General Manager & Principal Geomechanics Engineer

Expertise	Numerical Modeling, Mechanical Engineering, Mining Engineering
Education	Ph.D. (Engineering Systems, Mechanical Specialty), 2011 Colorado School of Mines
	M.Sc. (Renewable Energy Science, Geothermal), 2010 University of Iceland / University of Akureyri (Iceland)
	B.S. (Mechanical Engineering), 2005 Monterrey Institute of Technology and Higher Education, Mexico
Professional Affiliations	Member: American Rock Mechanics Association

Professional Experience

	ITASCA Minneapolis
2020 – Present	General Manager
2020 – Present	Principal Geomechanics Engineer
2017 – 2019	Senior Geomechanics Engineer
2011 – 2017	Geomechanics Engineer
	National Renewable Energy Laboratory, Golden, Colorado
2010 – 2011	Intern
	Colorado School of Mines
2005 – 2011	Research Assistant
December 2008	Teaching Assistant
	Monterrey Institute of Technology and Higher Education, Mexico
2002 – 2004	Teaching Assistant / Director, ProEngineer CAD Laboratory

Project Experience

Stope Stability and Potential for Mining-Induced Seismicity: Performed stability assessments of a Sub-Level Open Stoping mine with paste backfill based on two potential sequences using two in-situ stress regimes. The goal was to understand the potential for stope overbreak and general instability, as well as to assess the strainburst and fault-slip potential due to redistribution of stresses as mining progresses.

Assessment of Underground Mining Method and Infrastructure Stability: A transition from open pit to underground mining was evaluated. The results of an extensive point load test campaign along with laboratory data were used to construct and test synthetic rock masses using the Bonded Block Modeling (BBM) approach to characterize the strengths of the different lithological units. The study elucidated that the massive and competent nature of the Kimberlite did not allow for natural caving to be exploited as a mining method; therefore, Longhole Shrinkage (LHS) Stoping was selected as the mining method to exploit the orebody. Several LHS stoping sequences were evaluated and optimized to improve stability and minimize overbreak. Sill pillars were analyzed and sized to ensure drill drive survivability. Additionally, the crown pillar was evaluated and sized to maximize Kimberlite extraction while delaying dilution entry before it was blasted. Alternative infrastructure locations were evaluated to assess stability risks. This included geomechanical assessment of ramps as well as production and ventilation shafts.

Stability Assessment and Subsidence Potential: A mine-wide stability assessment was performed for the extension of a mine that historically employed a series of different mining methods across the deposit, including top-down Open Hole Stoping, Sub-level Shrinkage, Sub-level Open Stoping without backfill, Sub-level Cave and large Open Stoping. One of the objectives of this study was to understand the potential for ongoing caving of unfilled legacy stopes and to evaluate the potential for subsidence and disturbance to surface and underground infrastructure. Some legacy stopes were mined with a blasthole open stoping approach and, later, partially filled using unconsolidated rockfill. A study was also conducted to analyze a new part of the mine where stoping is planned, allowing us to provide recommendations on sizing, sequencing, and backfilling strategy for specific stopes to reduce their instability potential and protect nearby infrastructure.

Evaluation of Ground Support Design: The ground support design at Eleonore Mine in Quebec was studied through drift-scale Bonded Block Model (BBM) analyses to understand and back-analyze past failures, as well as to evaluate the adequacy of the current ground support design to handle future conditions as mining advances in different mining horizons. Sub-horizontal, shallow-dipping, undulated joints were explicitly modeled and found to strongly impact overall performance. Using the hybrid bolt logic in *3DEC*, two ground support systems were explicitly modeled: 1) rockbolts, super swellex, and cables; and 2) D-bolts.

Effect of Shear Stresses on Pillar Stability: Performed a back-analysis of pillar failures at Troy Mine (Montana) with the objective of using this experience to make forward predictions on pillar stability in the nearby Montanore deposit, which lies in a similar geomechanical setting. At Troy Mine, a progression of pillar failures in areas within the Middle Quartzite of the Revett formation led to the observed surface subsidence. The Troy Mine experience was used to understand the level of stresses and failure mechanism leading to the collapse of some pillars in the North Orebody in order to estimate pillar strength in quartzite beds within Troy's mountainous terrain. The learnings from this study were then applied to evaluate the local pillar factor of safety against shear at Montanore. This was used to inform the selection of local extraction ratios within the different beds at Montanore to achieve a pre-defined factor of safety.

