtained when commercial silicates dispersant (sodium silicate) was applied. Results indicated that in the presence of 300 g/ton of chitosan polymer, the recovery of phosphate minerals was ~70% as compared to ~40% when the same dosage of sodium silicate dispersant was used. Results suggested that chitosan can be used as a green and sustainable depressant of silicate minerals in phosphate flotation process under specific conditions.
Tuesday, February 25  
Afternoon

2:00 PM • North 131B/C  
Tailings – Perspectives for a Changing World: Tailings Governance (Ethics Credit Eligible)  
Chair: C. Priscu, Anglo American

2:05 PM  
Introductions

2:25 PM  
Tailings Governance and Management System: Freeport-McMoRan’s Perspective  
T. Speigl and G. Lysay; Freeport-McMoRan, Phoenix, AZ

During the last fifteen years, Freeport-McMoRan Inc. (FMI) has developed and implemented programs, processes, personnel, documentation, and reporting at its operations to enhance the structural stability and safe operations of its Tailings Storage Facilities (TSFs). FMI’s tailings management philosophy is to have no failures of its TSFs. This paper presents key programs including Tailings Stewardship, Technical Review Board, Key Performance Indicator tracking and reporting and Essential Functions Evaluation. These programs allow for a cycle of planning, execution, review, and improvement while encouraging collaboration between the site operations and engineering teams, corporate teams and Engineersof-Record. These programs and our overall tailings management system are key to setting strategic direction, defining roles and responsibilities, promoting alignment with corporate policies and procedures to foster ownership, transparency and accountability among our operations. FMI continues to embrace the changing culture of TSF management and understands the need to proactively review and improve these programs so they remain effective elements of the FCX governance system.

2:45 PM  
Global Dam Safety Program and Governance Framework at Anglo American  
C. Priscu; Anglo American, Vancouver, BC, Canada

This paper outlines Anglo American’s evolving approach to going beyond good governance on the most important aspect of tailings stewardship: safety of tailings and water dams. In 2013-14, Anglo American has developed a Group-wide technical standard and supporting technical documents, drawing upon best practices worldwide, and adding additional specific and novel requirements. The standard identifies and incorporates a series of minimum requirements for planning, design, construction, operation, monitoring, surveillance and closure of facilities, providing a solid basis for consistent governance across the Group. This paper presents the five key pillars of the program, as well as the risk management framework that is currently being implemented, covering both tailings and water retaining dams. Implementing the dam safety program at global level does not come without challenges; this paper will also discuss implementation efforts and strategy, and will comment on the success stories, as well as the areas of improvement of the various Governance and risk management processes.

3:05 PM  
Global Tailings Standard and ICMM Tailings Guidance  
M. Davies; Teck Resources, Vancouver, BC, Canada

The catastrophic failure at Brumadinho, Brazil in January 2019 is a watershed moment for the mining industry. This event was a stark reminder that, while the industry has come a long way in improving how it operates, there’s still much more that can be done to safeguard lives, improve performance and demonstrate transparency. The International Council on Mining and Metals (ICMM), United Nations Environment Programme (UNEP) and Principles for Responsible Investment (PRI) share a commitment to the adoption of global best practices on tailings storage facilities. To that end, they co-convened a global tailings review to establish a Global Standard. This standard, and how it build upon the ICMM Framework established with the goal of eliminating catastrophic failures, will be described and explained in terms of how all industry participants can assist in this goal. In addition to the Standard, ICMM has developed a supportive Guidance Document to the Global Standard to provide an overall best practices in tailings governance document for the global industry. This document and how it interfaces with other existing/pending guidance will be described.

3:25 PM  
Panel Discussion: Tailings Governance  
C. Priscu; Anglo American, Vancouver, BC, Canada

The final three time slots of the session are reserved for a panel discussion focused on better understanding various governance systems and their advantages and limitations. Panelists will delve deeper into corporate governance models that have been implemented to reduce the risk to owners, shareholders and the public, and technical and operational governance systems/components. The discussion will include time for audience questions and participation.

Tuesday, February 25  
Afternoon

2:00 PM • North128 B  
Valuation: Lessons Learned and Fundamental Issues  
Chair: D. Werthessen, New Mexico School of Mines, Bridgewater, MA

2:00 PM  
Introductions

2:05 PM  
Asset Appraisal Versus Company Valuations  
A. Jacobsen and R. Cameron; Behre Dolbear Group Inc., Edgefield, SC

There are fundamental differences between the appraisal of a mining project and the valuation of a mining company. The appraisal of a mining project generally takes into account the technical aspects of a project, such as mining rate, metallurgical recovery and market sales; whereas, the valuation of a mining company will take into account not only the technical aspects of its mining projects and mineral properties, but the business-related issues such as debt and equity as well. What does this mean for the appraiser? This paper explores the different valuation methodologies that are commonly used along with the methods used to determine discount rates and their appropriate application to either the appraisal of a mining property or a mining company.
Reliability of the mineral projects’ feasibility studies are basis for investment appraisal assignment requires the former (e.g., for minerals in-place) will greatly overstate the opinion of just compensation.

Deterministic Versus Stochastic Modeling – The Role of Each in the Appraisal Process
C. Wood; Stagg Resource Consultants, Inc., Cross Lanes, WV
Historically, individually and companies used a deterministic discounted cash flow model to develop a “point estimate” of the “value” of a mining operation and/or the underlying mineral interest. Over time, practitioners recognized the dubious nature of depending on the output of only one model due to the inherent uncertainty of the various inputs. As this analysis became more sophisticated, multiple deterministic models were prepared to test the sensitivities of those inputs and their potential impact on model results. Eventually, the probabilistic approach was developed, with a series of models prepared and subjectively weighted to yield a weighted-average result for this analysis. Finally, with the advent of faster computer processors and advanced software packages, stochastic modeling arose, which allows for: numerous trial runs, randomly-generated model inputs within specified ranges, and statistically-determined results. This paper reviews the development and application of both deterministic and stochastic modeling by potential acquirers, discusses the pros and cons of each method, and illustrates how each can have a role in the appraisal process.

Impact of Operational Cost Estimation and Commodity Price Forecast on Feasibility Study Cash Flow Model: An Iron Ore Case Study
N. Duru; Freeport-McMoRan Inc., Sahuarita, AZ
Reliability of the mineral projects’ feasibility studies are basis for investment decision making processes. However, there is generally a potential to deviate from feasibility study cash flow model input parameters. Some of the most important factors that determine precision of the discounted cash flow evaluations are the accuracy of the production parameters, operational expenditure estimates and commodity price forecasts at which the product is to be sold. Alternate cash flow model scenarios and sensitivity analyses are common tools to define project risks clearer and evaluate mineral projects. This paper presents the impact of price and cost input parameter deviations on an iron ore project cash flow model.

Development of a Robust Ultra-Wideband Module for Underground Positioning and Collision Avoidance
A. Kianfar, F. Uth, R. Baltes and E. Clausen; Advanced Mining Technologies, RWTH Aachen, Aachen, NRW, Germany
As indoor positioning provides particular challenges due to the unavailability of GPS-Signals, various systems such as Ultra-Wideband (UWB), radio-frequency identification (RFID), Ultrasound, Wireless Local Area Network (WLAN), etc. have been proposed in recent years. Some of these technologies are currently being marketed and some are still being developed. UWB technology allows for higher precision whilst also reducing power consumption. Hence, the underground automation and localization systems can use this technology for more accuracy and robustness. This presentation discusses a new robust UWB module used for underground positioning. The module was developed at the Institute for Advanced Mining Technologies (AMT) of RWTH Aachen University. It was successfully tested with a Technology Readiness Level (TRL) of 6 in a localization system and in collision avoidance with regard to human safety in underground hard coal mining operations.

Improvement on Adiabatic Experimental Method for Evaluating the Effects of Heat of Water Vapor on Low Rank Coals’ Self-heating Process
Y. Luo¹, Y. Zhang¹ and X. Wang²; ¹West Virginia University, Morgantown, WV and ²mining engineering, Liaoning Technical University, Fuxin, China
Most of the coal spontaneous combustion events occur in surface and underground mines when extracting low rank coals indicating their high propensities for spontaneous combustion. According to coal ranking, low rank coals have high moisture content. However, it is hard to induce the initial stage of self-heating process using the current laboratory testing methods that results in low propensity for spontaneous combustion. In theory dry low rank coal has strong ability to absorb water vapor in the air while the heat contained in the moist air is transferred for spontaneous combustion. According to coal ranking, low rank coals have high propensity for spontaneous combustion events in surface and underground mines when extracting low rank coals indicating their high propensities for spontaneous combustion. According to heat of water vapor on low rank coals’ self-heating process using the current laboratory testing methods that results in low propensity for spontaneous combustion.

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coalmine in Virginia, and a deep stone mine in Kentucky. This presentation shall enumerate the instrumentation results and discuss the modeling approach, in FLAC3D, to determine the Ground Reaction Curve for the overburden and Support Reaction Curve for the mine pillars. Based on the interaction of the two curves, the stability of the coal pillars vis-a-vis global stability of the overburden will be analyzed.

10:05 AM

**Influence of Cable Splices on Magnetic Field Coupling from Proximity Detection Systems to Trailing Cables**

C. Zhou, N. Damiano and J. Carr; NIOSH, Pittsburgh, PA

Proximity detection systems (PDSs) are a critical safety system used in the mining industry for protecting miners from pinning, crushing, and striking hazards. The magnetic field can be parasitically coupled from a PDS generator to a trailing cable which often causes false alarms and thus should be avoided. Researchers at the National Institute for Occupational Safety and Health (NIOSH) have conducted extensive studies to investigate the parasitical coupling from a PDS to an unspliced (continuous) trailing cable. Trailing cables, however, often have splices and whether a splice would affect the coupling is still unknown. We designed an experiment to characterize the influence of cable splices on the parasitic coupling. Two splices were made with one close to the generator (≤1m) and one far one (>5m) from the generator. The coupled magnetic fields from a commercial PDS were recorded before and after each splice. The results show that both splices introduce no noticeable changes to the coupled fields. The conclusions and findings in this paper can help better understand the safety concerns caused by parasitically coupling from PDSs to trailing cables.

10:25 AM

**User-Friendly Finite Element Analysis of Five Mine Design Problems**

W. Pariseau¹, M. Larson² and M. Nelson¹; ¹Mining Engineering, University of Utah, Salt Lake City, UT and ²NIOSH/CDC, Spokane Mining Research Division, Spokane, WA

Five important mine design problems are addressed by a user-friendly finite element package. Analyses of: (i) main entries, (ii) barrier pillars defending "mains", (iii) bleeder entries and (iv) interpanel barrier pillars, all in longwall mining, and also (v) safety of rooms and pillars in room and pillar mining are readily accomplished. Distributions of stresses, displacements and local safety factors are obtained in three simple steps: (1) preparation of a strata properties file, (2) automatic, interactive mesh generation and (3) execution of a finite element program. The last is a simple "double click"; the second is easy, while the first is the most difficult because the elastic moduli and strengths of strata above and below the mining horizon must be known. A website http://ut3pc.net/ makes the software and a User Manual available at no cost. Examples from coal, trona and other mines illustrate applications and results in extension of previous work.
investigating the presence and effect of surface occlusion on respirable coal mine dust particles
C. Keles and E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA
Epidemiological studies and bench research have both shown that the surface condition of respirable particles can influence the lung response. In the case of crystalline silica, particle surface occlusion by a thin layer of clay (e.g., aluminosilicate minerals) appears to reduce toxicity versus un-occluded particles. In the mid-1990s, NIOSH researchers first explored the presence of surface occlusion on silica particles in coal mine dusts. To shed light on dust exposures in modern mines, we are now investigating surface occlusion more broadly—including on silica and coal particles. In this presentation, we will highlight work on three parallel projects aimed at characterizing the relative occlusion of dust particles from different sources, and their relative toxicity in rodent studies.

Wednesday, February 26
Morning

9:00 AM • North 225B
Coal & Energy: Research and Development
Chairs: S. Schafrik, University of Kentucky, Lexington, KY
C. O’Connell, J.H. Fletcher & Co.

9:00 AM
Introductions

9:05 AM
Investigation of Improved Communication from Portable Refuge Alternatives to Facilitate Mine Escape and Rescue
S. Cotten, M. Trevits and J. Urosek; Rebuilding Their Future Foundation, Lockport, NY
This investigation explored and evaluated the feasibility of improved means for reliable emergency communication between occupants of an underground refuge alternative (chamber) with mine personnel on the surface and/or approaching rescue teams or, possibly, occupants of other nearby refuge alternatives located underground. The premise for the study was that modest modifications to both portable refuge alternative construction and commercially available mine radio communication system equipment might better permit occupants of a refuge alternative to share critical information such as their location, number, individual physical condition, refuge alternative status, and surrounding in-mine conditions to assist in coordinating their rescue or escape. Interoperability and potential use scenarios for three commercially available mine radio communication systems that operate in three widely different frequency bands (5 kHz, 450 KHz, and 900 MHz) was demonstrated in an operating underground coal mine. This project was conducted with funding provided by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc.

9:25 AM
Effect of Polymeric Variations on Mineral Briquette Green Strength
C. Silva Gaxiola¹, A. Beveridge² and A. Samei³; ¹BASF Corporation, Tucson, AZ; ²BASF Australia Ltd., Sommersby, NSW, Australia and ³BASF Chemicals India Pvt. Ltd., Navi Mumbai, Maharashtra, India
The aim of this work was to improve the performance of existing organic binders by determining the optimum process and chemical parameters that could be applied to the formulation and physical form. Testwork included a study of green strength over time with binder variables that were prepared to include a range of: anionic ratio, molecular weight, molecular weight distribution, chemical composition and physical form (gel, bead, solution, emulsion). Coal fines and ferro alloy fines were used as test substrates and the experiments designed so that interactions as well as single responses could be defined. The results showed which of the variables had greater or lesser impact on the briquette quality and the optimum range for future formulations. Mechanism theories for the optimized formulations were investigated through viscosity v time profiles and showed the development of binder functionality and rate of activation when moisture is added.

9:45 AM
Compressive and Tensile Strengths Development Based on Early Age of Laboratory Scale Cemented Rockfill Used at Canadian Diamond Mine
B. Linga and D. Apel; Civiland Environmental Engineering, University of Alberta, Edmonton, AB, Canada
Backfill strength properties are the determinant factor that is firstly considered in an underground mining support with backfill application. Cemented rockfill as one type of backfill has a prospective potential compared to other types of cemented backfills because it usually has higher strength. However, the critical period of cemented rockfill is when its strength properties are still developing. Therefore the strength development prior 28-days period is of interest in this experiment. Understanding the compressive and tensile properties of underground cemented rockfill were conducted with granite aggregate rock material retrieved from diamond mine in Northern Canada. Two different mixtures of cemented rockfill as used in the mine were recreated and went to uniaxial compression test and split tensile test, the test were conducted based on 7, 14, 21, and 28 days of specimen’s age. The result of the experimental study showed that the second type mixture has 28-day compressive and split tensile strengths respectively three times of the first mixture.

10:05 AM
Machine Learning Based Understanding of Coal Strength
S. Saurabh; Mining and Mineral Resources Engineering, Southern Illinois University, Carbondale, IL
Coal mining is an age old activity and a huge technological advancement was made when data collection during mining became easier. It is now possible for modern computers to process this huge database at once very quickly and help us in predictive modeling and classification problems of industrial and scientific nature. In this study, We established a huge database of coal strength and the various properties affecting and various machine learning algorithms to develop understanding about properties like cohesion, confining stresses, compositional parameters and others and how they affect coal strength?

10:25 AM
Applicability of Distributed Optical Fiber Sensing for a Longwall Face
M. Barros Daza¹, N. Ripepi³, Y. Zhu², G. Pickrell², K. Luxbacher¹, G. Shi², D. Horna² and X. Su²; ¹Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA; ²Center for Photonics Technology, Virginia Tech, Blacksburg, VA and ³Virginia Center for Coal and Energy Research, Virginia Tech, Blacksburg, VA
Real-time sensing of mine gases is critical to safety in underground coal mines, as changes in the atmosphere can occur quickly and lead to explosive environments. Over the last century of sensing development for underground coal the persistent challenges in sensor design are ruggedability and permissibility for underground coal mines, especially given US regulation. In particular, longwall gob represents a highly dynamic and high risk area which is difficult to access and characterize in real time. This paper details the current state-of-the-art in gas sensing in underground coal mines, and describes optical fiber sensing. Additionally, the applicability of optical fiber sensing technology for continuous and distributed sensing of gases at the longwall face, is presented, along with preliminary design for a full face sensor.

10:45 AM
A 2D CFD Model of Flame Propagation in a Longwall Coal Mine
T. Nguyen, C. Strebing, A. Juguanda, J. Brune and G. Bogin; Mechanical Engineering, Colorado School of Mines, Golden, CO
Longwall coal mines are subject to methane gas explosions and resulting flames and pressure waves propagate throughout the mine, causing damage to the mine and miners. A full scale 2D computational fluid mechanics model was built to simulate an explosion under a variety of ignition scenarios to better predict explosion events for improved mine safety. Results show that for an ignition in the gob at the tailgate corner, a pressure wave expands ahead of the flame front,
11:05 AM
An Optically Accessible 1/40th Scaled Dynamic Ventilation Model of a Longwall Coal Mine

H. Pinheiro1, R. Gilmore2, C. DeRosa2, A. Juganda1, G. Bogir1, J. Brune1, K. Gallage1, N. Sandovall2, F. Wilson6, N. Shapen6 and D. Rozendaal6; 1Colorado School of Mines, Professor of Practice, Golden, CO; 2Colorado School of Mines, Master's Student, Golden, CO; 3Colorado School of Mines, Assistant Research Professor, Golden, CO; 4Colorado School of Mines, Ph.D. Student, Golden, CO; 5Colorado School of Mines, Associate Professor, Golden, CO and 6Colorado School of Mines, Undergraduate Student, Golden, CO

The explosibility of methane-air mixtures is a well-known hazard in the coal industry. To investigate such behavior in longwall coal mines and validate computational fluid dynamics (CFD) numerical models, researchers at the Colorado School of Mines have designed and built a 1/40th scaled-version, optically accessible model of an underground longwall mining section. The experimental apparatus allows detailed investigations on diverse strategies for mine ventilation, methane control, and mine explosion hazard mitigation in complex underground mining layouts. The physical model uses a modular design that allows testing different ventilation systems and strategies, variations on the coal face advances, modification of the gob and strata materials, and flow visualization experiments. The results of initial ventilation testing proved the model to be fully functional.

Wednesday, February 26

Morning

9:00 AM • North 226A
Coal & Energy: Ventilation Innovations

Chairs: P. Tukkaraja, South Dakota School of Mines and Technology, Rapid City, SD T. Artz, RESPEC, Rapid City, SD

9:00 AM
Introductions

9:05 AM
Pressure Balancing Systems to Control Sponcom in Coal Mines

F. Calizaya; Mining, University of Utah, Salt Lake City, UT

This paper presents a summary of basic requirements for the design, construction and operation of pressure chambers to control the on-set of spontaneous combustion in underground coal mines. It includes a brief introduction to passive and active pressuring balancing systems, construction details of two pressure chambers and the monitoring requirements to maintain the gob at a pressure slightly higher than the barometric pressure. It also includes a summary of procedures to test the performance of pressure chambers to reduce or eliminate the self-heating of coal, thus reducing the possibility of starting the spontaneous combustion in the mine gob.

9:25 AM
Heat Management Alternatives in Deep Underground Mines as a Crucial Part of Mine Ventilation

P. Rao, M. Momayez, K. Muralidharan and K. Runge; University of Arizona, Tucson, AZ

The demand for thermal regulation in deep underground mining arises due to harsh conditions during operations in addition to concerns regarding worker’s safety. Mine ventilation is thus extremely important to maintain a hazard free work environment for maximum efficiency and productivity. As an alternative, we present in this research, an inexpensive thermally insulative porous material, based on aluminosilicate precursors, which when applied onto the mine walls may inhibit the geothermal heat from entering into the mine passages. This scientific research involves synthesis of highly porous foams with density as low as 0.22g/cc as well as their characterization for morphology via SEM and chemical bonding by NMR. In addition, thermal conductivity values have been obtained as a function of density of the material by transient plane source method. The mechanical properties have been characterized by techniques such as AFM at the nanoscale and ultrasound tests for macroscopic bulk specimens and the results are hereby reported. Furthermore, the results from flame retardance experiments are also included.

9:45 AM
Simulating Longwall Mine Ventilation using an Aerodynamic Scale Model

V. Gangrade, S. Schatzel, E. Watkins and J. Addis; National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA

In longwall mining, ventilation is considered to be an effective means for controlling gases and dust. In order to study longwall ventilation in a controlled environment, researchers built a unique physical model called the Longwall Instrumented Aerodynamic Model (LIAM). The LIAM is a 1.30th scale physical model geometrically designed to simulate a single longwall panel with a retreating coalface. LIAM ventilation modeling is used in conjunction with numerical simulations and field investigations with calibration and correlation between these three complementary research approaches. This paper discusses gob-face interaction, airflow patterns within the gob, and airflow dynamics on the face for varying roof caving characteristics for bleeper/bleederless ventilation configurations. In addition to its research applications, the LIAM also serves as a dynamic, visual tool for demonstrating longwall ventilation to mining industry stakeholders and the research community. This article will discuss the development, applications, findings, and a 360 degree virtual tour of the LIAM.

10:05 AM
More Efficient Way to Increase Ventilation in Deep Underground Mines

A. Chaurasia1, M. Momayez2 and K. Muralidharan2; 1Mining and Geological Engineering, University of Arizona, Tucson, AZ and 2Material Science, University of Arizona, Tucson, AZ

The thermal transport properties of porous amorphous aluminosilicate structures are investigated using a combination of molecular dynamics simulations and finite element methods. The extent of porosity on the thermal conductivity of the aluminosilicate (AS) structures is characterized. It is seen that the thermal conductivity of the aluminosilicate (AS) structures shows a monotonic dependence on the amount of porosity introduced in the system for densities varying between 2.45 to 0.5 g/cc. Interestingly, for a given density (i.e., for a given volume of pores introduced), a larger distribution of smaller pores results in lower thermal conductivity. This observation is correlated with more phonon-scattering centers in such systems. The objective is to use the mine tailings to make the aluminosilicate geofoam of desired thermal conductivity so that we can use it as a thermal insulator in the form of sprayable coating in the deep underground mines. This will help in mitigating the geothermal heat and enhance the underground ventilations.

