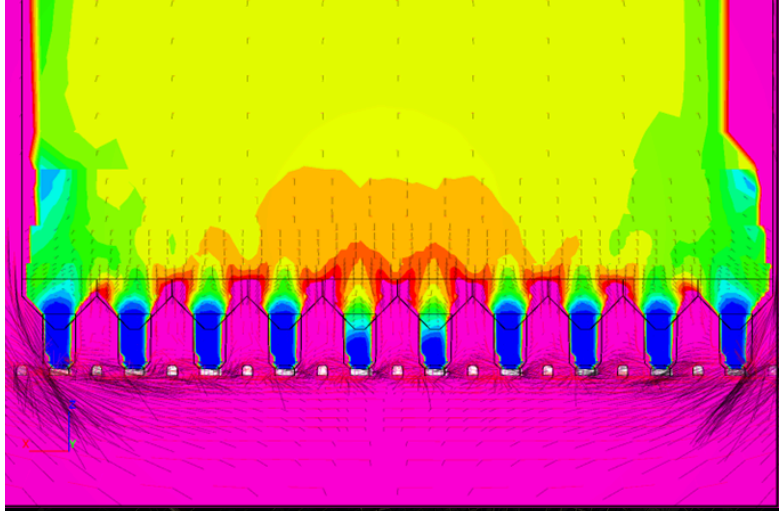
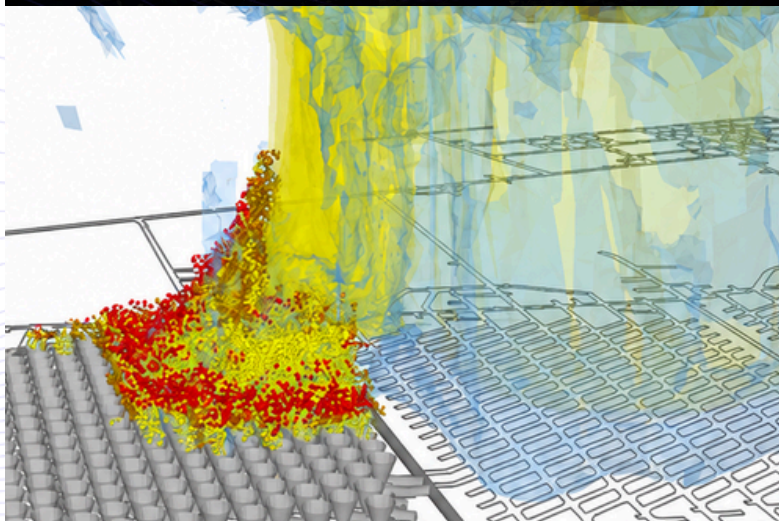
ITASCA

Services in Caving Geomechanics





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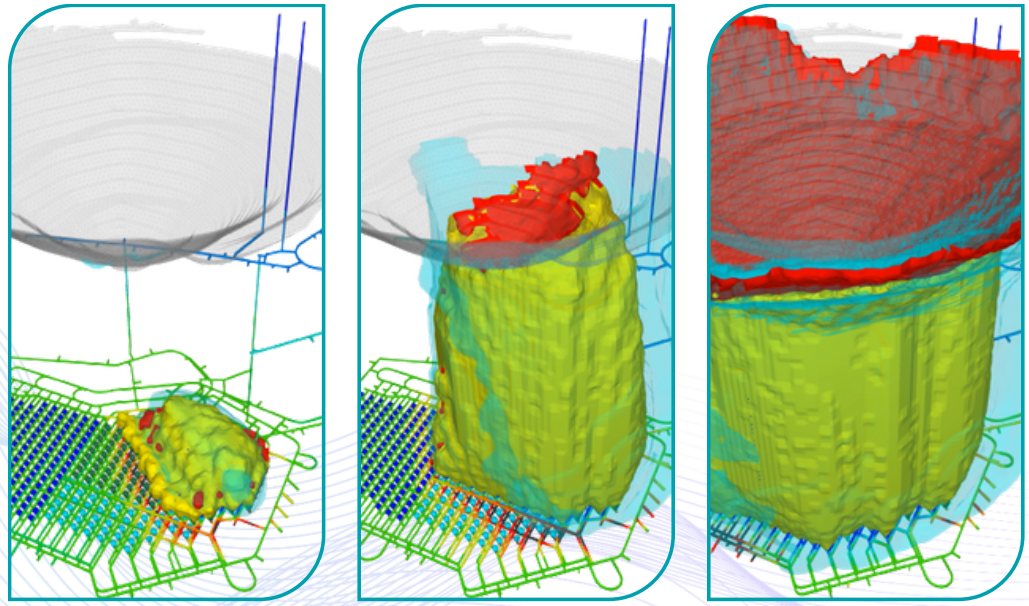
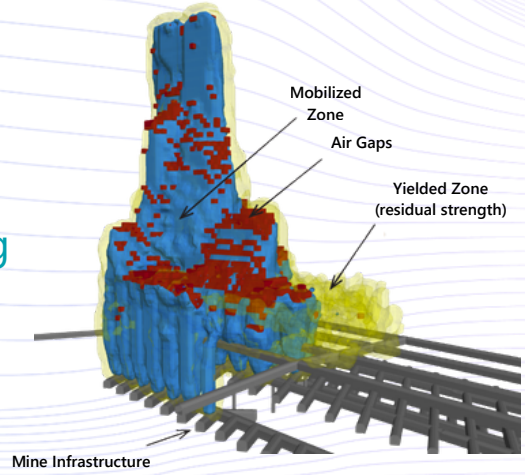
Context