Assessment of Surface Subsidence Potential Associated with Caving: Developed a series of numerical models to evaluate caveability and potential surface subsidence associated with caving at a mine in Arizona for operational risk and environmental impact assessment. In order to assess potential risk with the design analyzed, the sensitivity of subsidence predictions to rock mass strength, fault strength, and in-situ stress regime were examined under a given production schedule. The potential building damage and subsidence were evaluated directly in the numerical model through the evaluation of horizontal strain and angular distortion at ground surface.

Assessment of the Surface Subsidence Potential Associated with Caving of a Pre-existing Historic Mine: An evaluation of the current subsidence extent along with the general condition and character of the rock mass both underground and in the vicinity of the craters at a historic mine in Mexico was performed. During the site visit, surface cracks were mapped in the vicinity of a crater resulting from historic mining to provide a more accurate representation of the current fracture limit that needed to be captured by the numerical model before any forward prediction was made. A numerical model was developed to simulate the current conditions at the mine site. The emergent results obtained by this numerical model were in close agreement with observations of current conditions made on site. Therefore, this numerical model was deemed representative of the current conditions and used in a forward analysis by incorporating the proposed mining sequence and tonnages to elucidate the potential impact caving would have on ground subsidence and building damage.

Mechanical Behavior of Excavations in Creep Susceptible Ground: Developed a series of numerical models focused on understanding the creep behavior of a shaft excavated in artificially frozen ground. Successfully completed a back-analysis of the shaft deformation in order to determine a set of constitutive properties that produced a response consistent with measured field data, including liner pressure evolution and ground closure. A forward analysis using the calibrated model was done to evaluate the creep behavior under a series of what-if scenarios to aid in constraining the future design.

Stability Assessment of the MSP-Airport Light Rail Station due to Parking Ramp Extension: Constructed and calibrated a 3D distinct element method model using *3DEC* to evaluate the potential impacts the expansion of a parking ramp on top of the MSP airport LRT station would have on the roof behavior. The model explicitly considered the different limestone bedding planes and mapped joint sets. The model was calibrated based on surface settlement data (surface survey points, inclinometers, and extensometers) from the original construction.

Development of a Bonded-Block Model for the Study of Brittle Rock Masses: A bonded-block model was developed using *Kubrix* and *3DEC* to model heavily veined massive rock masses. The model consisted of a collection of tetrahedral blocks bonded at their contacts. Contact strength was informed via a cumulative distribution of tensile strength based on point-load test data to represent a network of veins and intact rock. Sub-contacts were allowed to break when their shear or tensile strength is reached, mimicking the initiation and propagation/coalescence of fractures. The model has been used to study the mechanical response dependence of brittle rock masses to confinement at and near a tunnel wall, as well as the unidirectional bulking associated with spalling. This approach has also been used to study primary fragmentation of rock masses in a cave mine.

Caveability and Spatial Distribution of Primary Fragmentation in a Cave Mine: A series of numerical models were developed to make design recommendations based on the potential caveability of a sublevel cave mine taking into account the spatial variability of the rock mass strength. Rock mass properties were derived using a bonded-block model (BBM) approach based on point-load test data. By combining the induced stresses at failure through the cave with the results of a fragmentation analysis based on BBM, the spatial distribution of primary fragmentation through the cave was estimated. The potential ground surface subsidence was also evaluated.

Underground Excavation Stability Subjected to Challenging Stress Environments: Developed a series of numerical models to provide recommendations for geomechanical mine design employing a combination of Sublevel Longhole Open Stoping (LHS) and Post-Pillar Cut and Fill (PPC&F). Recommendations included basic design criteria (pillar, stope, and panel dimensions), as well as regional barrier-pillar and crown-pillar dimensions, sequencing, and set back of infrastructure and access. The design was constrained by an analysis of potential ground surface subsidence based on extensile horizontal strain and angular distortion. Necessary backfill strength requirements were also investigated.

Seam Inclination Effect on Design in a Longwall Mine: The effect on pillar design, gateroad, rib, roof, and floor stability in a longwall mine was evaluated. A back-analysis of a longwalled area was successfully completed in order to determine material properties and numerical model parameters that produced a response consistent with that observed at the mine site. A forward analysis was completed using this calibrated model and data set to evaluate a series of longwall face-advance scenarios.