10:25 AM
An Investigation on the Behavior of Blasting Induced Fumes in Underground Mines

A. Adhikari, Y. Pan, A. Jha and P. Tukkaraja; Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD

A detonation of explosives such as ANFO, Emulsion, and dynamite would ideally produce only steam (H2O), Carbon dioxide (CO2), and Nitrogen (N2), that are non-toxic; however, in the real world conditions, toxic gases produced include Nitrogen dioxide (NO2), Nitric oxide (NO), and Carbon monoxide (CO). This study focuses on the blast fumes entrapped in the muckpile. Previous studies reported that as much as 60% to 70% of the fumes or gases produced during underground blasting can remain entrapped in the adjacent rock mass or in the muckpile. The toxic fumes trapped inside the muck pile are slowly released and could be fully uncovered during the mucking process. This could potentially cause a hazardous environment for the miners. This study investigates the behavior of blasting induced fumes using Computational Fluid Dynamics (CFD) simulation techniques; this will help in determining i) precise re-entry times and ii) emission rate and direction of the fume flow. CFD is preferred over physical models because it is inexpensive, a wide range of scenarios can be tested quickly, and the toxic gas flow patterns and behavior through underground openings are analyzed and visualized better.
For the development of a fire safety plan of the occupants and an emergency response layout for underground space environments, there is a crucial need to simulate numerous fire scenarios. Due to the complex physics close to the fire source and nonlinear behavior of combustion products dispersal, the fire simulation is costly. Coupling of computational fluid dynamics (CFD) models and 1D network modeling simulations of a fire event (multiscale method) is a successful technique to increase the computational efficiency. The challenging part of the multiscale approach is determining the interface boundary for decomposition of 3D and 10 subdomains. The research in this paper develops a novel methodology to determine the interface boundary upstream and downstream of the fire source at a tunnel with low ceiling height. The novel algorithm incorporated the physics of the fluid structure, turbulent kinetic energy (TKE) of the dynamical system, and the vortex dynamics. Heat Release Rate (HRR) of the fire in this analysis is set to 200 kW. The calculated error between CFD and coupled models for the mean temperature and the mean velocity at the outlet was calculated less than 6%.

Environmental geochemistry demands attention at every stage of a mining project, starting with exploration and continuing into the operations stage and through post-closure. The earlier in a project that potential environmental impacts can be identified, the earlier management plans can be formulated and integrated with mining plans, which will minimize interference with production and assure compliance with regulatory obligations. The geochemical data should be updated periodically through the project life cycle to ensure they accurately reflect changing conditions and needs. Environmental geochemistry is essential at the closure stage to plan for the appropriate closure strategy and to monitor and manage the post-closure program. Early involvement of the environmental geochemistry team also allows identification of the limitations in collection and application of geochemical characterization data.

In Alaska, mine exploration projects commonly include total cyanide and weak acid dissociable (WAD) cyanide in analysis of surface water during the environmental baseline study phase of an exploration project. This data, may then be applied to the interpretation of cyanide data during operations where cyanide is part of the metal extraction process. This session will talk through the collection of baseline data, laboratory analysis and positive cyanide detections which were initially met with skepticism. With the QA/QC standards shown to have been in control, we will discuss how the study team was able to delve into the possible sources of cyanide, leading to the addition of analyses for transition metal cyanocomplexes on the environmental samples. Cyanide was detected in surface water, soil, sediment and plant tissues over several years of baseline studies in a remote area of Alaska. This session is targeted to Environmental Scientists, Chemists, Environmental Managers, Permitting Managers and Regulators who want to gain a better understanding of cyanide in several environmental matrices.

This presentation will outline the methods and considerations for conducting an air dispersion modeling analysis for a surface coal mine in the western United States. Air emissions from surface mines predominantly consist of fugitive dust, along with Carbon Monoxide and Nitrogen Oxides from explosive blasting. These fugitive emissions can be quite high, but are not typically considered under the federal New Source Review air permitting program, which requires an analysis of air quality impacts. With increasing scrutiny of the coal industry from the public and ever-tightening National Ambient Air Quality Standards, more permitting agencies may begin requiring air quality modeling evaluations for surface mining operations that had not been modeled before. Surface mining presents unique challenges when characterizing and modeling sources. In particular, characterizing open pit sources, truck traffic, and explosive blasting operations at a facility that is constantly changing. The time it takes to process the model, even with modern computers, can also be significant.

Our presentation describes the mitigation challenges mining companies encounter when compensating for historic mitigation liability requirements. Typically, historical impact and functional assessment methodologies are not comparable to current assessment protocols, resulting in an unbalanced assessment comparison and the potential for increased mitigation costs. We will provide a real-world example demonstrating how EIP and GEC teamed to successfully develop an Army Corps of Engineers approved conversion while keeping mitigation costs comparable to historic rates. We will discuss how the conversion gave the mining company an opportunity to streamline regulatory compliance while benefiting from the risk reduction of purchasing mitigation bank credits.

Aligning with (then) Goldcorp’s vision of Environmental Sustainability an area of opportunity was identified to further reduce dust emissions in Peñasquito’s Open-pit Mine Operation through the conversion of two haul trucks and create uniformity of water truck fleet equipment. This conversion, coupled with the integration of G-2 Digital Controlled Water Distribution System, supported the objective of increased equipment performance, reduced safety incidents resulting from over watering, as well as water and dust management optimization through the introduction of real-time reporting analytics. Objectives identified prior to implementation based on the following challenges: Over-watering and/or poor water application resulting in safety incidents Track flowrate and manage water distribution Track optimization of water truck Meet mine operation water distribution needs Project Objectives: Installation of the G2 System Integration of G-2 data supporting geo-zone management, geospatial analytics, PI reporting structure, and correlation between tonnage movement and water distribution. Project objective supports current Environment Departments Dust Management initiative.
Includes valuable strategies and also situations to avoid. This perspective comes from a former regulator and may be stretched as thinly as you are. Regulators have pressures and processes in maintaining productive relationships. Identification of the appropriate strategy is critical, thus this presentation will identify regulatory considerations applicable to each strategy and provide thoughtful insight into the use of these tools.

The presence of waters of the U.S. (WOTUS) can significantly impact permitting timelines and compliance obligations for U.S. mine projects. The extent of WOTUS in the arid southwest has long been a source of confusion and debate. Two key U.S. Supreme Court decisions have only added to the uncertainty, and three administrations in a row have attempted to clarify the definition of WOTUS. The most recent draft rule published by the administration promises to provide clarity along with regulatory relief. Here we provide a brief overview of WOTUS history and a discussion of the new rule and its implications.

If you work in the environmental profession as an owner, facility staff, or a consultant, you routinely interact with regulators. Regulatory agencies are typically large, bureaucratic, and have politics influencing their decisions. You may be pursuing a permit, documenting permit compliance, non-compliance, or providing an assessment of environmental impacts for a proposed project. Tense interactions may include violations, enforcement action, and occasionally, litigation. Understanding and respecting the obligations of your regulator is of key importance in maintaining productive relationships. Regulators have pressures and processes to follow, bosses to keep satisfied, and may be stretched as thinly as you are. This presentation will describe an approach for the regulated community and its contractors to develop and maintain productive relationships with the regulators who can impact your project. This perspective comes from a former regulator and includes valuable strategies and also situations to avoid.

Alternative NPDES compliance strategies can provide an opportunity for demonstrating compliance with permit limits and the Clean Water Act (CWA). This presentation will discuss various NPDES alternative compliance strategies allowed by the CWA. These strategies include the removal of designated uses from waterbodies through use attainability analysis and use and value demonstrations; the use of sound science to identify site-specific standards; the applicability of variances from water quality standards; and use of schedules of compliance. Identification of the appropriate strategy is critical, thus this presentation will identify regulatory considerations applicable to each strategy and provide thoughtful insight into the use of these tools.

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10:05 AM
**Gravel Bed Reactors (GBRs): Effective Treatment of Metals in Surface Water and Groundwater at Mine Sites**

E. Cox; GeoSyntec Consultants, Waterloo, ON, Canada

The mining industry continues to require robust, reliable and cost-effective treatment technologies to remove metals and inorganics from surface waters and groundwater at active and abandoned sites. Recently, selenium has emerged as an expensive and challenging problem to solve. Gravel Bed Reactor (GBR™) technology is proving to be effective in treating selenium and nitrate, and GBRs have also been shown to be capable of treating problematic metals such as arsenic, zinc, chromium, uranium, cadmium and lead. GBRs consist of an engineered bed of gravel or waste rock. Amendments such as carbon-based electron donors, nutrients or pH buffers are added to the water at the inlet of the GBR to reduce or immobilize the metals and inorganics. GBRs offer simpler, less engineered systems compared to conventional above-ground water treatment facilities. The need for less infrastructure allows easier installation of smaller systems in less accessible locations such as montane topography, and the potential to treat water at/near the source of impact. This presentation will describe case studies where GBRs have been effectively used to treat selenium, nitrate, arsenic and other metals.

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10:25 AM
**In Situ Sulfate Mediated Metal Remediation (i-SMMR) for the Treatment of Mine Impacted Groundwater**

F. Mascioni; GeoSyntec Consultants, Inc., Phoenix, AZ

Trevor Carlson and Fabrizio Mascioni GeoSyntec Consultants, Phoenix, Arizona

Groundwater impacts at mining sites are often comingle mixtures of sulfate, associated with the sulfuric acid leach solutions commonly used in mineral extraction, as well as various metals associated with the ore body or host rock being mined. The focus of the research presentation is the development of cost effective and reliable processes for biologically reducing sulfate, yielding biological and abiotic chemical processes that result in the precipitation or geological sequestration of the metal-based contaminants present in the groundwater at mining sites. This presentation describes the development and microcosm testing of SiREM’s MB-1® sulfate reduction consortium, grown in water from a metal impacted mine site located in Chile. This research is ongoing and is the basis of new in-situ passive approaches and bioremediation products for remediating metal-based groundwater contamination at mining sites.

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10:45 AM
**The Saltout Process: Sulfate Precipitation and Trace Metals Capture**

T. Hanson and R. Johnson; US Water, Superior, WI

The Saltout process is a sulfate removal method that meets variable effluent standards, including trace metals capture into a coproduct matrix suitable for landfill. This process is a valuable tool that will prevent future Acid Mine Drainage, improve recycled processing water quality, and meet tightening environmental standards. US Water has developed a high density sludge process to precipitate sulfates, metals, and encapsulate into an inert filter cake which is highly resistant to leaching. We will chronicle the pilot work and the removal rates of a variety of species; such as arsenic, mercury, selenium, copper, nickel, chrome, and barium.

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11:05 AM
**Passive Treatment Systems for Mine Impacted Water: Biochemical Reactor Substrate Longevity**

R. Thomas¹, J. Bays¹, B. Page² and R. Nairn²; Jacobs Engineering Group, Atlanta, GA; ¹School of Civil Engineering and Environmental Science, The University of Oklahoma, Norman, OK and ²Red River Environmental Laboratory and Consulting, Oklahoma City, OK

Biochemical reactors (BCRs) have become an important treatment unit within passive treatment systems (PTS) designed for mine impacted water; however, operational longevity has remained a persistent concern. This presentation will present an overview on the background, history and principles on the use of BCRs to treat mine-impacted water. This will include a detailed review of the configuration, operation and performance of a typical BCR system and will provide data and observations from two-long term (>8 years) operating BCR systems as examples: Coal Mac 002 PTS in southern West Virginia and Mayer Ranch Passive Treatment System (MRPTS) located in the Tar Creek Superfund Site in northeastern Oklahoma. This presentation will demonstrate that BCRs are an effective low cost, long term, and sustainable option for meeting water quality targets of mine impacted waters. In addition, we will touch on the benefits and limitations, capital and operation-maintenance costs, and regulatory challenges of passive treatment using biochemical reactors.

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11:25 AM
**Long-term Performance of a Constructed Wetland System for Copper and Other Metals**

M. Huddleston and K. Rose; Sciences, SynTerra Corporation, Greenville, SC

In October of 2000, a constructed wetland treatment system began receiving a combination of stormwater and wastewater from the A-01 outfall located at the U.S. Department of Energy’s Savannah River Site (SRS) in South Carolina. The constructed wetland treatment system was designed to treat approximately one million gallons of stormwater and wastewater per day. The A-01 outfall is an NPDES permitted discharge, and prior to construction of the wetlands, contained copper at levels toxic to aquatic organisms. The constructed wetland system consisted of an upstream retention basin that provided consistent flow via gravity to eight one-acre wetland cells planted with giant bulrush (Schoenoplectus californicus). Compliance for copper, mercury, and toxicity has been achieved at the A-01 outfall since the wetlands system began receiving wastewater nearly 20 years ago. The constructed wetland system has provided numerous research opportunities from conceptual design through long-term operation. Much of the design basis and research will be presented. SRS has saved over $60 million in treatment costs over the life of the constructed wetland system.

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**Wednesday, February 26**
**Morning**

9:00 AM • North 128 A

**Health & Safety: Moving Toward Zero-Harm**

**Chairs:** J. Brune, Colorado School of Mines, Golden, CO
W. York-Feirn, Colorado Division of Reclamation Mining & Safety, Denver, CO K. Jennings, Colorado School of Mines, Arvada, CO

9:00 AM **Introductions**

9:05 AM **Driving Towards ‘Zero-Harm’ and Maximum Productivity in the Digital Mine**

K. Shikoluk; General Electric, San Ramon, CA

The Industrial Internet technology wave provides industry capabilities and applications to analyse and manage relevant process data that allow meaningful insights to optimize the overall production process. Under the premise to be more competitive and maximize productivity, mining players have a strong incentive to implement these solutions and take advantage of these tools. This presentation will explore what strategies are available, more specifically within above ground surface mining to address concerns around vehicle interaction risk reduction, improved situational awareness and recordable risk reduction. In addition, this presentation describes the key components of the industrial internet and how to take these new skills, process and technologies and implement within Mining. Finally, the presentation will cover case studies, tried and tested in above ground mining applications both in Australia & South America and how these solutions can effectively reduce the number of accidents which could occur between pedestrians in close-proximity with heavy mobile equipment.
9:25 AM
Sharing Critical Controls
B. Ross; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

The University of Arizona, through a grant with the National Institute for Occupational Safety and Health, has held three workshops to solicit and document critical control systems that mining companies have implemented to share with the mining industry. The focus of these workshops has been placed on sharing critical controls for geotechnical events, and a database of the critical controls has been recorded. Two separate workshops were held with professionals across a variety of companies: first with geotechnical experts, the second with hydrology experts. The third workshop was held with geotechnical experts from one mining company. This paper describes the process used to collect critical controls, reviews the database that was developed and provides instructions on how the industry can access the database as part of the sharing process.

9:45 AM
Mine Accidents Analysis Using Machine Learning
R. Anoako, J. Buaha and A. Brickey; Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD

Over the past three decades, the global mining industry has recorded significant declines in accident and injury rates. This is attributed to advancements in technology, increased enforcement, and safety consciousness. Despite these declines, mining remains high risk compared to other industries. In 2008, NIOSH launched the concept of achieving zero injury and occupational illness on mine sites. Researchers have since sought ways to further reduce mine accident occurrence. Towards this end, we present an alternative means of examining mine accidents and injuries using a machine learning technique known as the multi-class logistic regression. We implement this technique on a ten-year injury data set from MSHA to help identify significant risk factors associated with different classes of mining accidents. The risks identified therein could provide information that allows for targeted safety training and mitigation efforts. The logistic regression model could also be used as a tool for assessing an employee’s susceptibility to a particular class of accidents/occupational illness under specific circumstances.

10:05 AM
The Continuous Improvement Lifecycle: A Human Performance-Based Safety Management System to Create Experts
L. Brown and M. Pouton; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

Traditional safety programs are often oriented toward “fixing” as opposed to “empowering” a culture of safety. In this work, we outline the Continuous Improvement Lifecycle (CIL), which re-frames the four pillars of safety management as a human performance problem: 1) Safety policy. Evaluate standard operating procedures against patterns of performance to identify gaps and institutionalize best practices. 2) Safety assurance. Identify safety competency in an ever changing work environment by aggregating traditionally isolated data sources, such as serious games, job task analyses, and IOT sensing, into a heterogeneous database of human performance metrics that can be mined for knowledge, skills, and abilities. 3) Risk management. Develop performance histories to train generative computational models of behavior, revealing potential risks in new situations. 4) Safety promotion. Use targeted training and adaptive scaffolding to provide spot learning and fast refreshers at safety shares, tailgates, and monthly safety meetings. We outline our CIL framework and a proof of concept implementation, describing pilot studies and external research supporting effectiveness.

10:25 AM
Design of a Foot Operated Hoist Brake Control System for the Reiche Zeche Mine
K. Callahan1, J. Brune2, H. Mischo2 and F. Reuter2; 1Mechanical Engineering, Colorado School of Mines, Golden, CO; 2Mining Engineering, Colorado School of Mines, Golden, CO

In order to accommodate a hoist operator with a non-work related disability, a research team at the Reiche Zeche research mine at TUBAF designed a new foot-operated hoist brake control system. Miners use the hoist on a daily basis, and any malfunction in the brakes can negatively impact their health and safety. Therefore, the brake control system must have high reliability and accuracy. The
Wednesday, February 26

9:00 AM • North 127C
Health & Safety: Risk Assessment and Hazard Recognition

Chairs: S. Duzgun, Golden, CO A. Jha, University of Utah, Salt Lake City, UT G. Beckstrom, Pace Analytical Services Inc

9:05 AM
Why are Haul Truck-Related Fatal Accidents still Occurring?

J. Bellanca¹, M. Ryan¹, T. Orr² and R. Burgess-Limerick³; ¹Human Factors, CDC NIOSH, Pittsburgh, PA and ²Minerals Industry Safety and Health Centre, The University of Queensland, Brisbane, QLD, Australia

The use of powered haulage at mine sites continues to be hazardous, with haul-truck-related accidents being the most common. To better understand why haul-truck-related accidents continue to occur and what we can do to prevent them, researchers reviewed U.S. haul-truck-related fatal accidents from 2005 to 2018. Researchers constructed bow-tie representations of each event using the Mine Safety and Health Administration’s (MSHA) final fatality reports. The analyses explored the context of the accidents with a focus on the initiating event, event outcome, hazards present, and possible preventative and mitigative controls. The results of this study suggest a need to focus on improving low-level defensive controls, especially related to haul truck operation, and a need for further investigation into operator decision-making and organizational controls.

9:25 AM
Advancement of Safety Technology Drives Innovation and Cost Savings for the Mining Industry

S. Martell; PRECO Electronics, Boise, ID

In some of the most inhospitable parts of the globe, mining owners and operators face many significant risks throughout the mining cycle, from environmental responsibility/liability to health/safety. Sharing the industries fatal mining incidents involving heavy mobile equipment in hopes of increasing awareness, the U.S. Mine Safety and Health Administration identifies fatalities which could have been avoided if the best practice of installing and maintaining collision avoidance/warning technologies on mobile equipment had been implemented. Providing operators with tools capable of enabling spatial awareness and blind spot visibility are imperative to mobile equipment safety, and radar systems are a strong and reliable solution to this persistent problem. By identifying risks throughout our 70+ years of experience in the industry, it has become apparent that by adding intelligent collision mitigation technologies to the existing infrastructure, mining companies can continue to deliver with safety solutions tailored to the specific operating environment, reducing risk, minimizing downtime and significantly boosting productivity.

9:45 AM
Competencies for the Competent Person: Defining Workplace Examiner Competencies from the Health and Safety Leader’s Perspective

J. Hrica and B. Eiter; PMRD, CDC/NIOSH, Pittsburgh, PA

The ability to identify hazards during a workplace examination is a critical skill for mine workers to have in order to maintain a safe workplace. While research suggests that being able to successfully recognize hazards requires a complex set of competencies, it is unclear which competencies are most critical to adequately perform a workplace examination. To better understand how the industry is selecting and preparing workplace examiners, researchers from the National Institute for Occupational Safety and Health (NIOSH) interviewed nine safety professionals at surface stone, sand and gravel mine sites throughout the United States. The purpose of these interviews was to identify critical competencies, understand why these competencies are critical, and determine how safety leaders are preparing their workforce for the task. Finally, the results of this study will be presented within the context of current NIOSH research findings related to hazard recognition.

10:05 AM
Hazard Recognition: Identifying the Influence of Age, Experience, Risk Tolerance and Risk Perception on Accuracy Scores

B. Eiter and J. Bellanca; National Institute for Occupational Safety and Health, Pittsburgh, PA

Mineworkers face a challenging and dynamic work environment. To maintain a safe workplace, mineworkers must be able to recognize worksite hazards while they perform their jobs. While hazard recognition is a critical skill, recent research from the National Institute for Occupational Safety and Health (NIOSH) indicates miners fail to identify a significant number of hazards. To further understanding of mineworker hazard recognition ability and to begin to address performance, NIOSH researchers analyzed data collected during a laboratory research study to determine the effect of individual miner factors such as age, number of years of mining experience, risk tolerance, and risk perception on hazard recognition accuracy. The results of this study will be discussed in the context of competencies critical for hazard recognition ability and potential strategies that can be used to address these factors.

10:25 AM
Effectively Managing MSHA Incident and Special Investigations

N. Scala; Conn Maciel Carey LLP, Columbus, OH

The hours, days and weeks following an on-site accident are stressful and at times chaotic environments for employees and managers alike. While the well-being of any injured party is the priority, operators must also ensure appropriate action is taken to comply with MSHA regulations and assess the incident while taking steps toward preventing a similar occurrence. These concerns are enough to manage without the likely visit from MSHA to investigate, at which time inspectors will conduct employee interviews and issue citations and orders in the event of alleged noncompliance. This presentation will review immediate compliance requirements following an accident, as well as strategies to limit exposure and protect company interests while allowing MSHA to complete an investigation. During this presentation, participants will learn about: Responsibilities of mine operators and independent contractors in the event of an accident; Miner and mine management rights during a subsequent MSHA investigation; and Best practices for conducting internal accident investigations.

10:45 AM
A Quantitative Risk Assessment of Occupational Accidents in Turkish Hard Coal Enterprises

H. ERDOGAN¹, S. DUZGUN² and A. KESTEL³; ¹Directorate for Strategy Development, Ministry of Energy and Natural Resources of Turkey, Ankara, Turkey; ²Actuarial Sciences Program, Middle East Technical University, Ankara, Turkey and ³Mining Engineering, Colorado School of Mines, Illinois, CO

Turkish Hard Coal Enterprises (TKK) is the only public authority responsible from hardcoal production in Turkey. Five underground mines exist in the district. This study proposes quantitative risk assessment methodology for accident risks in TTK. The risk assessment involves the determination of hazards and possible severities. The data set covers underground accidents causing injuries. First the data of accidents between 2000 and 2014 are statistically analyzed regarding number, type and location of accidents, main duty, injured parts, education level, age and experience of casualties and days lost. ANOVA is applied to the data to compare the mines. In the study, hazards are classified as individual, operational and locational hazards and quantified using contingency tables and conditional and total probability theorems. Event trees are also prepared for all hazard categories. In some of the most inhospitable parts of the globe, mining owners and operators face many significant risks throughout the mining cycle, from environmental responsibility/liability to health/safety. Sharing the industries fatal mining incidents involving heavy mobile equipment in hopes of increasing awareness, the U.S. Mine Safety and Health Administration identifies fatalities which could have been avoided if the best practice of installing and maintaining collision avoidance/warning technologies on mobile equipment had been implemented. Providing operators with tools capable of enabling spatial awareness and blind spot visibility are imperative to mobile equipment safety, and radar systems are a strong and reliable solution to this persistent problem. By identifying risks throughout our 70+ years of experience in the industry, it has become apparent that by adding intelligent collision mitigation technologies to the existing infrastructure, mining companies can continue to deliver with safety solutions tailored to the specific operating environment, reducing risk, minimizing downtime and significantly boosting productivity.

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Effect of Karst Voids on Pillar Strength in an Underground Limestone Mine
A. Soni, J. Monsalve, R. Bishop and N. Ripepi; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA
Karst voids can lead to hazardous conditions during underground limestone mining operations. An advance into these voids may originate ground control problems due to a sudden inrush of water or loose claye-rock material. Also, the presence of these voids in the pillars or their interaction with the discontinuity network in the immediate roof may lead to local instability. This study evaluates the stability of a pillar with a karst void in a multi-level room-and-pillar mine. Further comparison is made to a scenario with the pillar without the void. This comparison would help understand the effect of karst on pillar strength, which may then be related to local stability around the pillar. The case-study mine hosts an interconnected system of karst reservoirs. Laser scanning and Ground-penetrating radar (GPR) were utilized to map the discontinuities and detect the voids in the underground mine. DistinctElement modeling using Discrete Fracture Networks (DFN) is used to simulate the presence of discontinuities and karst voids in the pillar. An effort is made to understand the importance of pillar design and dimensions in a karst terrane to ensure local mine stability.

Using Virtual Reality as a Test Environment for Evacuation Drills and Related Train Procedures
J. Sattarvand and S. Gaab; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV
Underground mines have to hold mandatory evacuation drills at least every six months including all underground personnel. This costs time and money, since they hurdle or even hinder mine production. This paper investigates the advantages if these drills are conducted in a virtual environment instead. Therefore, a virtual mine model replicating a Nevada gold mine has been developed. A group of people evacuated this virtual mine – wearing head-mounted displays – and completed a user study survey. Based on these results the potential to substitute or support in-situ drills, evaluate evacuation routes and signage as well as train evacuation procedures was examined.

Wednesday, February 26
Morning

9:00 AM • North 125B
Industrial Minerals & Aggregates: Aggregates & Industrial Sands
Chairs: A. chandra, University of Kentucky, Lexington, KY R. Winn, R.E. Janes Gravel Co, Slaton, TX

9:05 AM
Supply and Demand - The Lesson That is Never Learned
A. Stagg; Stagg Resource Consultants, Inc., Cross Lanes, WV
Demand exceeds supply, prices rise. Supply exceeds demand, prices fall. Ah yes, the commodity cycle, so well understood by those experienced in the mining industry. Or is it? Yet another classic case study awaits the aspiring MBA candidate-the West Texas Frac Sand Rush. From no production to a substantially oversupplied market in three years is more fodder for late night sessions around the virtual campfires. One participant provides his observations from ground zero.

2nd Edition-Dust Control Handbook for Industrial Minerals Mining and Processing
A. Czecala, J. Schall, J. Colinet, E. Haas, J. Patts and R. Stein; CDC/NIOSH, Pittsburgh, PA
The second edition of the Dust Control Handbook for Industrial Minerals Mining and Processing was recently published by NIOSH in March 2019 and represents a successful collaborative effort of both government and industry personnel with the goal of protecting the health of U.S. mine workers. The two principal stakeholder partnerships active in creating this handbook were the NIOSH’s Mining Program and the Industrial Minerals Association—North America. The recent updates and revisions to the first edition of this handbook were performed by a dust task force of safety and health specialists, industrial hygienists, and engineers to provide information on proven and effective control technologies that lower workers’ dust exposures during all stages of mineral processing. The handbook describes both dust-generating processes and the control strategies necessary to enable mine operators to reduce worker dust exposure. Implementation of the engineering controls detailed in the handbook can assist operators, health specialists, and workers in reaching the ultimate goal of eliminating pneumoconiosis and other occupational diseases caused by dust exposure in the mining industry.

Aggregate Protection Statutes in Arizona: Avoiding Untenable Land Use Conflicts through Productive Collaboration with Lawmakers and Public Agencies
e. means1 and S. RusselP; ‘Haley & Aldrich, Phoenix, AZ and ‘Arizona Rock Products Association, Phoenix, AZ
In 2007, the Arizona Rock Products Association sponsored changes to Arizona Revised Statutes regarding General Planning for counties and cities. The new law required that sources of aggregates be identified in General Plans and that development policies be implemented to prevent conflicting land use issues. In 2017, a survey of the 50 largest cities and counties which showed only 50% compliance with the revised statutes, even where there was significant mining and serious land use conflicts between mining operations and development. Our findings suggested that compliance was correlated with the availability of AZGS mapping tools and that areas lacking AZGS mapping had substantially lower compliance. In response to this analysis, the statute was amended again in 2019 to require planning agencies to reference existing AZGS mapping or identify registered mines in their planning districts and the AZGS. This talk focuses on the important learnings from the rulemaking, shares best practices for community planners and state agencies, and identifies impediments to compliance with the statutes and the benefits of productive collaboration with a notable state agency.

Geological Mapping Products as Applied Tools for Industrial Minerals and Aggregate Resources
C. Richardson, P. Peatree and B. Gooden; Arizona Geological Survey, University of Arizona, Tucson, AZ
Geological maps and derivative products capture diverse information that can be utilized in the exploration for aggregate resources, expansion of existing operations, and long-term planning for future resource exploitation by both producers and users. The Phoenix area serves as a case study where most aggregate deposits are associated with major river systems. Phoenix is served by abundant aggregate resources; however, the continued growth of the metropolitan area and land-use disputes threatens new aggregate operations via development over known and potential resources. Geologic mapping, subsurface characterization, and proactive planning of aggregate resources prior to their need is becoming increasingly essential to effectively balance competing needs for development.

Considerations for Mining Materials River Transshipment Facilities Design
P. Sullivan; Civil & Environmental Consultants, Inc., Pittsburgh, PA
It is a fact of operations life that mining companies are constantly looking for ways to reduce the transportation costs to ship their product to market. For mining sites located close to rivers, transportation costs can be reduced if the river can be used for shipment by barge. In order to take advantage of nearby rivers, mining companies need to consider many engineering design factors, including river and harbor shoreline and channel topography, river flow conditions, geotechnical
The paper will review the decision support concept, digitization concept, goals, and considerations, as well as operations considerations such as throughput, material type, and structural engineering. This paper examines these engineering considerations.

Wednesday, February 26
Morning

9:00 AM • North 125A
Industrial Minerals & Aggregates: Applications of Data Analytics, Artificial Intelligence in Industrial Minerals

Chairs: A. Choudhary E. Tarshizi, Michigan Technological University, Houghton, MI

9:00 AM
Introductions

9:05 AM
Experiences from the use of a predictive asset health monitoring platform in Grinding

M. Perruccio; ABB Switzerland, Baden-Daettwil, Aargau, Switzerland

The maintenance process has been changing from corrective and preventive to predictive maintenance in order to improve availability of assets and productivity. While the first two paradigms focus on maintenance upon a failure or at fixed periods, the predictive maintenance continuously monitors health of the equipment and offers condition-based maintenance. In order to develop a reliable condition based monitoring platform, data is collected, stored and analyzed using advanced signal processing and artificial intelligence methods. This presentation shows a holistic condition-monitoring platform applied in Grinding mills, where a broad fleet asset data is aggregated in a central platform, allowing for big data processing using machine learning techniques and providing asset health and advanced failure notifications. Real cases will be illustrated where unplanned shutdowns have been prevented by utilizing the remote diagnostic platform in conjunction with predictive maintenance techniques. A comparison among different types of techniques is presented while trying to understand which methodology fits best to the ultimate target of the maintenance strategy.

9:25 AM
Using Artificial Intelligence and 3D Point Clouds to Provide Real-time Bulk Volume Measurement for Conveyor Belts

C. McKinnon¹, S. Karimifard² and I. Bell²; ¹Marketing, Motion Metrics, Vancouver, BC, Canada and ²Research & Development, Motion Metrics, Vancouver, BC, Canada

To optimize material processing, mines must monitor the bulk volume (and corresponding tonnage) of materials transported downstream by conveyor belt. Using this data to adjust crusher settings and conveyor belt speed, mines can deliver an optimal amount of material to the next phase of production and maximize performance along the entire comminution chain. Our proposed solution uses artificial intelligence and a 3D camera to provide bulk volume measurement for conveyor belts. The solution uses deep learning algorithms to calculate the conveyor belt speed and the volume of transferred material from 3D point cloud data with high accuracy.

9:45 AM
Mine Digitization – Methodologies, Impacts, Implementation and Tips

R. Tamir; Engineering, CEMEX, Miami, FL

The paper will review the decision support concept, digitization concept, goals, key words & terms, methodology, relevant technology, phase integration of “mine to client”, upstream / downstream impacts, implementation methods, conclusions and recommendations. In addition, it will provide tips for successful integration.

10:05 AM
Building Data Generating Systems and Using that Data to Generate Actionable Insights for Belt Cleaners

B. DeVries; Engineering, Flexco, Downers Grove, IL

Mines today are collecting data from their equipment, but up until now, no one has gathered and analyzed data from belt cleaners. Flexco, a global leader in belt conveyor in belt conveyor productivity, has partnered with Uptake, the leader in industrial AI and IoT software, to turn belt cleaner data it into immediate, actionable insights. This presentation will focus on generating data and converting the raw data into actionable insights for your belt cleaners. Utilizing that raw data and hours of in-field research, we created dashboard that measure the performance of belt cleaners, while predicting the longevity of the components and the maintenance required. Is your belt cleaner being properly maintained? When will you need to swap out a new blade? Are you getting optimal blade-to-belt contact? These are all questions that can be answered with the touch of a button using the newest data science technology. We’ll also discuss the future of belt conveyor data conversion, including the timeline for adding other conveyor system components and evaluating the conveyor system as a whole.

10:25 AM
Improving Aggregate Plant Production Using Artificial Intelligence (AI)

K. Dagdelen; Mining Engineering, Colorado School of Mines, Lakewood, CO

The production planning at an aggregate plant involves calibration of future sale forecast to products produced. To meet the expected product demands, product inventories have to be built by operating the plant in different modes in certain time slices. Managing the monthly product inventories to produce products with expected sale forecasts and prices are normally done in MS Excel. Most plant managers either use their experience or MS Excel to manipulate the plant operating hours in different modes manually to generate desired product tonnages in the stockpiles. Use of Artificial Intelligence (AI) based techniques in production planning appear to improve production efficiency of an aggregate plant significantly. This presentation will demonstrate implementation of the AI method for real world applications and discuss resulting financial benefits through better planning and controls.

10:45 AM
Using Artificial Intelligence and 3D Imaging to Provide Real-time Particle Size Analysis on Haul Trucks

C. McKinnon¹, B. Sameti², S. Karimifard² and I. Bell²; ¹Marketing, Motion Metrics, Vancouver, BC, Canada and ²Research & Development, Motion Metrics, Vancouver, BC, Canada

Particle size analysis is a key metric for meeting blast targets. To capture statistically valid particle size data, it is important to sample material frequently. In most mines and quarries, the blasted material is loaded onto haul trucks and then transferred to the crusher; measuring the particle size of each haul truck load therefore provides an adequate sampling rate. We propose a particle size analysis solution for haul trucks that does not impact current operational workflows. Using artificial intelligence and 3D imaging, our solution reliably localizes and identifies haul trucks as they drive by, then accurately calculates the particle size distribution of the visible material in each truck load.

11:05 AM
Detection of Geological Features using Aerial Image Analysis and Machine Learning

R. Sahu; Strayos, Saint Louis, MO

Geologic structures are one of the crucial parameters in blast design. Structural geology and rock properties influence drilling pattern, blast layout, and initiation systems. This paper aims to identify geologic features in a bench using images obtained from the drone. Images obtained from mine site are annotated for geological features such as faults and joints. Semantic segmentation of images is achieved using an encoder and decoder structure available in the machine-learning pipeline. The encoder consists of initial convolution and pooling layers to...
capture essential features of the geology and rock patterns from two-dimensional RGB images. Batch normalization is used to put all the features on the same scale. These images are then inputted as training data for the machine-learning algorithm. Machine learning model is trained on sub-section of interest to achieve reasonable accuracy. After the model achieves reasonable accuracy, it is used to recognize geological features on new data. Geological features identified on the new data can be used by the blasting crew in blast design and keeps the geological maps updated that can help the geotechnical team.

Wednesday, February 26
Morning

9:00 AM • North 126A
Industrial Minerals & Aggregates: Sustainable Developments, Tailings & Water Management
Chairs: S. Gaillard, United States Gypsum Co., Tawas City, MI; K. Kosloski, Luck Stone, Richmond, VA

9:05 AM
Effects of the Mine Dust on the Efficiency of Solarpowered Mines
A. Rasti, H. Ranjekhash Adarmanabadi, M. Hassanalian and P. Roghanchi; Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM

Mining is among the industries that consume significant energy. The industry is predominantly powered by traditional fossil fuels, although there has been a desire to incorporate renewable energy sources such as solar energy. In the application of solar energy, solar intensity, efficiency, reliability, and environmental pollution are the challenges that need to be addressed before solar power can replace fossil fuels for power generation. Among the environmental pollution, dust can significantly reduce the efficiency and the power generated by the solar devices. In this paper, experimental studies were carried out in order to conduct parametric analyses of the effects of dust and environmental factors (i.e., temperature, humidity, and wind speed) on the efficiency of solar panels. For each simulated condition, the output voltage, current, and power of solar panels were measured. For different levels of dust accumulation, the efficiency of the solar panels was calculated. It was illustrated that dusty environments such as mine sites significantly reduces the efficiency of the solar panels.

9:25 AM
Backfill to Reduce Tailings Surface Storage Requirements
M. Treinen; Paterson & Cooke, Golden, CO

The Mount Polly tailings dam failure Expert Review Panel recommended placing tailings underground as backfill as one of the best available practices to mitigate tailings dam risk. This paper discusses considerations for implementing a backfill system to reduce tailings stored on surface. Provided the mining method is amenable, typically only about 50% of tailings produced can be placed underground. This percentage is dependent on the ore to tailings density differential and replacement factor. Additionally, both surface and underground infrastructure location plays a role in designing backfill systems for surface tailings reduction. Legacy operations may be able to use legacy tailings storage facilities as a backfill source, while also reducing the environmental risk from those facilities. Process optimization including tailings cycloning to increase placed backfill density, and geochemical segregation, such as sequestering acid generating tailings in paste backfill underground can further incentivize backfill use. Finally, incorporating filtered tailings surface disposal becomes more attractive where backfill is already planned, since filtration infrastructure is already required.
F. Fouedjio and J. Caers; Geological Sciences, Stanford University, Stanford, CA

High-Order Geostatistical Simulation of Geological Domains at a Gold Deposit
D. Morales and R. Dimitrakopoulos; Cosmo, McGill, Montreal, QC, Canada

A new, data-driven, high-order geostatistical simulation method. The later method uses high-order spatial statistics from the available data. The application at a porphyry copper deposit shows the practical aspects of the method including the validation uses high-order spatial statistics from the available data. The application at a porphyry copper deposit shows the practical aspects of the method including the validation

Resourceful Geologist's Toolkit for Rapid, Geologically Sound Domain Characterization
D. Wentland, M. Moore and S. Sullivan; Maptek, Golden, CO

Geologists are expected to make critical decisions about their rocks with dense geologic information in increasingly shorter time spans. In this situation, it is common for geologists to solely use mathematical models that lead to quick results, but it is crucial that time is not the determining factor for domain characterization and deposit economics. Luckily, with the enhancements in geologically controlled mathematical modeling, machine learning, and explicit modelling, today's geologists can take the time to determine which method, or combination of methods, will provide the most efficient, geologically-driven domain characterization. Geologist can use that spare time to validate the results in and out of the field to determine a variety of more realistic scenarios. The various tools, including a machine learning approach, will allow geologists to rapidly generate domains based on geologic data such as drillhole samples, blastholes and geological, geotechnical, and geometallurgical observations. Case studies from a variety of deposit types will be showcased with comparison against traditional methods.

Recoverable Reserve Estimation using Non-Gaussian Copula Based Simulation for Copper Deposit
K. Dinda, B. Samanta and D. Chakravarty; Department of Mining Engineering, Indian Institute of Technology, Kharagpur, Kharagpur, West Bengal, India

The present study attempts to develop geostatistical simulation technique based on non-Gaussian copula for recoverable reserve estimation taking into consideration of support and information effects of a well-known open pit copper deposit in India. The prime focus is to explore the efficacy of copula-based simulation model. This is assessed by comparing the estimated reserve by the said technique with the reserve determined using ground-truth blast hole sample. The error statistics on the estimated values indicate that the copula-based model provides improved accuracy in comparison with other non-linear geostatistical techniques like multi-Gaussian kriging and disjunctive kriging.

The Mollehuaca and San Juan de Chorunga deposits are hosted in the poorly understood Peruvian Central Andes geologic province. The aims of this study are to develop a geostatistical simulation technique that accounts for spatial and temporal geological and mineralogical heterogeneity and uncertainty. This approach can be used to estimate the recoverable reserves of copper deposits in the Central Andes region.

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of simulated realizations of geological domains through the reproduction of the high-order spatial indicator moments of the data.

**10:45 AM**

**Mineral Resource Estimation Uncertainties and Classification**

*K. Dagdelen; Mining Engineering, Colorado School of Mines, Lakewood, CO*

This paper will investigate the different classification techniques used by the gold mining industry professionals to classify mineral resources into measured, indicated and inferred categories, to characterize mineral resource estimation uncertainty. The research is based on forty-five (45) public disclosure reports from System for Electronic Document Analysis and Retrieval (SEDAR) and one general classification guideline of a major gold producer unlisted on SEDAR. The survey includes public documents categorized by various geologic types of deposits and companies considered as major, mid-tier and junior gold mining operators. It encompasses 19 NI 43-101 technical reports filed in 2018 and 26 reports filed between 2006 and 2017. The purpose of the research is to explore and understand how the different mining companies perform classification of mineral resources in terms of the requirements used and different deposit type consideration. The paper summarizes the survey results, discusses the general implications and the need for developing more formal approach to mineral resource classification.

**11:05 AM**

**A Multi-Hierarchical Classification of Mineral Deposit Models**

*D. Lefebure¹, S. Cantor¹ and S. Richard¹; *Economic Geology, Minerva Intelligence, Vancouver, BC, Canada and ²Economic Geology, Minerva Intelligence, Vancouver, BC, Canada*

The classification of mineral deposits remains a challenging task that needs to accommodate both descriptive characteristics and mineral systems concepts. Traditional hierarchical classification systems are hampered by an expert-asserted relationship between classes as well as a single tree structure design. A taxonomy utilizing logic programming can classify mineral deposits based on their shared attributes, providing proof of internal consistency while also allowing for multi-hierarchical navigation. Focusing on shared attributes allows disagreeing parties to focus only on the differentiating attributes, and the multi-hierarchical structure allows for multiple scientifically valid classification schemes to exist simultaneously. This structure is critical to artificial intelligence applications as a single tree structure imposes an arbitrary bias that hinders advanced data science approaches. The new classification system is delivered and navigated using Minerva’s open-access software program called ACE, the Aristotelian Class Editor.

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**Wednesday, February 26**

**Morning**

**9:00 AM • North 222B**

**Mining & Exploration: Innovation & Technology: Automated Mining: Making an Impact**

*Chair: M. Baker, CheckMark Consulting, Tucson, AZ*

**9:00 AM**

**Introductions**

**9:05 AM**

**Anthropogenic Autonomy: The Human Aspects of Mining Automation**

*C. Gilbert and C. Apperle; Caterpillar Inc., Tucson, AZ*

Mining technology is at the forefront of any modern-day mining operation. Command for Hauling (CH) truck automation combines existing mining technologies into a machine capable of not only operating on its own, but making safe decisions and maintaining consistent, predictable production goals. With several sites operating with autonomous haulage across the globe, CH has enabled productivity increases of over 20%, and has moved over one billion tonnes autonomously in the past seven years. But long before the trucks begin hauling autonomously, the implementation journey involves extensive preparation, training, and change management. People, processes, and technology on a mine site make up a three-legged stool: each one is crucial in successful implementation. Without well-trained people and efficient processes, technology will only exacerbate current operational issues. If the right processes are in place, however, then the potential benefit though utilization improvements can have significant gains on safety and production on site. Training regimens, personnel requirements, and operator feedback is compiled here to provide insights into the human element of autonomous mining.

**9:25 AM**

**The Road to the Autonomous Mine: How to Prepare, How to Advance, and what the Future Holds**

*M. Lewis; Technology Interoperability Center of Excellence, Komatsu, Tucson, AZ*

What does the journey to the autonomous mine look like? How is the industry advancing options for smart equipment and interoperability? How is the workforce starting to adjust to the coming evolution? Learn more at this presentation from the market leader in commercial autonomous solutions.
and benefits observed during a ground up automation implementation in an up-ramp, down-ramp, long hole stope mine in a remote location. It also explores digital data gathering and reporting within the larger scale context of an innovation/ digital roadmap.

10:45 AM
The Mine of Future - What to Expect?
A. Ebrahimi; Mining, SRK Consulting, Vancouver, BC, Canada
New technologies are changing the lives of humans and societies in different ways and the mining industry is no exception. New technology comes in different forms, from autonomous trucks to innovations in communication systems and software to allow rapid decision making. Technological advances have already been implemented in many mines. It is not uncommon for machines to be controlled by someone many kilometers from where it is operating. Process plant control has been well established for the past 30 years, including artificial intelligence or advanced control logic. The next phase of plant technology involves dynamic ore selection and scheduling to stabilise metal recovery and optimise plant economics. Mine specifications as well as mining regulations need to change to adopt the new technologies. Although the mining industry has learned a lot so far, there is still a long way to go. New technology will change – slowly but surely – the way we design both mines and process plants. This presentation summarises examples the authors have explored over the past year on the effect of technological change to better understand these trends and issues facing the industry.

11:05 AM
Automatization of the Mining Software for Reserves Evaluation, Life of Mine, Mine Planning, and Ore Control
P. Alvarado Herrada; SME, Aurora, CO
Mine engineering professionals demands automated mining software applications to deliver reserves, life of mine, mine planning, and ore control results. Many professionals make the same question: Is possible to create and evaluate multiple complex mine plans and realistic scenarios automatically? Complex mine plans evaluation in current commercial software can take days or weeks. With limited analysis, professionals will not always get the best scenario. In this paper the author will be answering these mine engineering professionals’ questions such as: How professionals can take advantage of the automated mining software to reduce the amount of time to generate complex scenarios? Is possible to run mine plans by phase, by year and evaluate equipment at the same time? How efficiently professionals are going to evaluate a scenario where the project has undefined variables like a new intangible area? How feasible is to evaluate a scenario where the size of the pits should get reduced because a new facility must be built? The automatization of the applications of the mining software reduces in more than 50% the time of the economic evaluation of these complex scenarios.
Improvements in terms of high optimal solution quality, stabilization of searchability, based on combining improvements. The obtained results indicate the proposed firefly algorithm (IFA) to deal with the problem of the optimal operation of OOMSP and more complicated constraints. There have been a huge number of studies taken into account. The problem becomes more and more complicated since more as much as possible; while all the constraints of an open-pit mining operation are concerned in the long-term production scheduling operation field due to its key utilization procedures, data input requirements, and output analysis process.

The optimal operation of the mining sequence problem (OOMSP) has been widely concerned in the long-term production scheduling operation field due to its significant important role. In fact, mining sequences are using a huge amount of ore/waste blocks for extracting while this is not possible except to meet physical and operational limitations. The objective of the OOMSP problem is to determine the extracted blocks of mining sequence so that the total profit can be increased as much as possible; while all the constraints of an open-pit mining operation are taken into account. The problem becomes more and more complicated since more and more complicated constraints. There have been a huge number of studies considering OOMSP as a main problem. This paper presents a novel improved firefly algorithm (IFA) to deal with the problem of the optimal operation of OOMSP to reduce the expected economic loss (EEL). The proposed IFA is developed based on combining improvements. The obtained results indicate the proposed improvements in terms of high optimal solution quality, stabilization of searchability, and fast convergence for the OOMSP.

The use of Blast Movement Monitors (BMMs) to translate two-dimensional dig polygons is a well-established best practice in surface mines globally, minimizing ore loss, dilution & misclassification translating into millions of dollars of additional revenue & ore yield. While the vertical movement of BMMs is often used to optimize digging elevations on a bench-by-bench basis in multi-flitch mines, it has not previously been used in BMM Explorer software to make vertical adjustments on a blast-by-blast basis. In addition to this limitation, the differential horizontal movement in single flitch mines is ignored and the ore is often translated by the greatest horizontal movement at mid-bench, leaving a small amount of dilution in the upper bench, which moves considerably less in the horizontal plane. Blast Movement Technologies and Deswik’s mining software company have collaborated to combine 3-D BMM vectors, made up of both horizontal and vertical movements to translate a mines block model data using proprietary algorithms, and then Deswik’s Dig Optimizer tool is applied to the post-blast block model data to create new 2-D dig polygons. Presentation outcomes from Australian Gold Mine.

The paper investigates the development of algorithms and methodologies for automated drillhole detection on drone images taken from blasting sites using Machine Learning (ML). The work describes the drillhole detection results obtained by applying Aggregate Channel Features (ACF) on orthomosaic and
elevation models of the site made be photogrammetry based on the aerial images captured with drones in mining operations in Nevada and Chile. The results of this methodology as the final as-built positions of the drillholes is useful for drilling accuracy control which helps to improve the explosive energy distribution through adjusting the blasting parameters. The application is valuable in mine sites where the drilling machines do not have accurate GPS or where signal loss is experienced.

10:05 AM
**Applying Artificial Intelligence to Automated Blast Hole Drills**

C. Stacy; MineWare, Denver, CO

Automated systems for blast hole drills have been in the marketplace for decades. Unfortunately the existing systems have not significantly increased hole productivity as they have been designed with relatively simple set point algorithms. Applying artificial intelligence (AI) to control an automated blast hole drilling system has demonstrated a significant increase in hole productivity by applying intelligent adjustment to drill controls that provides a cleaner hole that virtually eliminates backfill traditionally caused by rough sides during drill extraction, automatic depth control, and most importantly, rapid drilling with reduced machine stress that exceeds not only human performance capabilities, but those of traditional automated blast hole drill control systems. This presentation will illustrate the results of an automated blast hole drill system that uses AI in its control algorithm.

10:25 AM
**The Value of a Digitally Connected Mine for Optimized Blast Performance**

J. Dudek and T. Bußo; Split Engineering, Tucson, AZ

Drilling and blasting can impact the entire mining process, from mining equipment efficiency, crushing and grinding circuit performance, all the way down to recoveries and final product quality. Common drilling and blasting workflow starts with the mine plan and ore control in each bench, then an engineered blast pattern design and timing, a drill operator drilling the blast holes, followed by an explosive team loading the holes with explosives and blasting the material. This might seem like a straightforward process; however, blast optimization is not a simple task, as there are many activities to track and pieces to connect. Now that you have all this technology and data, how are you going to make sense of it to optimize blast performance? How are you going to link the resulting fragmentation back to the original blast design? One approach is through the use of a centralized platform to automatically integrate data sources and link all the steps of the drilling and blasting process. Using this technique enables blast optimization to become much simpler and easier to understand, closing the loop between design, drill, blast, fragmentation measurement, and continuous improvement.

10:45 AM
**BlastHole Drills: Enabling Automation or Optimization?**

T. Berens; Epirec, Garland, TX

Excitement and many questions are common reactions when discussing automating drilling operations that have predominantly always required full time human interaction. What are the reasons large, medium, and small mining houses are enabling drill automation? Where is the value found throughout the mining processes? How is data being used to drive these decisions? These questions will be addressed using global real world examples for the audience to visualize the impact automation is making in mine’s value chains. Our customer’s mines are walking through structured models to properly develop and deploy automated drills into their operations with great success. The change management blueprints continue to mature into repeatable processes for each mine to capitalize on previous learnings. This presentation will explore not just the automation portion, but how Automation implementation teams view the mine as a manufacturing process utilizing data to gain its advantages. Automation is a journey. We will conclude with where this journey may go in the near future given the tremendous opportunities automation offers.

11:05 AM
**The Application of Unmanned Aerial Vehicle Technology to Detect Blast Movement in USA Gold Mine**

A. Kendir; Senior Consultant, Blast Movement Technologies, Arvada, CO

Operating in 100+ mines, BMT® designed Blast Movement Monitors (BMM®s) measure blast movement, so that ore polygons can be translated to an accurate post-blast dig location. By translating ore polygons to accurate post-blast dig locations, mines minimise ore loss and dilution and maximise grade and recovered tonnes, adding tens of millions of dollars to their bottom line. As part of the monitoring process, mine personnel walk the muck pile to detect BMMs. At some mines, the muck pile can be dangerous due to gas, voids and unstable ground, creating various safety risks. To eliminate these hazards, BMT has equipped a UAV with BMM detection hardware to locate BMMs post-blast. Mine personnel are not required to walk the muck pile, reducing safety risks and potentially minimising production delays from standoff periods. This paper presents the UAV-BMM detection results from an American gold mine. The results indicate improvements in detection time and the elimination of the safety hazards associated with walking on the muck pile. This new technology improves the lives and safety of mining personnel along with enabling once restricted organisations the ability to incorporate the BMM system.
Electrochemical Study of Neodymium Electrolysis Relative to Potential (E-pO2)- Diagram in a Fluoride Media
P. Sarfo, H. Huang and C. Young; Met & Mat Eng, MT Tech, Butte, MT

Investigations of fluorode as a fused salt LiF-CaF2-NdF3 bath for separating rare earth metals and the electrochemical behavior of Nd(III)/Nd in the bath were performed. Results were compared to thermodynamically calculated E-pO2-diagrams of the system and clearly stipulate a need to institute a Standard Electrode due to electrochemistry of the molten salt and collaboration between the metal and molten salt. By using a platinum reference electrode, measurement of the redox potential in the fluoride molten salt at high temperature were detailed using cyclic voltammetry by the demonstration of current peaks and their corresponding voltages.

M. Archambo and S. Kawatra; Chemical Engineering, Michigan Technological University, Houghton, MI

Some steel plants in the U.S. import pellets from Europe, but are situated next door to aluminum processing plants. Aluminum process waste includes red mud which contains a very high iron content, comparable feedstock to North American iron mines. Processing this red mud would allow cost savings in transportation, and reduce the environmental hazard which the red mud presents. The iron nugget process was explored to recover iron from the red mud. This is a one-step process to reduce and separate metallic iron from the red mud. This process takes a mixture of ore and a solid reducing material and heats them to temperatures above 1400 degrees Celsius. The reducing compound decomposes and reduces iron oxides and the high temperature allows the iron and slag to melt and separate. The solid reducing material chosen for this process was a mixture of powdered hard and soft wood. The resulting iron nuggets contain purities that are comparable to blast furnace pig iron. Purity of iron nuggets and total iron recovery were studied and optimized with changing system conditions such as furnace residence time and temperature.

Selective Recovery of Zinc from Zinc Ferrite
V. Kashyap1 and P. Taylor2; 1Metallurgical Engineering, Graduate Student at Colorado School of Mines, Golden, CO and 2Metallurgical and Materials Engineering, Distinguished Professor at Colorado School of Mines, Golden, CO

Presence of iron in sphalerite induces the formation of zinc ferrite phase during roasting. Zinc refinery residues (ZRR) and electric arc furnace flue dust (EAFD) contain significant amount of zinc ferrite and is difficult to decompose. According to some studies, up to 68% of gallium in ZRR was found associated with zinc ferrite. Dissolution of zinc ferrite is inefficient even in aqua regia, probably due to its complex structure. Waeltz process is an existing process to recover zinc from electric arc furnace dust by reduction followed by volatilization of zinc. In this study, zinc was selectively extracted from zinc ferrite by partial reduction of zinc ferrite at low temperature. Pure zinc ferrite sample was partially reduced into zinc oxide and magnetite by using H2 gas as reductant. Presence of magnetite and zinc oxide was confirmed by X-ray diffraction (XRD) technique. The roasted product was then leached with dilute sulfuric acid. A maximum of 95% zinc extraction was achieved by this method. The paper also discusses the effect of time and temperature of roasting on the extraction of zinc and iron from ZF.

Synthesis of Phosphonium-Based Ionic Liquids and Selective Extraction of Co(II)
O. Restrepo Baena and D. Chaverra; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

Cobalt is a metal used in numerous commercial, industrial and military applications, many of which are critical and strategic. Usually, cobalt is obtained as a byproduct of nickel metallurgy and its separation represents a challenging hydrometallurgical problem. In this work the synthesis and application of phosphonium-based ionic liquids on the selective extraction of cobalt is presented. It has been found that it is possible to extract cobalt from aqueous solutions in sulphate medium, with the addition of sodium chloride, using of phosphonium ionic liquids. The extraction of cobalt is strongly dependent on the concentration of chloride in the solution, and is given by an anion exchange mechanism. Cobalt extractions greater than 98 % were obtained using the proposed methods. The extraction process developed is selective for cobalt over nickel, magnesium, calcium and zinc. The stripping of cobalt from the ionic liquid is possible with water. Therefore, an alternative extraction process to traditional organic solvents is proposed. This alternative has additional advantages such as easy handling, lower costs in reagents and equipment and risk reduction.
Automated Mineralogy (AM) technologies are a critical tool that can provide quantitative modal mineralogy, grain size, liberation, association and exposure data for various commodities. Mineralogy can be carried out on composites and variability samples to understand where the payable metals occur in terms of recoverable or non-recoverable minerals via flotation or gravity or leaching; also, the size of these minerals to determine the primary grind for a particular mineral/s to be liberated or exposed for flotation or leaching. Samples can be taken from various points on the flowsheet during development to troubleshoot regrind sizes, unexpected abundances of the payable minerals within the various tailing products or gangue identification if the concentrate is not hitting the expected grade or deleterious/payable elements within the final concentrate. Examples will be shown from copper porphyry, polymetallic and gold flowsheets of where automated mineralogy can be shown to provide support for flowsheet development.

Effect of Different Frothers on Gas Dispersion in a Cavitation Sparger Using Electrical Resistance Tomography

P. Heldsworth, R. LaDouceur and C. Young; Metallurgical and Materials Engineering, Montana Technological University, Butte, MT

Axial dispersion in column flotation is critical for optimizing particle-bubble interaction and maximizing recovery. The effect of different flotation frothers on axial gas dispersion rates in a column flotation cell were measured using electrical resistance tomography (ERT). Gas holdup can be measured using ERT and utilized in the determination of axial gas dispersion rate in the column. The ERT is constructed with two sensor planes making it possible to simultaneously capture gas holdup values at and immediately above the cavitation sparger. Three frothers of varying strengths were used to investigate axial dispersion rates. Experimental conditions were modified by altering the superficial gas rate, frother concentration, and sparger pump speed. Utilizing a two-phase (gas-liquid) system, the effects of varying experimental conditions were captured and are represented using concentration tomograms. There is a strong positive correlation between axial dispersion rate, frother strength, and machine operating parameters.

Effect of Industrial Process Water on the Adsorption of Starch on Hematite Surfaces

N. Parra Alvarez¹, V. Claremboux¹ and S. Kawatra²; ¹Chemical Engineering, Graduate Student, Houghton, MI and ²Chemical Engineering, Professor, Houghton, MI

In the processing of hematite, it is very common to use reverse cationic flotation over the world. During this flotation modified starch is used to flocculate and depress the hematite. A typical starch modification includes gelatinization by digestion in boiling water under caustic conditions. It is clear that calcium plays a critical role in this gelatinization process, but the mechanism by which this influence an iron ore flotation is not fully understood. Tests showed that flotation with a concentration of 16.6 ppm resulted in a grade of 63.3% Fe and a recovery of 56.7%. By increasing the concentration to 298.9 ppm of, the iron recovery decreased to 54.7%, and by decreasing the concentration to 0 ppm of the recovery was reduced to 39.2%. This data indicates that both too little and too much calcium is detrimental to the flotation process. This study investigates the adsorption mechanism of starch to the hematite surface in the presence of calcium ions to attempt to characterize these ions impact on the flotation process. In addition, the optimum ionic concentration in the process water is determined.

10:45 AM

Silica Surface States and their Wetting Characteristics

J. Jin¹, X. Wang², C. Wick³ and J. Miller¹; ¹Metallurgical Engineering, University of Utah, Salt Lake City, UT; ²Chemistry, Louisiana Tech University, Ruston, LA and ³PNNL, Richland, WA

Depending on procedures for preparation, silica surface states can vary from the polar silanolated silica surface to the nonpolar siloxane surface. Wetting of the silica surfaces depends on surface polarity and the extent of hydroxylation. This study focuses on four selected silica surfaces with different levels of polarity, including the t alc (001), silanolated quartz, tridymite (001), and quartz (001) surfaces. Classical Molecular Dynamics (MD) and ab-inito simulation methods have been used to determine the contact angle, interfacial water structure, hydroxylation reaction, and hydration energy of the selected silica surfaces. These results have been compared with experimental results from the literature. The nonpolar siloxane surfaces are characterized by a contact angle of about 80 degrees, an MD water exclusion zone thickness of 3 Å, a relaxed interfacial water orientation, an inertness to hydroxylation, and a minimal hydration energy, all indicating relatively weak interaction with interfacial water molecules. On the other hand, silanol groups form at the quartz surface creating a polar surface state due to hydroxylation reactions.

11:05 AM

Surface Free Energy Characterization of Copper Sulfide Minerals

J. Zhang and W. Zhang; University of Arizona, Tucson, AZ

Contact angle measurement was carried out to obtain the contact angle of various probing liquids, i.e., 1-Bromonaphthalene, 1-methylenedioxy, water and formamide, on copper sulfide minerals, i.e., chalcocite, chalcolite and bornite. The measured contact angles were further used to calculate the surface free energies of these minerals, using the van Oss-Chaudhury-Good (OCG) equation. The results of surface free energy characterization showed that for these copper sulfides, δsLW was 41-45 mJ/m2, and δs+ was close to 0; while δs- was a quite large non-zero number, suggesting that these minerals were essentially “hydrophilic” in spite of an above 50° water contact angle being measured. Contact angle measurement and surface free energy characterization were also carried out after these minerals contacted potassium amyl xanthate (PAX) solutions (5×10-5M and 5×10-4M) for 10 minutes. Results showed that δsLW decreased, and δs- decreased greatly to almost nil, suggesting a transformation of mineral surface to “hydrophobic” after the adsorption of PAX. The study shed lights on the function of collector in copper flotation in terms of the change of solid surface free energy.

11:25 AM

Hydrophobization and Coagulation of Iron Oxide Fines with Fatty Acids

I. Chernyshova¹ and S. Ponnurangam²; ¹Geoscience and Petroleum, Norwegian University of Science and Technology, Trondheim, Norway and ²University of Calgary, Calgary, AB, Canada

Direct anionic flotation using fatty acids as a collector is widely used to separate iron ores from silicates. It is generally accepted that the main mechanism behind separation is chemisorption of fatty acids on the iron oxide surface. However, this paradigm is unable to explain why the maximum floatability of hematite is observed near neutral pH. It is also unclear how variations in the surface structures of hematite particles affect their interaction with fatty acids, how and why particle size in the submicron range affects the adsorption of fatty acids on iron oxides, as well as under which conditions fatty acids promote aggregation and dispersion of submicron iron oxide particles. These problems relate to the flotation of fines, which becomes growingly important with the growing decrease in the ore grade. To address these problems, we systematically study the effect of nanoparticle size on how hematite and ferrihydrite nanoparticles interact with sodium laurate (dodecanoate) and how this interaction affects aggregation/dispersion of these nanoparticles. We discuss possible origin of the observed effects and their implication to the selective flotation of hematite.
MPD: Plant Design II

9:00 AM • North 227C

Introductions

9:05 AM

Conveyor Pulley Design, Analysis and Standards
A. Hustrulid; Hustrulid Technologies, Bonita Springs, FL

As modern conveyor systems have increased in tension, belts have become wider, and modern fabric carcass constructions allowed smaller pulley diameters, calculation methods for designing pulleys have languished based on methodologies published in the 1960’s and 1970’s. This paper presents a modern axisymmetric FEA model with non-axisymmetric loading. The applied loads from common locking assemblies used in pulley designs are reviewed for proper application in the design. Design standards and common practices from Australia, Europe, South Africa and North America are presented and contrasted. Recommendations for mining customers concerned about ensuring quality pulley design are offered.

9:25 AM

Nevada Copper Pumpkin Hollow Process Plant
S. Haggarty; Process & Metallurgy Consultant, Haggarty Technical Services, Burlington, ON, Canada

Nevada Copper’s Pumpkin Hollow Project is an underground, high-grade copper producer which progressed through to completion in Q4 2019. The site is one of a limited number of new mining properties and start-ups within the United States. Commissioning of the 5,000 tpd facility occurred in Q4 2019 involving a SAG-Ball Mill grinding circuit, sulfide Cu flotation, thickening, filtering and dry stack tailings impoundment. Situated in the historic copper producing Yerington District, the potential for a substantial, longer term operation is being considered including the expansion of stand-alone higher tonnage processing facilities and staged development of open pit mining activity in close proximity to the site. The presentation will capture highlights and provide an update from various phases of the project including the EPC deliverable accomplished with Sedgman Pty Ltd., operational readiness, commissioning and related Owner activities which resulted in the on-schedule and on-budget completion of the project.

9:45 AM

Redesigning the Capstone Pinto Valley Mill Discharge
C. Churchman¹, M. Volger² and T. Wayment³; ¹Capstone, Apache Junction, AZ; ²Howe Systems, Reno, NV and ³Polyudeck, Spartanburg, SC

Capstone Pinto Valley mills have been in service since 1977. Screening systems were replaced in teh early 2000’s without screening efficiency in mind. With optimization efforts plant tonnages have increased without screen improvements leaving a screen under rated for the duty. With the help of FLS - Ludowici the secondary dry screens were redesigned with efficiency in mind. The implications of fitting new technology into an existing plant along with the metallurgical and maintenance criteria will be discussed.

10:05 AM

A Step-Change in Thickener Bed Level Measurement
M. McCaslin; International Sales, Westech Engineering, Murray, UT

There are several options for continuous measurement of sludge bed depth in a thickener, but few if any are consistent enough to provide reliable control across a wide spectrum of installations; or in some cases they struggle to even deal with variations in feed. Many operators rely on manual readings taken periodically with a “sludge judge” or similar device. Some manage their thickener operation without any measurement, running the risk of plugging the thickener, or more often live with underperformance in their process This paper will discuss a new continuous bed level instrument that has proven to work exceedingly well, has unique measurement characteristics, and great potential for optimizing thickener performance in a wide variety of applications.

10:25 AM

The Do’s & Don’ts of Floating Pump Stations (Barge Systems)
A. HUTCHINSON; CAID Industries, Tucson, AZ

Designing and building pump stations is full of complexities! Designing a station that floats is even more involving, and not to be taken lightly. Whether for PLS, Raffinate, Reclalm Water (TSF), Process Water, or others...This presentation is targeted at reviewing several of the key ingredients for a successful barge system. Key topics includes fluid characteristics, materials of construction, buoyancy, stability, mechanical equipment (pumps and motors), system design/modularity, structural integrity, power/electrical systems, piping systems, functional performance, maintenance, and most of all safety!

10:45 AM

Delivering Productivity Through Equipment Lifecycle Optimization – Copper Concentrator
R. Siwale; Service Line Management, FLSmidth Inc, Sandy, TX

Mining operations looking into increasing their productivity need a methodology to help managers look at the life-cycle of a plant or asset and optimize OPEX. Operational excellence implies a continuous focus on maintenance improvement, increased asset availability and throughput improvement. Achieving that requires a determined focus on reducing downtime and improving productivity of assets through advanced reliability and maintenance approaches. FLSmidth, strengthening its role as a strategic productivity partner, has developed a Total Cost of Ownership (TCO) Tool that’s allows operations to identify maintenance activities that are economically viable and generate optimal and reliable degrees of up-time and reliability for the equipment. The tool can identify maintenance activities that are duplicated, in excess, have had a high failure probability, do not benefit the business or that result in high execution costs and generate high costs associated to profit loss. This paper presents the concept, development and analysis performed at a South American copper concentrator plant using RCM methodology based on cost for equipment of high criticality.
Pyrite depression in the flotation of copper ores becomes more and more difficult nowadays due to the use of saline water and the presence of secondary/oxide copper minerals. The use of saline water results in low pulp potential and low dissolved oxygen concentration which facilitate copper activation on pyrite. The presence of secondary/oxide copper minerals generates a high concentration of copper ions available for copper activation on pyrite. To depress the flotation of copper-activated pyrite, traditionally high pH with the addition of a large amount of lime is used. However, this method is invalid in saline water where buffer pH exists and problematic in fresh water where the depression of valuable minerals and difficult water recycling are observed. In this study, a new technology was developed to selectively depress the flotation of copper-activated pyrite at slightly alkaline pH based on the radical chain reaction involving the redox cycling of Cu(II)/Cu(I) induced by sulphite species. This paper presents how this new technology was developed and applied in a number of cases to selectively depress the flotation of copper-activated pyrite.

9:25 AM
Flotation Recovery of Gold in High-Clay CarlinType Gold Ore
L. Wang; School of Metallurgical and Ecological Engineering, University of Science and Technology Beijing, Beijing, China
Flotation of high-clay Carlin-type gold ore is one of the difficulties in mineral dressing and also a research hotspot. There are two difficulties in recovery of gold in the ore. One is the slime of clay minerals under fine grinding fineness and its secondary coating of gold-carrying minerals during flotation; the other is the large differences in floatability of the gold-bearing minerals, pyrite and mélilite. In this paper; the study was carried out in deep dispersion and depression on clay minerals by using a combined regulator, sodium carbonate, sodium silicate, and BKYL, and preferential activation and flotation of pyrite and mélilite based on their natural hydrophobicity at different velocities. The research results show that the middlings circulation load was reduced without removing the clay in advance, and much better flotation indexes were obtained by flotation closed-circuit testing, the grade of the gold concentrate was increased from 10g/t to 24.61g/t, and the gold recovery rate was increased from 40% to 80.42%.

9:45 AM
Pionera Biopolymers for Better Pyrite Depression
A. Lauter; Pionera, Sarpsborg, Norway
Depression of pyrite is a ubiquitous challenge in most flotation plants concentrating sulfide minerals. It is a challenge because pyrite can become activated. Activation implies that pyrite mimics characteristics of the valuable sulfide mineral and it reports as an impurity to the flotation concentrate. A wide range of collectors and depressants are used to promote depression of pyrite. In this paper we review some cases where Pionera biopolymers are used in conjunction with different collectors. Results from plant trials have revealed that a change from the current depressant to a Pionera depressant improves depression of pyrite. The stronger depression may also allow a change to a weaker collector which indicates that there are synergies between collectors and depressants. This synergy will be discussed, both in relation to the results obtained in plant trials and with respect to fundamental aspects of their interaction with pyrite.

10:05 AM
5-(butylthio)-1,3,4-thiadiazole-2-thiol Used as the Selective Collector for Improved Flotation Separation of Galena and Sphalerite from Pyrite
W. Zhang, J. Cao and Z. Gao; Central South University, Changsha, China
Xanthate is the most commonly used collector in sulfide mineral flotation, but suffers from the disadvantage of low selectivity. Sulfoxidion anion within xanthate molecule non-selectively bonds with metal ions on mineral surfaces. In addition, sulfur-containing functional groups (sulfoxidion anion and thiocarbonyl) in xanthate molecule are with an inferior selectivity. Over the past decades, the challenge of improving the selectivity of xanthate molecule to against pyrite has captured the attention of reagent chemists. In this work, we developed a new collector 5-(butylthio)-1,3,4-thiadiazole-2-thiol by modifying sulfoxidion anion into thioether through forming a heterocyclic framework containing diazole fragment. As a result, an increased number of chelation site and improved chelation ability of new collector molecule lead to a better selectivity compared with xanthate. Flotation tests proved that Pb-Zn concentrates against pyrite could be collected selectively by using new collector, indicating that 5-(butylthio)-1,3,4-thiadiazole-2-thiol has a promising industrial application potential in sulfide mineral flotation.

10:25 AM
Depression of Pyrite in Polymetallic Sulfide Flotation using Chitosan-Grafted-Polyacrylamide
K. Moryake¹ and L. Alagha²; student, Rolla, MO and ¹Mining & Nuclear Engineering, Associate Professor, Rolla, MO
Chitosan-grafted-polyacrylamide (Chi-g-PAM) was tested as a potential depressant of pyrite in the bulk flotation of galena from a complex sulfide ore containing galena, chalcopyrite, sphalerite and pyrite. Laboratory scale froth flotation tests were carried out in the presence/absence of Chi-g-PAM, sodium cyanide (industially used pyrite depressant), chitosan, and polyacrylamide (PAM) at 50 g/t where sodium isopropyl xanthate was used as a collector. The following order of galena floatability (GF) was observed: GF /Chi-g-PAM > GF /Chitosan > GF /PAM > GF /NaCN. Beta potential and adsorption density studies verified that Chi-g-PAM had a preferential adsorption on pyrite as compared to galena. Results obtained from this work suggested that Chi-g-PAM could potentially be used to replace toxic inorganic depressants at the same time improving recovery and grade of galena (PsI) in flotation concentrates.
Results indicated DAF technique has highest efficiency and recovery by using Potassium Amyl Xanthate as a collector at non-acidic pH. In addition, by increasing percentage of recycled waste water, recovery increased. At the optimum defined experimental conditions (recycle ratio: 100%, pH: 7) more than 80% of the zinc ions were effectively separated from an initial concentration of 500 ppm.

11:25 AM
Bagdad Concentrator Improvement: Flotation Reagent Optimization using Agile Methodology
L. Roman, R. Bajagain, E. Britvec, W. Liu and F. Molto; Freeport-McMoRan Mining Company, Bagdad Operations, Bagdad, AZ
High throughput strategy attracts growing attention in Bagdad. However, the current reagents cannot handle the coarse particle size with high solid density. In this regard, PAX and F-507 were evaluated as copper collector and frother to improve the flotation performance. Agile methodology was used in the plant testing and implementation in a timely manner. The lime was increased to reject pyrite. The Cu and Mo recovery increased +1% and +3%, respectively. The total incremental annual revenue is projected to be 12 million dollars. The plant trial result improves the coarse particle flotation and provides reference for mining industry.

Wednesday, February 26
Morning

9:00 AM • North 131B/C
Tailings: Perspectives for a Changing World: Tailings Continuum – Selection of the Right Tailings Technology
Chairs: M. Davies, Teck Resources, Langley, BC, Canada R. Jansen, Paterson & Cooke, Golden, CO

9:00 AM
Introductions

9:05 AM
Considerations for Tailings Dewatering (Across the Continuum)
C. Kujawa; Paterson and Cooke, Golden, CO
Tailings dewatering is highly dependent on the nature of the tailings and the project specific drivers which have a major impact on the final dewatering target moisture. The objective of the presentation is to cover the pertinent aspects of tailings dewatering over the full dewatering continuum as required for the various tailings storage methods of conventional, thickened, paste, filtered and engineered tailings. There will be an emphasis on the fundamental role of the nature of tailings, the thickening and mechanical dewatering technologies and tailing storage requirements with the change in dewatering target moisture. This will include challenges the tailings industry is facing now. Lastly the importance of new dewatering technologies and their potential will be discussed.

9:25 AM
Tailings Facility Design and Advancements in Tailings Technologies
K. Patterson; Klohn Crippen Berger, Vancouver, BC, Canada
Over the last approximately five years there has been an urgency within the mining industry to improve tailings dam safety. One avenue for this has been to remove as much water as possible from tailings facilities by considering alternative tailings technologies and facility types to conventional tailings facilities, such as dewatering tailings prior to deposition (e.g., thickened, paste and filtered) and placement of tailings within facilities with inherently less water (e.g., thin lift placement in a cone/ downslope configuration, “dry” stack/pile, co-disposal with waste rock). However, it remains true that every project and tailings facility has a unique combination of site conditions, tailings characteristics, available resources, social and regulatory environment, and countless other factors that must be considered when selecting a tailings management strategy, approaching design and management throughout the project life-cycle. There is no one-size-fits-all approach to tailings management and selection should be based on evaluation of the full risk profile of alternative tailings management strategies (including life-cycle costs).

9:45 AM
The Future is NOW
D. Collini¹, A. Pezzi² and D. Stenglein¹; ¹Aqseptence Group, Lugo, Italy and ²Aqseptence Group, Lugo, Italy
Mining tailings have and continue to be stored as a slurry. In this century-old process, the slurry is stored in a tailings pond constructed of man-made embankments. As recent events have shown, dam failures can lead to significant economic loss, environmental destruction and loss of life. An option for tailings pond is “dry stacking” and the process has been around since the 1910’s. With the recent dam failures, none would have occurred if the tailings were dry-stacked. Tailings dewatering is now a focus and manufacturers have tailored their product line for this application. Currently, the GHT2500F is one of the filter models available for large-scale tailings dewatering projects. The trend of tonnages for tailings is on the rise and as a result of this trend, the future of tailings dewatering requires larger models. We will cite an example where the slurry was stored in a pond and now converted to dry stacking. We will provide details of the decision process to this change as well as the performances achieved with the GHT2500F. We will present the next generation of filters highlighting the design challenges faced and will present test & simulation data with different products.

9:55 AM
Recent Developments in Tailings Dewatering Technology
T. Wisdom; FLSmidth, Park City, UT
Mineral reserves continue to deteriorate in quality as the better ones are consumed, pushing miners to develop lower grade deposits in more difficult locations, often with increased restrictions on the consumption and use of water. Processing more ore to recover needed metals directly increases the amount of tailings produced from a mine. Tailings dam failures are the most significant environmental liability for a mining project. Recovering water from these tailings and disposing of the solids in sustainable processes are new challenges for this industry. Consequently, techniques for dewatering large tonnages of tailings, with minimal operational costs and making use of economies of scale, through larger equipment are continuously being sought. This paper will present some of the recent developments of large plate pressure filters, including the new 5m x 3m plate, and discuss design and operational challenges associated with them. New techniques for producing co-mingled tailings and waste rock using a process called EcoTails™ will also be presented along with the advantages of this process.

10:05 AM
Tailings Continuum: An Integrated Approach to Assist Owners in Selecting the Optimal Tailings Management Solution
K. Mayhew; Teck Resources Limited, Vancouver, BC, Canada
Tailings facilities are historically well-managed with very few incidents; however, when incidents occur there is the potential for significant impact on communities, local economies and the surrounding environment. As such, Teck takes extensive measures during planning, design, construction, operation and decommissioning of our tailings facilities to ensure that structures are stable and well-managed. In addition to managing existing tailings dams, Teck is evaluating different technologies throughout the tailings continuum to mitigate current and future dam risk. This includes methods to promote de-watering of tailings which enhances dam strength and improves water recovery. While assessing tailings facilities individually, Teck is also taking a more global approach of reviewing geology and mining methods to more effectively enhance mineral recovery thereby reducing the production of tailings. This integrated approach, which includes evaluating innovative methods to both reduce tailings production and de-water tailings, ensures that the highest standard of safety is maintained at our operations.
The grinding process is the most energy intensive process in minerals processing, and the criticality of the operation of the grinding circuit to the performance of the entire plant brings extra focus to the availability of this equipment. This presentation will focus on two key areas of improvement in grinding technology, namely: reduction of grinding energy requirements with HiGlmi® Technology for fine and ultrafine grinding, and availability improvements for horizontal tumbling mills with Polymer Bearing Technology. A description of the technology along with a case study for each of these technological advancements will demonstrate how the proper technology selection can ensure both the lowest energy requirements to meet the duty and the highest availability to meet your targets.
cases in this study demonstrate the importance of understanding the geological environment and mine design to ensure that the proper support is installed.

2:25 PM
Moderate Cover Bleeder Entry and Standing Support Performance: A Case Study
M. Van Dyke¹, I. Tulu² and D. Tuncay²; ¹Ground Control, NIOSH, Pittsburgh, PA and ²Mining Engineering, West Virginia University, Morgantown, WV

Bleeder entries are important to longwall mining for the moving of supplies, miners and dilution of mine air contaminants and must stay open for many years. Standing support in moderate cover bleeder entries and three bleeder entries were observed, numerically modeled, and instrumented. The measurements of the installed bore hole pressure cells (BPCs), standing support load cells and convergence meters, and roof extensometers are presented in addition to the numerical modeling results and visual observations made by NIOSH researchers in the bleeder entries. The results include the effects of multiple panels being extracted in close proximity to the instrumented site as well as over one and a half years of aging. The standing supports closer to the longwall gob showed the greatest load and convergence. The roof sag was generally independent of the proximity to the longwall gob. The BPC readings were driven by both the proximity to the gob and the depth into the pillar. The results of this study demonstrated that the entry roof can respond independently of the pillar and standing support loading. The closer the entry, pillar or supports are to the gob, the greater the applied load.

2:45 PM
Upgrading the NIOSH Support Technology Optimization Program (STOP) with Updated Design Features
T. Batchler¹ and T. Matthews²; ¹NIOSH, Engineer, South Park, PA and ²NIOSH, Technician, Pittsburgh, PA

Over the last thirty years, there has been an enormous amount of innovative technologies developed that provide effective roof support systems in underground mines. In 2001, the National Institute for Occupational Safety and Health (NIOSH) developed the Support Technology Optimization Program (STOP), in order to evaluate how these various technologies can impact and improve both ground control conditions and mine safety. NIOSH has now developed a new STOP upgrade implementing important changes to STOP’s functionality, user interface and general appearance. This upgrade provides more capabilities to evaluate roof support systems for conditions which could not be fully analyzed in the original version of the program.

3:05 PM
Investigating Different Methods for Approximating Pillar Loads in Longwall Coal Mines
D. Tuncay¹, I. Tulu¹ and T. Klemetti²; ¹Mining Engineering Department, West Virginia University, Morgantown, WV and ²Pittsburgh Mining Research Division, The National Institute for Occupational Safety and Health, Pittsburgh, PA

Accurately estimating load distributions and ground responses around underground openings play a significant role in the safety of underground mining operations. There are various methods used to approximate mining induced loads in stratified rock masses to be used in pillar design. The widely used empirical methods are based on equations derived from various case studies. There are also numerical models that give mechanics-based solutions. They include site specific geological information and are usually used for local analyses. In this study, two longwall mines, a shallow cover wide panel, and a deep cover narrow panel are analyzed using different methods. One of the methods analyzed is the empirical method used in pillar design software developed by the National Institute for Occupational Safety and Health (NIOSH). Another method investigated is the displacement-discontinuity variation of the boundary element method used in LaModel. Finally, a recently developed numerical modeling approach, which has been successfully applied to various cases, is investigated using the finite difference software Flac3D. All methods are finally compared against field measurements.

3:25 PM
Parametric Analysis of a Yield Pillar Geometry aer a Gate Road Design of an Underground Longwall Mine
J. Castillo and Z. Agioutantis; Mining engineering, University of Kentucky, Lexington, KY

Gateroad design for deep underground coal mines often includes yield pillars next to the abutment or stable pillar. Yield pillars are designed to yield as the panel passes by, although the entries between the yield and abutment pillars should remain open. The design of such system systems is directly related to the roof and floor conditions in the area as well as the expected abutment stress generated by mining the panel(s). This paper will present a parametric analysis of an yield-stable-yield design for a mine located in the eastern United States using the LaModel package. The effect of changing pillar width will be evaluated with respect to depth, extraction thickness and panel width.

3:45 PM
Application of the Local Geology Dependent Ground Response Curve for Tailgate Stability Analysis
H. Zhao¹, I. Tulu¹ and T. Klemetti¹; ‘Mining engineering department, West Virginia University, Morgantown, WV and ²NIOSH, Pittsburgh, PA

In longwall mines, tailgate entries are required to remain open to maintain a safe escape way and for dilution of contaminants. The local geology is a major factor in maintaining these openings as is the ground response and support requirements. The ground reaction curve approach can be used in designing standing support for these entries. However, it is impractical to determine the ground reaction curve of an actual underground tailgate through field measurements. Calibrated numerical models can be used to determine the ground reaction curve, by progressively reducing the internal pressure in the modeled tailgate and simultaneously recording the resulting convergence. The ground reaction curve for a Pittsburgh seam mine was developed using the FLAC3D finite difference software. A systematic procedure was used to estimate the model’s mechanical inputs in the Pittsburgh coal seam and the field measurement data from a Pittsburgh coal seam were used to verify model results.

4:05 PM
A Simulation-Based Optimization Approach for Support Systems of Room and Pillar Coal Mines
A. Anani¹, W. Nyabá¹ and E. Córdova²; ¹Mining, Missouri University of Science and technology, Rolla, MO and ²Mining Engineering, Pontificia Universidad Católica de Chile, Santiago, Chile

The objective of this work is to develop an integrated tool for multi-objective optimization of coal room and pillar design and operational parameters. The study highlights a well-designed data collection exercise, a continuous miner (CM) cut sequence for varying panel widths, and a stochastic simulation model of the system. The results show the effects of panel width design, haulage fleet selection, and waiting area design on the CM’s productivity and utilization. A room and pillar coal mine in the mid-western region of the United States is used as a case study to develop the model and subsequently, validate the results.
2:00 PM • North 226B

**Coal & Energy: Rare Earth Elements In Coal II**

**Chairs:** T. Gupta, Graduate Student, Fairbanks, AK Q. Huang, West Virginia University, Morgantown, WV

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2:05 PM

**Modeling of the Solvent Extraction Process for the Production of Individual Rare Earth Elements from Coal-Based Sources**

V. Srivastava and J. Werner; Mining Engineering, University of Kentucky, Lexington, KY

To facilitate the design of a solvent extraction process for the separation and purification of individual rare earth elements, a model was developed to predict process performance. The model considered various design and operational factors such as the number of stages, pH, and aqueous-to-organic ratio. The models were utilized to simulate several solvent extraction circuit configurations. The distribution coefficients were estimated from bench tests performed on rare earth oxide concentrates produced from coal and coal byproducts. The experimental program involved the use of DEHPA and CYANEX 572 as the extractants over a range of concentrations and pH values. The distribution coefficients were derived from the experimental data and utilized in the model to ascertain the purity of the produced rare earth elements and verify the number of stages required. The results of both the extractant tests and flowsheet modeling will be presented including the development of a user interface to assist the design process.

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2:25 PM

**A Sequential Extraction Method for Assessing the Mode of Occurrence of Rare Earth Elements**

A. Valian¹, J. Groppo¹, C. Eble², J. Hover³ and R. Honaker¹; ¹Mining Engineering, University of Kentucky, Lexington, KY; ²Kentucky Geological Survey, University of Kentucky, Lexington, KY and ³Center for Applied Energy Research, University of Kentucky, Lexington, KY

Sequential extraction is selective dissolution of different categories of minerals and/or types of elemental associations in progressive sequences. Different sequential extraction methods have been applied for different purposes. Herein, a sequential extraction scheme was examined and modified for investigating rare earth elements (REEs). The procedure was then applied to a high-volatile B bituminous coal sample from the Illinois Basin. Different fractionations and absolute concentrations of REEs were released into the solution in different sequences. The dominant modes of occurrence of REEs are concluded based on the sequential extraction data in conjunction with the outcomes of mineralogical studies. The results show significant dissimilarities between the individual REEs in terms of their respective modes of occurrence in the studied sample.

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2:45 PM

**Modeling In-Situ Coal to Target Potential REE**

J. Anderson; Maptek, Golden, CO

Rare Earth Elements (REE) projects face many obstacles such as limited distribution, length of time for permit acquisition and national security importance. Recently, the Department of Energy has re-investigated its interest in establishing alternative sources of REE. Coal has been identified as a source for potential REE. The United States has multiple coal operations in areas such as the Powder River Basin and Appalachia. Recent research in Appalachian coal mines have identified acid mine drainage (AMD) as a potential source of REE. Identification of in-situ coal that could have a potential of holding REE is a way to alternatively mine coal for other process than thermal energy production. Mixed coal could either be shipped to processing facilities or treated on site for similar activities like leaching to extract REE. Modeling of these concentrations could create a reason to selectively handle coal from existing coal mines for use as a secondary product. Block models could concentrate on quality parameters such an ultimate analysis for coal samples to predict areas of suitable in-situ REE bearing coal. This could be a way to revitalize the coal industry that is already struggling.

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3:05 PM

**Separation of Thorium and Uranium from Rare Earth Elements Using Zeolite Adsorption**

D. Talan¹, Q. Huang¹ and R. Honaker²; ¹Mining Engineering, West Virginia University, Morgantown, WV and ²Mining Engineering, University of Kentucky, Lexington, KY

Recently, there has been an increasing interest in coal and coal byproducts being used as feedstock materials for rare earth elements (REEs) production. However, radioactive and hazardous materials, such as thorium and uranium, are typically enriched with the REEs due to isomorphic substitution. Therefore, special attention needs to be paid to the separation process with a focus on successfully removing thorium and uranium from rare earths. In this study, the potential of using zeolite adsorption to remove thorium and uranium from rare earth-bearing leachate solution was investigated. Zeolite was chosen due to the high porosity, high sorption capacity, and a wide variety of its applications in many industries as an adsorbent, ion exchanger or catalysts. To achieve an optimum separation, the effect of various parameters such as the zeolite particle size distribution, feed solution pH, and solid/liquid (S/L) ratio will be examined with respect to adsorption kinetics and isotherms. The final separation results and process selectivity will be presented and discussed in this study.

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3:25 PM

**Utilizing Biooxidation to Facilitate Low-Cost Rare Earth Elements Extraction from Coal-Based Resources and Eliminate Future Acid Mine Drainage**

M. Free¹, A. Noble², M. Leake², L. Allen¹, P. Sarswat¹ and G. Luttrell²; ¹University of Utah, Salt Lake City, UT and ²Virginia Tech, Blacksburg, VA

Coal-based resources such as waste from coal processing often contain significant quantities of rare earth elements. These resources can be recovered through appropriate processing of the coal feed material to produce a waste that is concentrated in rare earth elements. This process can be facilitated using heap leaching with solutions from engineered biooxidation of pyrite naturally found with the coal resource, and the leached REEs subsequently recovered through solvent extraction and precipitation. In order to utilize this opportunity for low cost REE extraction and recovery, this study was designed to demonstrate and improve methods to economically extract, recover, and upgrade the rare earth element (REE) contents through targeted coal pre-treatment, biooxidation, solution conditioning, heap leaching, solvent extraction, and precipitation technologies to produce REE-bearing products in an environmentally friendly way. Utilization of these integrated technologies will enable coal producers to utilize untapped resources to produce revenue and extend resource life while simultaneously reducing future environmental issues and costs as they supply critical domestic REEs.

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3:45 PM

**Modes of Occurrence of Rare Earth Elements in the Calcination Products of Coal and Coal Refuse**

W. Zhang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

The recovery of rare earth elements (REEs) from bituminous coal-related materials typically requires strong acidic and/or basic conditions to achieve satisfactory recovery values. Recent studies found that REE recovery can be significantly increased by calcination under 600-750 °Celsius for two hours. To obtain an in-depth understanding, sequential chemical extraction tests were performed on the raw materials and the calcination products. During calcination, difficult-to-leach RC minerals were converted into rare earth oxides after calcination which provided recovery improvement in the range of 50-60% under weak acidic conditions (e.g., pH 2-3). In addition, the portion of the REEs that were associated with the organic matter were converted to highly leachable metal oxides. Clay minerals, especially kaolinite, dehydrated and disintegrated into thin slices (meta-clay) thereby liberating the rare earth minerals. Overall, the findings indicated excellent potential for improved leachability of the REEs using calcination pretreatment.
Environmental: Abandoned Mine Lands: Where to Go, What to Do

Chairs: D. Williams, Bureau of Land Management, Butte, MT V. McLemore, NMBGMR/NM Tech, Socorro, NM

2:00 PM Introductions

2:05 PM Post-Mining: A Holistic Approach
J. Kretschmann, TH Georg Agricola University, Bochum, Germany

Germany terminated the production of hard coal at the end of 2018. The closure process decided by the federal government in the year 2007 has brought multiple economic, ecological and social challenges for the mining regions. The Research Institute for Post-Mining at TH Georg Agricola University (THGA) in Bochum, Germany, has developed a holistic approach to meet these challenges of the post-coal-mining era. This approach includes four strategic areas of thrust: environmental technology and hydrogeology to avoid and mitigate risks of groundwater contamination, geomonitoring to protect the surface from subsidence effects, industrial heritage engineering to secure and reuse former mine sites, and economic transition of the mining regions to provide a viable future for the next generation of citizens. The THGA Research Institute is aiming to fulfill central requirements of the UN to manage the Earth’s resources in responsible and sustainable ways. THGA plans to be a viable part of a national and international network in the interest of nature along with all stakeholders.

2:25 PM The Future of Good Samaritan Legislation Related to the Legacy of Mining in the United States and the Challenges it poses for our Social License to Operate
J. Collyard, SLR, Lakewood, CO

Is the social license to operate one of, if not the greatest challenge faced when expanding or opening a new mine? The public legacy of mining globally is one of human health and environmental destruction. This legacy is the result of short term vision, a lack of concern for impacts to the natural environment and human health, and a lack of adequate regulations. Fortunately we as an industry have committed to long-term planning, committed to preserving and protecting environmental and human health, and possess an ever evolving set of technical capabilities to execute both. Good Samaritan Legislation may present our greatest opportunity to change the legacy of mining, our public image, and ultimately improve our ability to obtain social licenses to operate. In this presentation I am going to present the history, current state, and potential future of Good Samaritan abandoned mine reclamation regulations. We, stakeholders involved directly or indirectly in the mining community, have the opportunity now, due to the current inadequate state of Good Samaritan legislation in this country (with the exception of Pennsylvania), to help shape this legislation to achieve these goals.

2:45 PM Transforming Abandoned Mining Areas into Energy and Water Storage Facilities
S. Nowosad, A. Hutwalker and O. Langefeld; Institute of Mining, Clausthal University of Technology, Clausthal-Zellerfeld, Germany

The governmental concept for the transition from fossil and nuclear fuel to renewable energy in Germany targets a share of 80% of renewable energy in the German electricity use in 2050. Pumped storage power plants are one of the options to store the fluctuating production of electric energy from wind and solar power plants. The Harz Mountains, with its numerous historic and abandoned underground mines, offers the needed height differences as well as large existing cavities underground, which could be used for pumped storage power plants. Furthermore, due to climate change, there is an increasing number of intense rain events in the last years causing heavy flooding in the foothills with severe damage to the local infrastructure. The presentation shows the holistic approach to cover three challenges in one project: A concept to store water for pumped storage energy plants combined with strategies to capture large volumes of precipitation water to prevent flooding has to be developed. Additionally, as a third pillar this concept should comprise the allocation of clean drinking water for a large commuting area in the northern foothills.

3:05 PM Quantifying Abandoned Mines in the United States
J. Mauk, J. Horton, C. San Juan, G. Schmeda, P. Scott and M. Mullins; U.S. Geological Survey, Denver, CO

The USGS USMIM project is capturing mining-related features from USGS topographic maps. Published results show more than 610,000 point and polygon mine symbolizations from approximately 80,600 topographic maps across 29 states. The database includes 52 feature types; including prospect pits (38%), gravel pits (23%), adits (11%), and mine shafts (8%). Each remaining feature type forms 4% or less of the database. Absolute quantities of mine features can be estimated from the topographic mine symbol data, which may be the most cost- and time-efficient method to determine the relative abundance of abandoned mines in each state.

3:25 PM A Study of Abandoned Mine Lands in New Mexico
N. Harrison¹, V. McLemore² and M. Silva³; ¹Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM; ²New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM and ³Mineral Engineering Department, New Mexico Institute of Mining and Technology, Socorro, NM

Abandoned mines (AML) are lands that were mined and left unreclaimed, where no individual or company has reclamation responsibility, and there is no closure plan in effect. These may consist of excavations, either caved in or sealed, where future mining is not intended. The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) and the Mineral Engineering Department at New Mexico Tech is conducting research to develop a better procedure to inventory and characterize abandoned mines in NM. This inventory was conducted by means of recording field observations, describing soil petrography of composite dump samples, and geochemistry and paste pH of waste rock piles samples. Many of the mine features in the districts examined so far are prospect pits and short adits, but approximately 20-30% have physical hazards (open shafts, adits) and require safeguarding. Most of the waste rock piles surrounding the mine features are suitable for backfill material. Samples from the Silverton area, CO and the Jicarilla district, NM have potential for generating acid and these materials need to be handled as such.

3:45 PM An Effective Bird Deterrent Program at the Anaconda Copper Mine, Nevada
E. Schlenker, E. Morrison and R. Hyatt; Arcadis, Highlands Ranch, CO

The Anaconda Copper Mine (Site) is an abandoned copper mine with highly acidic ponds that are attractive to birds. A bird monitoring and deterrent program was developed and implemented at the Site in 2008 to address potential bird deaths due to pond exposure. The program is dynamic and continually modified with improved deterrents and strategies in response to changes in operations, seasonal weather patterns, and research on new deterrent technologies. As a result, bird deaths have declined. Since 2016 only one bird death has been recorded. Program success is dependent on the use of a variety of active and passive deterrents specifically selected based on pond characteristics and the bird species that frequent the area; daily observation rounds conducted to identify and deter birds quickly; a rigorous bi-annual bird identification and deterrent training program for onsite staff; and Stakeholder engagement and proactive investment in deterrent innovations. The success of the program in reducing and eliminating bird deaths on the Site has strengthened the relationship between agencies and other stakeholders regarding Site operation during ongoing remediation activities.
Development of a new copper deposit near Superior, Arizona, has required Resolution Copper to address the legacy of earlier mining operations, including the abandoned Magma Copper Company smelter (1924–1971). The smelter and its iconic smokestack were long a symbol of Superior and a focus of the community’s mining heritage, but reclamation required the removal of all smelter structures. In 2018, to meet historic preservation guidelines and honor Superior’s history, Resolution hired WestLand Resources to document the smelter in detail. WestLand’s archival research, oral history, and architectural documentation generated an enduring record of the smelter reflecting Resolution’s commitment to Superior.

LESSONS LEARNED FOR ECOLOGICAL RISK ASSESSMENT AT A LEGACY CHROMALLOY PLANT

A. Thatcher, C. Meyer and J. Zodrow; Arcadis U.S., Inc., Broomfield, CO

A baseline ecological risk assessment (EIA) was conducted for an 333-acre site which includes an abandoned ferrochromium alloy processing plant and legacy slag in the eastern US. The EIA for the site included upland and floodplain habitat as well as in-stream aquatic habitat for an adjacent creek which loops around the Site. COPCs include hexavalent chromium, total chromium, and other heavy metals with alkaline pH. There are many lessons learned for this site, specifically regarding metals exposure to ecological receptors and the way in which site-specific information can impact the findings of the BERA. There were three biocriteria studies conducted for the adjacent creek and all three indicated the creek ecosystem was healthy. The lines of evidence converged to indicate there was unlikely risk for receptor exposure to media at the site. The findings of the BERA supported on-going evaluations for remedy and reclamation decisions.

S. O’Mack; WestLand Resources, Tucson, AZ

Documenting the Magma Copper Company Smelter at Superior, Arizona

Development of a new copper deposit near Superior, Arizona, has required Resolution Copper to address the legacy of earlier mining operations, including the abandoned Magma Copper Company smelter (1924–1971). The smelter and its iconic smokestack were long a symbol of Superior and a focus of the community’s mining heritage, but reclamation required the removal of all smelter structures. In 2018, to meet historic preservation guidelines and honor Superior’s history, Resolution hired WestLand Resources to document the smelter in detail. WestLand’s archival research, oral history, and architectural documentation generated an enduring record of the smelter reflecting Resolution’s commitment to Superior.

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Wednesday, February 26

2:00 PM • North 127B

Environmental: Environmental - Integrated Operations and Closure Water Management

Chairs: L. Kirk, Enviromin Inc, Bozeman, MT D. Castendyk, Golder Associates, Denver, CO

2:00 PM

INTRODUCTIONS

2:05 PM

Enhanced Natural Attenuation of Nitrogen Compounds Produced by Cyanide Degradation In Mine Tailings

L. Figueroa; Civil and Environmental Engineering, Colorado School of Mines, Golden, CO

Ammonia and nitrate build up in cyanide heap leach process waters and solid residues and are subject to environmental regulations. Microbial attenuation of ammonia and nitrate of heap leach water and residues is a potentially low cost method to meet environmental goals. Ammonia and nitrate transformations were examined in the laboratory for combinations of heap leach waters, solid residues and environmental conditions. The extent and products of nitrogen transformations varied depending on material sources, environmental conditions and microbial and chemical supplements. Implications on nitrogen management in heap leach waters and solid residues will be discussed.

2:25 PM

Smart Water Management for Mines

V. Bourgier; Veolia Water Technologies, Cary, NC

Water management is increasingly becoming a major concern within the mining industry. Water costs, scarcity and the public’s call for “green” solutions are causing mines to focus on system performance, cost-effectiveness and compliance with process and environmental requirements. Digitalization is the new game-changer. The innovation is the cloud-based platform on which the data can be remotely monitored, controlled and forecasted, in real time and utilized in powerful algorithms to define valuable KPIs, giving instant insight into trends and understanding into equipment and process performance optimization. Data analytics offer many advantages, such as cost savings and risk mitigation in the management of water. Cloud-based platforms allow 24/7 availability, reducing travels to remote mine sites. Predictive maintenance can minimize downtime of water treatment systems. Secondary benefits are peace of mind that the water treatment plant will run smoothly at a higher level of safety, as they will receive notifications to take proactive decisions. The presentation will describe the new smart water management solutions for mines, illustrated with specific examples.

2:45 PM

Evaluation of Water Quality Characteristics for Two Alternative Tailings Management Strategies

A. Haus; Foth Infrastructure and Environment, Lake Elmo, MN

This presentation will compare and contrast two alternative tailings management strategies, highlighting components of geochemical mass balance models, and describing assumptions in water quality prediction for drainage pH. The first design concept included a lined facility with 9 layers of thickened tailings, each separated by lifts of waste rock assumed permeable to oxygen transport. The second design included 3 layers of slurried tailings surrounded by waste rock berms, and assumed less weatherable surface area of tailings. Predicted water quality of effluent from the first model was acidic and metalliferous; the second model predicted nearly neutral drainage.

3:05 PM

Development of Site-Specific Hydrologic Parameters Through Rainfall and Run-off Monitoring

C. Jones and M. Groseelose; Haley & Aldrich, Burlington, MA

Historic mining sites, as well as tailing storage facilities, present specific challenges for the development of hydrologic models to aid in the assessment and design of stormwater management systems. Many hydrologic applications were developed for agricultural and suburban rainfall run-off modeling, not for mining sites. We developed an adaptive monitoring and regulatory approach to assess the effectiveness of the current stormwater management system by monitoring response to precipitation events over three years. Due to site specific challenges, a non-contact flow monitoring system was developed to observe flow in critical watersheds in response to precipitation events. This flow monitoring network was coupled with spatially variable precipitation monitoring stations and water level monitoring in critical management structures to develop a site wide water balance. Site specific hydrologic parameters for the critical watersheds at the site were developed using this observational data to indicate that the existing models were overpredicting rainfall run-off volumes. The outcome saved the client the considerable cost of unnecessary stormwater system capacity upgrades.

3:25 PM

On-Site Rainfall Simulation: A Field Method to Improve Erosional Stability in Reclamation Designs for Mine Waste Facilities and Disturbed Lands

R. Peroro1, E. Howard2 and T. Braun1, 1SRK Consulting (U.S.), Inc., Denver, CO and 2Landloch Pty, South Lake, WA, Australia

Erosion design for mine land reclamation relies a combination of erosion models. These models were primarily developed for agricultural or watershed applications. However, their application to mining is increasing as methods to calibrate and integrate them into mining have developed. On-site rainfall simulation involves the application of simulated rainfall and runoff to test surfaces such as existing mine waste facility slopes or reclaimed areas. It can also be applied to purpose-built surfaces to test the performance of capping options. The data generated are site and material specific and play an important role in the use of erosion models. It enables assessment of the current performance of a mine waste facility slope and performance improvements that are possible by landform design modifications.
Rainfall simulation has been used for many design tasks both within the US and internationally. The results have been validated against measured erosion data for numerous facilities. This paper describes the rainfall simulation method and applied examples.

3:45 PM
Draindown Treatment Using Electricity
P. James; Blue Planet Strategies, Madison, WI

Traditional wastewater treatment of drain down solution is costly and generates large amounts of often hazardous mixed sludge requiring disposal. Selective recovery of residual metals solution and solution neutralization using electricity in place of chemicals to treat drain down solution, raffinates, or bleed streams may be accomplished by new technology. Such treatment generates new revenues and removes common, often major constituents, reducing contaminant loads on downstream traditional water polish treatment, leading to lower treatment costs and less sludge generation. An example electricity based treatment method is discussed and removal of several metals from a representative mixed-metal target stream presented. Projected application to a drain-down scenario is described with potential implementation and economic features considered.

4:05 PM
ARD Source Control; Successful Proof of Principle Testing
J. Gusek¹, p. eger¹, L. Josselyn¹ and T. Clark²; ¹Linkan Engineering, Golden, CO and ²Solfatara Labs, Golden, CO

Effective acid rock drainage (ARD) source control techniques were shown to be effective over 30 years ago, but the lack of consistent, well-documented case studies and application challenges have limited its use. Barite Hill, an EPA superfund site, is a reclaimed open pit gold mine that continues to leach acid and trace metals despite periodic pit lake neutralization and the capping of waste rock stockpiles. Pit lake pH is around 3 with elevated metals; the iron concentration is about 1,600 mg/L and copper is about 90 mg/L. The major source of continued acid input into the pit lake appears to be from the reclaimed waste rock stockpile which contains three distinct zones consisting of unsaturated, transition, and saturated material. Proof of principle ARD source control tests were conducted on a bulk composite waste rock sample from several test pits. Three different test protocols were developed, one for each zone. ARD-inhibitors assessed included sodium lauryl sulfate (SLS), milk, and alkaline amendments alone and in combination. In general, combinations of treatments worked best: SLS/alkalinity for the unsaturated zone, and milk/alkalinity for the transition and saturated zone.

4:25 PM
The Science, Monitoring, Management, and Path Forward for Pit Lakes
S. Taylor; Jacobs, Phoenix, AZ

As mining projects mature and close, owners and regulators have to deal with both legacy and developing pit lakes presenting environmentally challenging water and geochemical issues. This paper presents the state of science and computer modeling used in understanding and predicting pit lake behavior, the state of equipment and techniques used in monitoring pit lakes, and the science and art of interpreting the models and data to make intelligent design choices and then to successfully manage pit lakes. Potential trends and avenues for advancement are discussed.

Wednesday, February 26
Afternoon

2:00 PM • North 127C
Health & Safety: NORA: Health and Safety in Tomorrow’s Mines

Chairs: L. Saperstein, Missouri University of Science and Technology, Nantucket, MA D. Snyder, NIOSH, Pittsburgh, PA M. Malekian, Freeport, Silver City, NM

2:05 PM
Introductions

2:05 PM
AR for Assisting Miners in Low Visibility Conditions of Underground Mine Fires
D. Demirkan, E. Isleyen and S. Duzgun; Mining Engineering, Colorado School of Mines, Golden, CO

Augmented reality (AR) applications are utilized for realistic and immersive safety training scenarios for different industries, including underground mining. AR has great potential in enhancing search and rescue efforts in case of underground mine fires, where visibility is highly reduced due to smoke. The study presents an AR tool that leverages search and rescue operations as well as emergency evacuation in low or no visibility conditions due to smoke in the underground mines. The tool is developed by processing the mine layout data. First, the underground opening is scanned using LIDAR. The point cloud data from LIDAR scans later used to create a surface model for the underground openings. Then, a triangulation model of the underground openings is obtained and stored inside the AR device. This allows miners to visualize underground environment using triangulated meshes and to navigate in the underground environment in low visibility conditions.

2:25 PM
Human-Systems Integration for the Safe Implementation of Automation in Mining
R. Burgess-Limerick; Minerals Industry Safety and Health Centre, The University of Queensland, St Lucia, QLD, Australia

The introduction of automation to mining has considerable potential to improve safety and health by removing people from hazardous situations. However, automation does not remove people from the system - it just changes the tasks they undertake. These new tasks must be designed taking human abilities and limitations into account if the combined system is to function safely and productively. Automation can also introduce new failure modes and, potentially, new hazards. Human-systems integration is a systems engineering process of integrating the domains of staffing, personnel, training, human factors engineering, safety and occupational health into each stage of the systems capability life cycle - needs, requirements, acquisition, service & disposal. This presentation will draw on Australian mining industry examples of automation to explore examples of safety-related issues which may occur during the introduction of automated components in the mining context, and provide guidance on the adoption of human-systems integration methods for the safe implementation of automation in mining.

2:45 PM
Regulation Stagnation How to Modernize MSHA in the Context of Necessary Regulatory Restraints
M. Savit; Husch Blackwell and Predictive Compliance, Denver, CO

Every developed country has some system of mine safety and health regulation. In the United States, that regulatory regime is embodied in the Mine Safety and Health Act or 1977. Safety and Health regulations promulgated pursuant to that statute must comply with constitutional and statutory restraints that govern the creation of all regulations in the U.S. The restraints on how regulations must be promulgated, coupled with the way in which the statute is worded, make the regulation creation process extremely slow and resource intensive. Because of that, many regulations are obsolescent and the regulatory framework has become an impediment to the use of improved technology as it pertains both to mining systems, but also as it
pertains to the safety and health of those systems. This paper proposes a method for incorporating evolving technology into the MSHA regulations using a process envisioned by the Act, but currently used primarily for other purposes.

3:05 PM
Assessment of the Market for Electronic Technology in U.S. Mines
T. LaTourrette; RAND Corporation, Santa Monica, CA

Mine operators are increasingly seeing a need to automate their operations using sensors and a vast array of electronic technologies. The MINER Act of 2006 required mine operators to develop accident response plans that are technologically feasible, make use of current commercially available technology, and reflect the improvements in mine safety gained from experience under other worker safety and health laws outside of mining. The Act also assigned NIOSH the responsibility to enhance development of new mine safety and health protection technology and technological applications and to expedite the commercial availability and implementation of such technology. All of these directives and initiatives share a common goal: to implement current technology into the mines. This presentation will discuss a RAND Corporation assessment to identify and analyze the barriers to implementing new technology in the market for safety and health protection technology in underground coal mines. The assessment will involve a survey of stakeholder organizations in this market. The plan for the assessment and details of how to participate will be discussed.

3:25 PM
Enabling Telerobotic Technology for Mining in Forbidden Environments
G. Daniko and J. Sattarvand; Mining and Metallurgical Engineering, Univ. of Nevada, Reno, Reno, NV

Future of Mines system design addresses improved safety and health while saving costs for working under ever harder mining conditions with increased depths and higher temperatures. With greater depth and challenging geologic deposits, the mining industry is preparing for operating in hostile, forbidding environments for humans for assuring safety and health at reasonable and feasible cost. Conventional engineering technology for controlling the working environment is no longer the only viable solution for mining. We propose to search for new, disruptively-effective solutions, using telerobotics, ventilation control and energy management technology elements in the future of mines design. We address mining at depth at elevated temperatures and/or in adverse ground conditions; novel mine designs with automation and telerobotics which would minimize worker exposure; and related mine ventilation topics impacting air distribution, control, and cooling technologies, as well as remote monitoring methods. Parallel to the creation of new knowledge, a new type of experts must be educated, specializing in mine planning and design to ensure the future health and safety of workers in mines.

3:45 PM
Using a system Safety Approach to Manage the risks of Automation
G. Topham; Rio Tinto, Perth, WA, Australia

Maximising the lessons from Rail (as well as Aviation and Defence) to ensure the engineering controls to support automation are robust by integrating functional safety, safety in design, and Human Factors.

4:05 PM
Panel Discussion of Future Activities of the NORA Mining Sector Council
D. Snyder; NIOSH, Pittsburgh, PA

Led by the authors, the panel will engage the audience in a discussion of the potential future activities of the NORA mining sector council. The Council seeks to facilitate the most important research, understand the most effective intervention strategies, and learn how to implement those strategies to achieve sustained improvements in workplace practice. The Council strives to fulfill these goals through information sharing, partnerships, and enhancing dissemination and implementation of evidence-based practices. Thus there is a broad range of potential activity limited only by the interests and resources of the Council.

Wednesday, February 26
Afternoon

2:00 PM • North 125B
Industrial Minerals & Aggregates: Health & Safety in Industrial Minerals & Aggregates
Chairs: P. Roghanchi, New Mexico Institute of Mining and Technology, Socorro, NM S. Amini, Virginia Tech, Blacksburg, VA

2:05 PM
NIOSH S-Pillar Software Applications: From Concerns to Redesign
M. Murphy, G. Esterhuizen and B. Staker; Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Pittsburgh, PA

In 2009, The National Institute for Occupational Safety and Health (NIOSH) released the first set of guidelines to assist in the stable design for room- and pillar workings in underground stone mines. The guidelines were based on observations of actual pillar performance in 34 different underground operations in the Eastern and Midwestern United States. In 2011 NIOSH released S-Pillar, a software that incorporates the NIOSH-developed guidelines and calculation methods to analyze pillar layouts and the effects of modifications to the pillar layout. Since the initial release of these guidelines, a variety of scenarios have been studied through S-Pillar and this paper will review common applications of the software through case studies. This paper will also review recent changes in the software, including a 2018 update to the database of observed pillar failures where pillar sizes and estimated pillar stresses for several cases were updated based on new information collected since the original release. The paper will also discuss limitations of the software and current NIOSH research to address the limitations.

2:25 PM
Investigating the Effect of Thermal Radiation on the Thermal Comfort of Surface Miners
A. Rasti and P. Roghanchi; Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM

Performing work in a hot and humid environment can alter the thermoregulation process of a mine worker, which can significantly affect the health, safety, and productivity of workers. Mean radiant temperature is due to the principle that the net exchange of radiant energy between two objects is proportional to their emissivity multiply by their temperature difference to the power of four. In an underground mine, radiative heat transfer can be ignored due to the fact that mine mean radiant temperature is not far from the air ambient temperature. On the surface, however, thermal radiation is considered to be the major heat load that contributes to the heat stress and strain of mine workers. This study aimed to conduct a series of sensitivity analysis to investigate the effect of mean radiant temperature on the thermal comfort of surface mine workers. The analyses were carried out based on the maximum allowable exposure time that workers can be exposed to heat at various metabolic rates. The results of the study demonstrate that the mean radiant temperature has a strong influence on the thermal comfort of the surface mine workers.

2:45 PM
Evaluation of Engineering Controls at Bagging Operations to Reduce Exposures to Respirable Crystalline Silica Dust
A. Louk1, J. Patt’s1, E. Haas2 and A. Cecala1; 1'Dust, Ventilation, and Toxic Substances, CDC/NIOSH, Pittsburgh, PA; and 2'Human Factors, CDC/NIOSH, Pittsburgh, PA

The National Institute for Occupational Safety and Health (NIOSH) and the former U.S. Bureau of Mines (USBM) have given a significant effort over the past four decades in researching and developing engineering controls and interventions to reduce mine workers’ dust exposures during the bagging and palletizing of industrial minerals. Workers performing manual bagging and palletizing of 50- to 100-pound bags typically have some of the highest dust exposures of all workers
at mining and mineral processing operations. Some difficulties with controlling dust in work processes associated with bagging and palletizing are the wide range of equipment used and the variety of bag types. This paper will present the findings of a recent case study that was conducted at three different industrial sand operations to identify the current types of bagging and palletizing technology being used and to assess the effectiveness of implemented engineering controls in reducing workers’ exposures to respirable dust.

3:05 PM
Taking the Hazard Out of Industrial Minerals – Using Science to Achieve GHS & HazCom 2012 Reclassification
R. Lee and D. Ewert; Product Stewardship, RJ Lee Group, Monroeville, PA

While most companies understand the fundamentals of hazard classification and creation of an effective SDS, few go beyond the basics of raw ingredient profiling. Because of this, most mined mineral and aggregate materials receive hazard classifications, whether due to the presence of crystalline silica or as a result of some benign metals content – resulting in significant handling and transportation costs. To overcome these consequences, attendees will be introduced to the final mixture approach RJ Lee Group developed to successfully achieve GHS and HazCom 2012 declasification across a wide range of mined mineral products. Employing scientifically validated methods for toxicological characterization, this discussion details a host of internationally accepted techniques used to achieve Hazard Inversion. This highly regarded presentation intermingles GHS classification exemptions with real-world examples of the hazard reclassification process. In addition to engaging audience members in reconsidering their own As-Presented product scenarios, participants will be provided with a wide-range of recent case studies and real-world examples of Hazard Inversion success.

3:25 PM
Capability of the Airstream Helmet for Protecting Mine Workers from Diesel Particulate Matter
J. Noll, T. Lee, S. Vanderlice and T. Barone; NIOSH, Pittsburgh, Pa, United States Minor Outlying Islands

Diesel particulate matter (DPM) is considered a carcinogen to humans by the International Agency on Research on Cancer, and mine workers have some of the highest exposures. Therefore, mines have been developing engineering and administrative control strategies for reducing DPM exposures. In addition to these types of controls, a respirator program is used at some mines to provide further protection. However, sometimes mine workers may feel restricted by the use of a half mask respirator or inconvenienced by the requirement to remove facial hair. Another option which may be more appealing is an airstream helmet, which provides filtered air in the breathing zone of the worker. The airstream helmet does not restrict breathing, provides some cooling, and does not require the worker to be clean shaven to work properly. This study investigated how effective this helmet may be for reducing DPM exposures, and with a HEPA filter, it was found to reduce DPM exposures by over 99% in static conditions by both mass and particle counting data. The airstream helmet can be an important part of a mine’s DPM control plan because it can supply clean air in the worker’s breathing zone.

3:45 PM
A Comparison of the Modeling and Field Tests for a Fog-Based DPM Exhaust After-Treatment
J. Tabor¹, E. Sarver¹ and J. Saylor²; ¹Virginia Tech, Blacksburg, VA and ²Clemson, Clemson, SC

Diesel Particulate Matter (DPM) represents an occupational health risk for many underground miners. Particularly in large-opening mines, sufficient ventilation to mitigate high DPM concentrations can be challenging. Based on promising results from laboratory studies, an exhaust after-treatment has been envisioned that uses fog drops to scavenge DPM. Unlike diesel particulate filters, which are very efficient at removing relatively large DPM from the exhaust, the fog treatment has the potential to target the finest particles more efficiently. Here, we highlight results of recent field testing and present an analytical model to explain the major mechanisms driving DPM removal by the fog treatment.

4:05 PM
Towards Challenges in Automating the Loading Phenomenon Using Artificially Intelligent Neural Networks
J. Sattarvand and M. Salimov; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV

Despite all advances in the technology of autonomous systems in the mining and construction industry, developments in the field of loading automation are still lagging behind the other areas. Autonomous loading implies a fully automated scenario in which automated excavating machines load by themselves from a heap of bulk material and deliver to the dumping site. This research work studies on the development of artificial intelligence methods in the automation of loading equipment. The purpose of this study is to train an artificial neural network by monitoring expert operator of loading equipment and create a numerical model from collected data. In order to develop a simulation environment for testing and adjusting the parameters, a small robot with electric actuators was built and equipped with positioning and force feedback sensors. It also summarizes the latest technological advances of loading automation which are currently available in the mining industry. Finally, future research opportunities related to automation of loading equipment are highlighted.

4:25 PM
Forty Years of NIOSH/USBM Developed Control Technology to Reduce Respirable Dust Exposures to Miners in Industrial Minerals Processing Operations
A. Cecala, J. Patts, A. Lout, E. Haas and J. Colinet; CDC NIOSH, Pittsburgh, PA

Worker exposure to dust—especially respirable crystalline silica dust—has long been a paramount concern for the health of our nation’s miners and other workers. The inhalation of respirable crystalline silica can lead to silicosis, a disabling and potentially fatal lung disease, as well as also having other major health consequences. One main area of focus for the Pittsburgh Mining Research Division of the National Institute for Occupational Safety and Health and the former U.S. Bureau of Mines has been to conduct research to lower exposure to respirable crystalline silica dust and other respirable dusts and contaminants in mining operations. This report provides an overview of a number of effective engineering control technologies and interventions that have been developed and tested over the past 40 years and which have been demonstrated to be successful in lowering mine workers’ respirable dust exposures at metal/nonmetal mines and mills, and specifically industrial mineral processing operations.

Wednesday, February 26
2:00 PM • North 222A
Mining & Exploration: Geosciences: Geology: Numerical Modeling
Chair: M. Waqas, The University of Arizona, Tucson, AZ

2:00 PM
Introductions

2:05 PM
Numerical Study on the Mechanical Relationship between Point Load Test and Uniaxial Compression Test with PFC3D
Q. Shi, Y. XUE and B. MISHRA; Mining Engineering, West Virginia University, Morgantown, WV

Uniaxial compressive strength (UCS) is regularly used in the design of underground structures. The tests are expensive and time-consuming. Instead, point load test (PLT) is widely used as an alternative method to determine the UCS due to its simple testing machine and procedure. UCS is estimated from the PLT index through conversion factors based on the rock types. Numerous studies have determined the conversion factors for different rock types. However, little attention is paid to the mechanism correlating these two parameters and the influence of mechanical properties on the conversion factor. In this study, a series of laboratory
tests, including UCS test and PLT, was conducted on sandstone specimens, based on which the micro-mechanical parameters calibration and failure processes analysis were conducted. Furthermore, the mechanical properties, including stiffness, tensile strength, cohesion and friction angle, was varied sequentially in the numerical simulations of PLT and UCS test and the relationship between mechanical properties and conversion factor was determined. The findings from this study can help improve the application of PLT in determining UCS.

2:25 PM
Prediction of Brittle Rock Mechanical Behavior using a Semi-Deterministic Bonded Block Model
C. Contreras Inga, E. Holley and G. Walton; Mining Engineering, Colorado School of Mines, Golden, CO
Discontinuum models are frequently used to predict brittle failure mechanisms, which are relevant to the design of excavations in hard rocks. Previously published laboratory-scale simulations show a notable effect of the grain structure on the micro-mechanical behavior of the intact rock. In such simulations, the grain structure is usually approximated through a series of bonded blocks, where the grains are represented using polyhedral or Voronoi blocks. Voronoi block assemblies provide reasonable approximations of true grain structures, but the random nature of the assemblies adds uncertainty to the contact micro-properties obtained from the calibration process, potentially leading to incorrect estimations of the rock strength. This study assessed how a more realistic depiction of the grain structure could provide more realistic predictions of brittle rock mechanical behavior. A semi-deterministic Bonded Block Model of a core specimen of granite with a fully characterized 3D grain structure was developed to test the quality of agreement between the actual macro-mechanical behavior of the specimen and that predicted using the Bonded Block Model.

2:45 PM
Application of Numerical Modeling using FLAC3D at a Dipping Limestone Mine
M. Sears, B. Slaker and G. Rashed; CDC/NIOSH, Pittsburgh, PA
Ground falls represent a significant hazard in the nation’s underground stone, sand, and gravel (SSG) mines. Researchers from the National Institute for Occupational Safety and Health (NIOSH) are currently conducting detailed investigations into the complex loading conditions at underground SSG mines operating in challenging conditions. This paper presents the application of numerical modeling to analyze pillar and roof stability at a dipping underground limestone mine. A validated numerical model was used to explore the potential behavior of the pillars and roof as loading conditions change, overburden depth increases, and the mining sequence is altered. Results from the numerical modeling indicate that roof displacement will potentially double as the depth increases from 400 m to 760 m and the corresponding horizontal stress increases by 28%. Consequently, as the pillar load increases due to the change in stress, the average safety factor of the pillars is projected to decrease by as much as 20%.

3:05 PM
The Open Mining Format - Version 2.0
J. Kato*, M. Gabbitus* and D. Sarguinetti*; *Global Mining Guidelines Group, Vancouver, BC, Canada; *Deswik, Brisbane, QLD, Australia and *Micromine, Perth, WA, Australia
The first version of the Open Mining Format (OMF) was released by GMG in 2017 as a proof of concept to demonstrate that it is possible to have a file interchange format that allows for easy transfer of data between different mining software packages. In follow-up to that GMG did a survey of over 250 mining professionals to determine the data exchange pain points in their daily work. This presentation will discuss those findings and show how the newly released OMF 2.0 addresses them and allows for seamless transfer of block models and other critical data between applications.

3:25 PM
A Parametric Study for the Effect of Dip on Stone Mine Pillar Stability Using a Simplified Model Geometry
G. Rashed, B. Slaker, M. Sears and M. Murphy; NIOSH, Pittsburgh, PA
In this study, a parametric study was conducted using FLAC3D numerical models to examine the impact of oblique loading, generated from seam dip, on the strength and the failure propagation pattern of a stone pillar using two simplified geometry types. In type-1 the side walls of the pillars were assumed to be perpendicular to the roof and the floor, while in type-2 the side walls of pillars were assumed to be vertical. The complex pillar geometry in dipping mines was frequently modeled using these two geometries. To capture a complete picture of the effect of seam dip on pillar stability, the modeled width-to-height (w/h) ratio of the pillars, in-situ stress field, and pillars roof/floor interfaces were systematically varied to account for the potential distribution of values for these parameters across the underground stone mines in United States. Results from the numerical modeling indicate that dipping pillars have reduced strength compared to horizontal pillars. Also, an asymmetric failure propagation pattern could be obtained depending on an interaction between the w/h ratio, seam dip, in-situ stresses, and pillar geometry.

3:45 PM
Application of Conditional Simulation for Optimizing Drill Hole Spacing in Mineral Exploration Projects
A. Samal; GeoGlobal LLC, Riverton, UT
Geoscientific processes and techniques (mapping, sampling, geochemistry, and geophysics) are key in generating data that are crucial for success in mineral exploration. Planning for exploration drill holes and post drilling assessment of success provides key decision making information for advanced exploration projects. Geological software tools are capable of integrating data and information from various sources which are useful in the digital reconstruction of the mineralization. Conditional simulation techniques help in adding value through optimizing the exploration drill-hole spacing for improving confidence on estimated mineral resources in future exploration programs. A proper application of CS with a strong emphasis on the geology of the mineralization can provide results that will help to target the drill hole intercept points where more data would improve the confidence in the continuity of mineralization. In this presentation, anonymous project data is used to demonstrate how conditional simulation can help the exploration projects in assessing risks and opportunities associated with mineral resource estimation.

4:05 PM
Improving Haul Road Structural Design by Incorporating Truck Dynamic Forces Generated During Haulage
B. Kansake and S. Frimpong; Mining and Nuclear Engineering Department, Missouri University of Science and Technology, Rolla, MO
Haul road beds are typically designed using the maximum static truck tire force based on the truck’s loaded weight distributions. During haulage, however, dynamic loads generated significantly exceed the static loads. This can lead to poor designs, resulting in frequent road damage and poor truck performance. We developed a novel numerical model based on multibody dynamics for accurately estimating truck dynamic forces during haulage. The model was validated using data from an open-pit mine. The results show that dynamic loads can be 2.86 times the static loads. Ignoring this leads to poor structural designs in weak formations employing ultra-large trucks.

3:45 PM
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2:00 PM • North 222B
Mining & Exploration: Innovation & Technology: Equipment Technology Innovations

Chair: A. Howse, MacLean Engineering, Rossland, BC, Canada

2:00 PM
Introductions

2:05 PM
Battery Powered Vehicles that are Moving Us Towards Zero Emission Mining
K. Petersson; Epiroc Rock Drills, Orebro, Narke, Sweden

Episroc is leading the change towards sustainability in mining through battery electric, zero-emission equipment. Electrification in underground mining has been gaining more popularity and as an alternative of buying batteries, Episroc is offering a completely new concept called BaaS – Batteries as a service where the customer does not have to own the battery but instead only pay for the usage. The reasons for moving away from fossil fuels are many and battery electric equipment allows a mine to unlock a number of benefits: improved health and safety, reduced greenhouse gas emissions and decreased operating costs.

2:25 PM
Measuring the Energy Efficiency of Battery Electric Vehicles in Underground Mining
S. Lister; Marketing, CIM, Collingwood, ON, Canada

Since the inception of its full-fleet electrification program in 2016, the Ontario-based MacLean Engineering has designed, manufactured, sold and commissioned a total of 20 battery electric vehicles (BEVs). The single largest BEV fleet for MacLean is currently at Newmont Goldcorp’s Borden Gold project in northern Ontario, where 15 MacLean battery powered, production support mining vehicles are working underground. MacLean has also conducted a series of trials at underground mines in Canada. From these underground trials, performance data was gathered that has allowed MacLean to demonstrate that with a minimal amount of in-cycle opportunity charging, a high-tramming MacLean unit such as a boom truck can deliver full-shift operation. The other interesting outcome of MacLean’s BEV trialing has been the measuring of energy usage for equal work for the same MacLean unit – one battery electric, one diesel. The MacLean presentation at SME 2020 will focus on providing case study data of the real-world application of a zero-DPM, low-heat battery drive propulsion system, engineered for life underground, where the key is to connect the battery cycle to the mining cycle.

2:45 PM
The Drive to a Zero Emission Surface Mining Fleet
P. Wan; Teck Resources, Trail, BC, Canada

Mobile mining equipment are one of the largest sources of Greenhouse Gas (GHG) emissions in the mining industry. As companies increasingly look to reduce the carbon footprint of the mining industry, a range of innovative strategies are being evaluated to drive towards a zero emission fleet – more specifically, to produce zero GHG emissions from material movement processes. Given the expected long timeline to electrifying large mining equipment, mining companies must explore other avenues to electrification including trolley assist. In Pit Crushing & Conveying and specific use cases for electrification of mining equipment. This presentation will provide an overview of some of the technology considerations and options being explored by Teck Resources.

3:05 PM
Thermal Runaway Pressures of Iron Phosphate Lithium-Ion Cells as a Function of Free Space within Sealed Enclosures
T. Dubaniewicz, I. Zlochower, T. Barone and L. Yuan; NIOSH Pittsburgh Mining Research Division, Pittsburgh, PA

Mining vehicle manufacturers are developing lithium-ion (Li-ion) battery electric vehicles as an alternative to diesel-powered vehicles. In gassy underground mines, explosion-proof (XP) enclosures are commonly used to enclose electrical ignition sources to prevent propagation of an internal methane (CH4)-air explosion to a surrounding explosive atmosphere. Li-ion batteries can create pressurized explosions within sealed enclosures due to thermal runaway (TR). NIOSH researchers measured TR pressures of iron phosphate Li-ion (LFP) cells as a function of free space within sealed enclosures and observed an inverse power relationship. A well confined cell produced 293 bar (4260 psia), far exceeding minimum pressure containment specifications for conventional XP enclosures. Results indicate that a sufficient amount of free space surrounding LFP cells can reduce TR pressures to levels below that expected for CH4-air mixtures.

3:25 PM
Hydraulic Optimization: Validated Technology to Reduce Fuel Burn and Increase Productivity
D. Tegtmeier; Global Mining, Caterpillar, Dortmund, Germany

Validated under varying conditions, Caterpillar’s Next Generation of Hydraulic Mining Shovels utilize hydraulic optimization to increase productivity, reduce fuel burn, and extend engine life. Initially launched with the 6020B, hydraulic optimization is key to providing the lowest cost per tonne. This paper provides a brief overview of the technology and details the results of pilot testing.

3:45 PM
Clean, Safe, Profitable: The Case for Innovative, Digital, Autonomous Haulage
J. Fisk; Rail-Veyor Technologies Global Inc, Sudbury, ON, Canada

Case Study #1: Mine Manager in Quebec needed to find a way to stay in operation. A deeper mineral deposit was found but couldn’t be accessed profitably with standard haulage systems. Research found an innovative haulage system would eliminate the need for trucks which in turn would provide cleaner air quality and a safer environment. In addition, the digitally autonomous aspect meant fewer people in dangerous situations. The mine has been able to haul over 2 million tonnes of ore to date. Case Study #2: Mine Manager in Missouri was looking for an innovative way to move ore using existing above ground railroad tracks. Research found an innovative haulage system that could possibly use the tracks. Upon further consultation, it was determined that the rail-based system could be installed underground in existing drifts and eliminate the need to bring the ore to the surface, truck it over public roads, and take the ore underground again for processing. Each train eliminated ten truckloads per hour. Rough numbers show that previous haulage costs were $3/ton compared to a current cost around $0.25/ton.
2:00 PM • North 225A
Mining & Exploration: Operations: Operational Enhancements: Pushing forward
Chair: A. Ramos, Hecla, Coeur d'Alene, ID

2:05 PM
Introductions

2:25 PM
Long Hole Open Stoping Mining Method Sub-Level Height Determination
I. Traore; Mining, Mining, Kabali, Congo (the Democratic Republic of the)
Defining the sub-level height is one of the most important step of the design process of a long hole open stoping mining method. The long hole open stoping sub-level height when not adequately defined result in major geotechnical stability issue, higher dilution and ore losses, and subsequent consequences on the overall value of the project. In this paper, a robust iterative and comparative approach of defining the sub-level spacing is proposed for determining the sub-level spacing. Its consists of the designing the mine for a series of level spacing, follow by the stoping design and mining sequencing. In addition, geotechnical stability assessment is performed, geological confidence level evaluated, mine production, and drilling and blasting method reviewed. Furthermore, the mine production schedule and the net present value evaluated for various scenario. Even though increasing the sub level height reduced the overall mine development cost and capital expenditure, its impact required holistic assessment from geological, geotechnical, production drilling and blasting and mine scheduling perspective in order to define the sub-level spacing.

2:45 PM
Performance Optimization in Underground Mining Combining Strategic Development and Wireless Technologies
K. Pacheco Hague; Mining and Geologcal Engineering, SME Tucson Chapter, Tucson, AZ
Currently there is a trend to maximize the productivity of underground operations by implementing diverse technologies. However, the difference between manufacturers and the purpose of their functions becomes a major challenge for a smooth integration. At the same time, the design of excavations may represent a significant improvement in the effort of optimizing the overall performance. A proposed solution for implementing a mine plan that includes near-real time performance measurements, workstation design with tracking systems, the integration of diverse production areas, and analysis of results is presented to obtain measurable outcomes and help reducing operational delays while increasing safety for operators. Keywords: optimization, near-real time, performance, productivity, safety, wireless, underground, network, workstation design, tracking system.

3:05 PM
Real-time Production Monitoring System in Underground Grasberg Block Cave Mine
H. Sid Obturtar and A. Staahan; Engineering, PT Freeport Indonesia, Jakarta, Jakarta, Indonesia
PT Freeport Indonesia’s Grasberg Block Cave (GBC) will be located within the mine at an elevation of almost 3,000 m above sea level on the west side of the island of Papua, Indonesia. The developing block cave is beneath the active Grasberg Open Pit and will produce 160,000 t of ore per day from extraction level to the underground crushing plants. The design entails 2,400 drawpoints in a 700,000 m² footprint. Due to the scale of operations, effective and efficient data control is essential to ensure optimal cave management. To support production, Grasberg Block Cave Underground Mine utilizes manual and remote LHD integrated into a centralized monitoring system. On-board and off-board infrastructure will be installed to record and monitor all production data from the production units. This paper provides an overview of real-time production data monitoring system’s technical complexities and the associated support systems interactions. The paper also highlights the software and hardware infrastructure installation challenges of this project.

3:25 PM
Application of Unmanned Aerial Vehicles (UAVs) in Underground Mines
J. Shahmoradi, M. Hassanalil, A. Mirzaeinia and P. Roghanchi; Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM
Monitoring of inaccessible areas in underground mines requires a certified person to inspect the stability of the open cavern areas and conduct air quality test necessary to protect the safety of the miners. Exploration and monitoring of hazardous areas in an underground environment can expose the miners to potential hazards. This study aims to discuss the possibility of development of a remote monitoring system to inspect the inaccessible areas in underground mines using a fully autonomous encased drone. Application of drones in underground coal mines can be challenging. Harsh underground environments pose many obstacles to flying drones. The confined space, reduced visibility, air velocity, dust concentration, and lack of wireless communication system makes it extremely difficult for an operator to fly a drone underground. Furthermore, access to unreachable and dangerous locations in underground mines is practically impossible for a drone operator. This study offers solutions to above-mentioned challenges by proposing design an autonomous spherical micro-drone for underground mines safety inspection.

3:45 PM
Developing Open Data Sets for AI in the Mining Sector
M. O’Brien; Global Mining Guidelines Group, Baldwins, WA, Australia
The Global Mining Guidelines’s AI in Mining Working Group has begun to work collaboratively with its stakeholders to build the case for open data sets specific to the mining sector for AI development. GMG believes this will enhance the ability to build meaningful solutions for the industry by providing typical data relating to assets or operations for training and testing of models, and allowing all parties to have the ability to benchmark solutions and research more effectively.
A New Option for Managing Hydrometallurgical Iron Contamination

P. James; Blue Planet Strategies, Madison, WI

Problematic and common iron contamination in hydrometallurgical metal production leach and process streams degrades production processes and raises incremental production costs. Traditional management increases costly chemical consumption with bleeding losing valuable stream components and additives while direct compensation by overdosing also increases expensive additive consumption costs. Application of direct and selective iron removal in a compact solid form using electricity rather than chemicals is examined. Benefits and challenges are discussed along with representative results for treating representative copper leach solutions and production and economic implications for selected hydrometallurgical processing applications.

Reducing Crud Formation by the use of ACORGA® CR60 PLS Additive - Piloting and Commercial Results

J. DURAZO AGRAMON1, T. Mele2, J. Gill2 and L. Moya2; 1METAL EXTRACTION PRODUCTS, SOLVAY, Gilbert, AZ and 2Lisbon Valley Mining, La Sal, UT

Solvent extraction (SX) circuits around the world face countless challenges that impact the operational and financial performance of the operation. Crud formation is one of the most common issues as it is created naturally from the contact between organic, aqueous, air, and solid phases in the mixers. Crud accumulates afterwards in the settlers and impacts the physical performance. A conventional approach to limit accumulation is consistent crud pumping from the settlers, requiring specialized equipment such as filter presses, centrifuges, large holding tanks and pumps. Inefficient crud removal from the system and excessive crud built-up results in an increase in operational costs and in some cases requires lower PLS flow reducing copper production. ACORGA® CR60 has previously shown positive results preventing crud formation at various copper operations in Asia, Africa, South America and North America. Reducing crud formation with the additive has proven to reduce crud movement, impurity transfer and maintain higher PLS flow, which allows for higher production. This paper will discuss commercial performance at a North America operation after successful pilot trials.

Morenci SX Plant Optimization to Maximize Extractions & Minimize Bleed/Entrainments

S. Gosewade; Morenci Hydromet - SX, PMI Morenci, Thatcher, AZ

Morenci SX plant PLS flows and Lbs. distribution was not completely optimized for current operating conditions. Due to there being limited documented parameters for each plant, it was decided to start a plant performance optimization. Modeling was conducted to arrive at an optimized flow and Lbs. distribution to maximize extractions for all four SX plants at Morenci. This helped in distributing copper Lbs. equivalently based on each plant/settler capability. A plant performance matrix was designed for daily KPI dashboard to aid in daily process optimization and accountability. Morenci Technical services chose organic entrainments at Stargo and stripper aqueous entrainment at Metcalf as “low hanging fruits”.

An Extractant Blend for Separation Performance Enhancement Associated with Rare Earth Element Purification using Solvent Extraction

A. Chandra, J. Werner and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

The most common process used for concentrating and purifying rare earth elements (REEs) from pregnant leach solutions is solvent extraction (SX). To quantify and model SX separation performance, distribution coefficients associated with the major elements including the contaminant elements are compared and used to determine the number of separation stages needed to achieve the desired purity level. The efficiency and number of stages are highly dependent on a number of factors including extractant type, concentration, organic-to-aqueous ratio and the pH value of the aqueous phase. One of the most widely used extractants for REE separation is di-2-ethylhexyl phosphoric acid (DEHPA). In this study, the impact of additives on the distribution coefficients of the individual REEs and the separation factors between individual REEs was analyzed. A particular blend of extractants was identified which provided enhanced separation performance. The findings will be presented which will include the results that led to identifying the blend concentrations needed to maximize separation efficiency.

Effect of Electrowinning Parameters On Cathode Pre-Stripping

E. Gebrehiwot, S. Sandoval and W. Sanders; Freeport-McMoRan, Vail, AZ

Copper electrowinning involves stainless steel blanks or copper starter sheets as the cathode electrode in the process. Stainless steel blanks are for the most part preferred to copper starter sheets due to their rigidity, high production suitability, lower operating cost, easy maintenance, affordability and durability. Operational mismanagement, electrolyte impurities, improper maintenance and age are well known factors that can hinder stainless steel cathode performance. Pre-stripping of the cathode deposit, which is the separation of the deposit from the blank before the cathode is processed in the tankhouse stripping machine, is one aspect of poor stainless steel blank performance. The effect of operating parameters and electrolyte additives on cathode pre-stripping not has been systematically evaluated. Based on a commercial-scale pilot plant study, this paper presents the effect of operating parameters and additives on cathode pre-stripping. The presentation includes testing methodology, experimental approach, conclusions and findings. In addition, best practice recommendations are presented for consideration.
examined by molecular dynamics simulations and density functional theory, for the first time. The simulation results improve our fundamental understanding of these trithiocarbonate depressants in the flotation of molybdenite from chalcopyrite, and thus contribute to the possible replacement of NaHS with a trithiocarbonate depressant for safer conditions in flotation plant operations.

2:25 PM
Chalcopyrite Depression with Orfom® D8 of Cu-Mo Bulk Concentrates During Trial Runs
S. Tinbilla1, R. LaDouceur1, D. Laney2, A. Das3 and C. Young4; 1Met & Mat Eng, MT Tech, Butte, MT and 2Chevron-Phillip Chemical Co., Tucson, AZ
Orfom® D8 is a low carbon-chain trithiocarbonate (NaOOCCH2SSNa) with anionic functional groups at both ends. It was tested as an organic depressant in the differential flotation of molybdenite from chalcopyrite in the presence of either sodium isopropyl xanthate (SIPX) or potassium ethyl xanthate (KEX). Results show that it depresses chalcopyrite while molybdenite remains floatable. Orfom® D8 appears to adsorb specifically on chalcopyrite through its thiol (CSS-) functional group via both chemisorption and metal complexation. Chalcopyrite becomes hydrophobic because the carbonate (COO-) functional group protrudes from the surface. Because Orfom® D8 does not appear to bond with molybdenite, it remains hydrophobic. Orfom® D8 solution chemistry is detailed via its pKa constants and decomposition products. Results of successful trial runs of a large pilot plant facility are illustrated along with the economics comparing Orfom® D8 to traditional inorganic NaSH depressant.

2:45 PM
A New Paradigm for Metal Activation in Zinc Flotation
J. Jankolovits and T. Bhamthani; Mining Solutions, Solvay, Stamford, CT
Metal activation is practiced universally in zinc sulfide flotation circuits. While widely regarded as an absolute necessity for zinc flotation, multiple empirical studies contentiously claim zinc flotation without metal activation is feasible. The understanding of zinc flotation is complicated by iron sulfide activation, a phenomenon reported to reduce zinc concentrate grades. Nevertheless, significant zinc upgrading is achieved in plants that use high CuSO4 dosages. This work presents single mineral and batch flotation studies that challenge the prevailing understanding of activation and selectivity in zinc sulfide flotation. The zinc circuit flotation response is driven by the interplay between metal activation, mineral surface chemistry, and froth zone physics. The results highlight the need to holistically consider complex systems behavior to assess mechanisms and pathways in mineral flotation.

3:05 PM
Improved Frother Formulations for Sulfide Ore Flotation
A. Peljovas and C. Andress; OMS, Clariant Corporation, Tucson, AZ
Frothers are important flotation reagents that play many roles in the flotation process. A froth that is too stable would increase the amount of entrainment of gangue minerals and a froth phase that is too weak would not provide the optimum conditions to float coarser particles. Each operation has an optimum froth stability that ensures minimal gangue minerals are recovered with the maximum recovery of valuable minerals. Frothers and collectors may show synergistic effects that may provide an overall improvement in the froth flotation process. The proper selection of frother reagents is a crucial aspect to obtaining the highest recoveries and grades for a given reagent scheme at an operation. The main frother chemistries include alcohols, alkyloxy type, polyglycols, or mixtures of these different reagents. Newly developed novel frother reagents can increase recoveries at an operation. These innovative frother reagents contain specialized additives that were selected to provide more favorable flotation conditions that increase the overall flotation performance of a mining operation.

3:25 PM
Effect and Mechanism of Octanol in Cassiterite Flotation using Benzoylhydroxamic Acid as a Collector
L. Sun, Y. Cao, Z. Gao, W. Sun, Y. Hu and H. Han; School of Minerals Processing and Bio-engineering, Central South University, Changsha, Hunan, China
The neutral molecule has already aroused wide public concern in the mineral flotation field. Past research indicated that as one of the neutral molecule, octanol does not have collecting ability for cassiterite, while its presence as an auxiliary collector in cassiterite flotation can reduce the requirement of collector concentration. However, there are still a few studied explain the reaction mechanism. Through micro flotation tests, adsorption tests, and AFM, this article demonstrated that the addition of octanol could make the surface conformation changing from bilayer to monomolecular layer. This change makes the cassiterite surface homogeneous and slippery, thus enhancing its floatability.

3:45 PM
Fundamentals and Applications of Green Modifiers for Froth Flotation
M. Fan; Eriez Flotation Division, Eriez Manufacturing Co., Erie, PA
Low-cost environmentally friendly green froth flotation modifiers of plant origin such as tannins, guai gum, starch and carboxymethyl cellulose (CMC), etc., have been used in flotation of some sulfide and non-sulfide minerals. Certain green modifiers may be used as dispersants, flocculents, depressants or activators. The function of green modifiers in froth flotation highly depends on their molecular composition, flotation slurry chemistry and hydrodynamic conditions, etc. Some performances of green modifiers are better at a lower turbulence of slurry flows in flotation columns than in conventional flotation cells. This paper will discuss the fundamentals, current applications and potential new applications of green modifiers in valuable minerals and the unwanted gangue minerals flotation.

4:05 PM
Selective Recovery of Rare Earth Elements through Foam Flotation using Conventional and Greener Reagents
S. Shetty1, I. Chernyshova2 and S. Ponnurangam3; 1Chemical and Petroleum Engineering, University of Calgary, Calgary, AB, Canada and 2INU, Trondheim, Norway
Froth-treatment tailings from the oil sands recovery process in Alberta, Canada contain heavy minerals such as titania and zircon at 10-15 wt%, rare-earth elements (REEs) including Ce, La, Nd, Sm, Pr, Gd and Y at 0.3-0.5 wt%, and residual bitumen at 2-5 wt%. A major bottleneck for recovering these valuable minerals from the tailings is the lack of an economically feasible process that can achieve high mineral grades. These valuable REE elements are currently dumped into tailing ponds. The conventional process for REE extraction from ore bodies uses toxic and expensive reagents in froth flotation and solvent extraction and hence will compound an already complicated tailings management problem. In this talk, we present our work on foam flotation where we have achieved selective separation of REE elements (Ce, La, Gd, and Y). The foam flotation route presented in this work for separating REE ions/minerals using green surfactants is an environmentally benign approach with low material and energy costs.

4:25 PM
Improving Hematite Flootation by Partially Replacing Amine with Brothers
N. Parra Alvarez1, V. Claremboux1 and S. Kwatra2; 1Chemical Engineering, Graduate Student, Houghton, MI and 2Chemical Engineering, Professor, Houghton, MI
During the reverse froth flotation of hematite, silica can be recovered by true flotation and entrainment. Hematite is recovered only by entrainment, and thus by controlling entrainment the final product can be improved. Entrainment occurs when hematite and silica particles are trapped by bubbles and recovered in the froth layer. In order to decrease entrainment, it is important to control the bubble size and froth stability by changing the frother dosage. However, in reverse flotation the typical amine collectors used are also being used as the primary frother because they have significant frother properties, making it more difficult to use separate frothers to control the flotation. This study investigates the addition of a non-collecting frother to partially substitute the amine in the process and control the frothing and collecting characteristics separately. It was found that at an iron grade of 63.8%, the iron recovery increased by 4.84% with the addition of a Methyl Isobutyl Carbinol (MIBC) frother. Based on these results, further investigation was conducted to determine what type of frother and amine work best for this purpose.
Apatite and other phosphate gangue minerals can inhibit uranium leaching by requiring leaching under intense conditions to effectively extract the contained uranium. Brannerite, UTi₂O₆ is the most common of the refractory uranium minerals and WA, Australia.

Uranium Leaching
Mitigation of the Effects of Phosphate Gangue on the Past Time.

Moreover, changes within the structure of the ore vein due to the leaching and first paper discusses the impact of fracturing and borehole distance for bioleaching. Established at TU Freiberg and has started to leach an ore vein in April 2018. This for raw materials. Hence, after five years of development, the BHMZ has been managing sulfide ores, especially through their processing, has always been a sophisticated procedure, when the costs need to be low. Since the 1980’s bioleaching is used in primary and secondary processing plants for sulfides. Especially heap leaching has become a quite common method in the recent years with high extraction rates. Therefore bioleaching with in-situ borehole leaching have been combined to develop a new mining technology for narrow vein sulfide ore deposits in the context of a research project at TU Freiberg, Germany. Such narrow and complex deposits that include sulfides are expected to become significantly important in the future due to limited reserves and high demand for raw materials. Hence, after five years of development, the BHMZ has been established at TU Freiberg and has started to leach an ore vein in April 2018. This paper discusses the impact of fracturing and borehole distance for bioleaching. Moreover, changes within the structure of the ore vein due to the leaching and first monitoring approaches are presented. Finally, the effectiveness of bioleaching is discussed by means of the amount of dissolved metals produced in correlation to the past time.

2:45 PM
Mitigation of the Effects of Phosphate Gangue on Uranium Leaching
R. Gilligan and A. Nikolski; Engineering and Energy, Murdoch University, Perth, WA, Australia
Brannerite, UTi₂O₆ is the most common of the refractory uranium minerals and requires leaching under intense conditions to effectively extract the contained uranium. Brannerite is often found together with apatite in metasomatic deposits. Apatite and other phosphate gangue minerals can inhibit uranium leaching by generating phosphate ions which interfere with the reactions between acid ferric sulfate and uranium minerals. As part of a detailed fundamental study on the leaching reaction mechanisms for brannerite, selected tests were conducted with addition of 10 g/L fluorapatite to identify conditions where the negative effects of phosphate are reduced. Leaching was carried out for 5 hrs with 2.8 g/L Fe³⁺ as Fe₂(SO₄)₃ with 25-100 g/L H₂SO₄ and at temperatures between 25 and 96 °C. The results from these tests were compared to leaching performed with 2.8 g/L Fe³⁺ as FeC₂ and 36 g/L HCl. In the sulfate system, the effect of phosphate was weakest at the highest acid concentration (100 g/L H₂SO₄). In the chloride system, phosphate did not suppress uranium extraction, suggesting that HCl leaching could be a viable alternative for the leaching of high-phosphate refractory uranium ores.

3:05 PM
A Novel Method for the Preparation of Surface Modified White Carbon Black using Vanadiumbearing Shale Leaching Residue
S. Wang and S. Bao; Wuhan University of Technology, Wuhan, Hubei, China
Abstract: Hydrophobic and highly dispersed white carbon black (WCB) particles were prepared using the vanadium-bearing shale leaching residue (VSLR) as the raw material and sodium dodecyl sulfate (SDS) as a surface modifier. The VSLR firstly was leached by alkali and then was dispersed under ultrasonic field with wet surface modification. Ultrasound is introduced to hinder the agglomeration of the WCB particles during the surface modification process although SDS is soluble in water. This study investigated the effects of modifier dosage, ultrasonic power, ultrasonic time, and pH value on the modified products. Thermogravimetric (TG) analysis was used for the quantitative measurement of the organic groups on WCB particles. Brunauer–Emmett–Teller procedure (BET) and Fourier transform-infrared (FT-IR) were also used to investigate the specific surface area and the functional groups on WCB particles, respectively. The transmission electron microscope (TEM) results showed a better dispersed state of WCB particles after surface modification. Keywords: White carbon black; Surface modification; Ultrasonic dispersion; Residue

3:25 PM
Recovery of Scandium from Hydrometallurgical Residue of Nickel Laterite Processing: Organic Acid Leaching and Impurity Removal
R. Alorro¹, D. Iban₁, S. Jones₁, A. Chan², Z. Ichlas³ and G. Lee⁴; ¹IWA School fo Mines, Curtin University, Kalgoorlie, WA, Australia; ²University of Santo Tomas, Manila, Philippines and ³Research Institute of Industrial Science and Technology, Gwangyang City, Korea (the Republic of)
Scandium and its compound have found extensive applications in optical, electronic, aeronautical, and transportation industries due to its lightweight and high strength. Due to the absence of a sustainable source of scandium, a long-term and low-cost supply of the rare earth element is required to meet its growing demand. Nickel laterite ores have been identified as one of the most promising sources of scandium, where the metal can be recovered as a by-product. This paper presents outcomes of a study conducted at the WA School of Mines in partnership with Research Institute of Industrial Science and Technology (South Korea) on the recovery of Sc from a hydrometallurgical residue of nickel laterite processing. The residue containing 0.015% Sc with Fe, Cr, and Al as the major impurities, was leached using a suite of organic acids. Oxalic acid was found to be effective in solubilising Sc from the residue, with more than 94% recovery achieved at optimum conditions. However, the leaching also generated solutions containing high concentrations of Fe, Al, Mg, and Cr. Precipitation and solvent extraction methods were investigated to remove the impurities and selectively separate Sc.

3:45 PM
Ammonium Chloride Leaching and Recovery of Pb, Cu, Co, Ni, Zn and Ag from a Bulk Concentrate
B. Tanda; exploration & development, the doe run company, Viburnum, MO
Doe run has demonstrated that its Flubor Technology can selectively leach Pb from a bulk concentrate containing Pb, Cu, Co, Zn, and Ag as pay metals. This presentation will show the potential of ammonium chloride solution to leach target minerals from the Flubor residue with limited dissolution of target minerals. It also highlights the use of solvent extraction to recover Cu, Co, Zn and Ni from pregnant leach solution.
The Use of Cement during Grinding for Reduction of Cyanide Consumption During Agitated Leaching of a Gold Ore Containing Reactive Sulfide Minerals

J. McPartland, McClelland Laboratories, Inc., Sparks, NV

Agitated cyanidation testing on samples from the Peak gold/silver project in AK, USA, revealed the presence of reactive iron-sulfide minerals, which cause excessively high cyanide consumptions during leaching. During laboratory testing to optimize leaching conditions, tests were conducted to evaluate the effectiveness of adding cement to the ore before grinding and leaching for reduction of cyanide consumption. Those tests indicated that a substantial reduction (>50%) in cyanide consumption was achieved by adding cement during grinding. Select samples were used for more detailed testing, using statistical experimental design, to better evaluate and optimize cement additions for reduction of cyanide consumption. Mineralogical characterization was also undertaken to better understand the mechanism for the observed reduction in cyanide consumption.