- Caving is a **massive mining method**, well suited for disseminated orebodies, which is being considered for **increasingly deep, larger, stronger and heterogeneous mining projects** around the world.



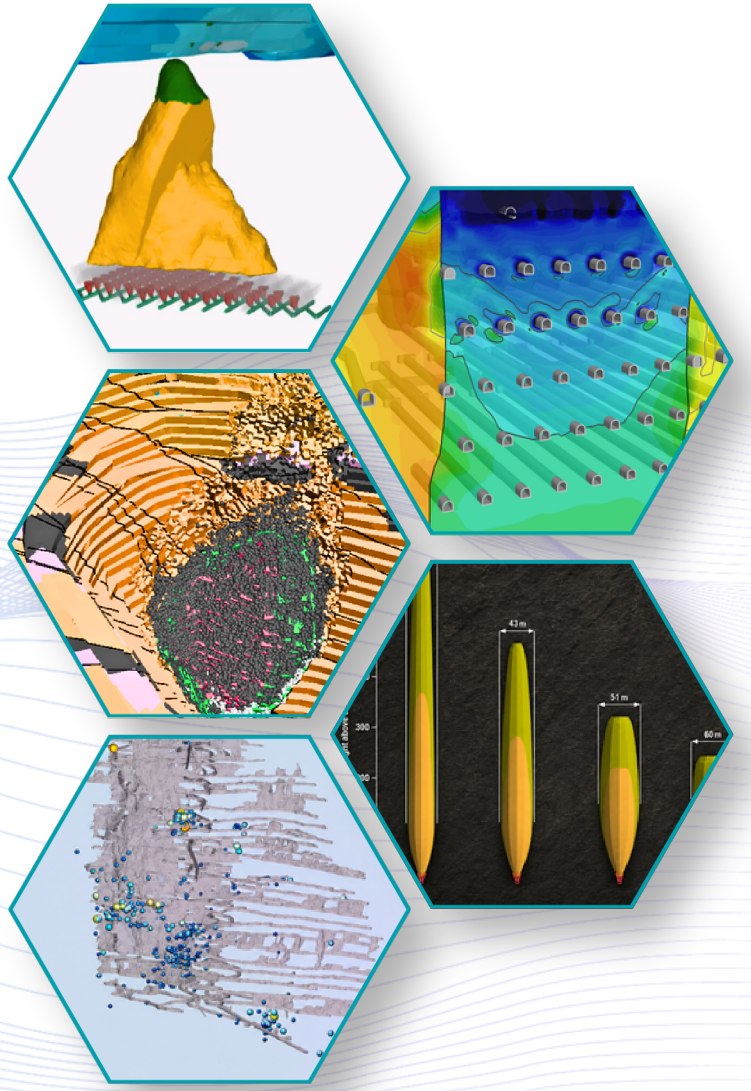
- These challenging conditions increase the risk of stranded reserves in overhangs, cave stalling and air-blasts, infrastructure rehabilitation or loss, and large-scale induced subsidence.

- For many years, ITASCA has been at the **forefront** of cave mine engineering, having **pioneered** the development of industry-leading tools applied at many block, panel, and sub-level caving **operations and projects worldwide**. Our tools and work have been **validated** through direct comparison with observed and predicted **behaviors**.



Our Services

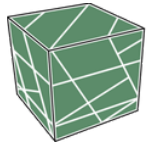
- The **geomechanical** analyses that ITASCA offers are **critical** to understand and predict aspects such as:
  - **Caveability** and mine-scale geomechanics;
  - **Infrastructure stability** and serviceability;
  - Cave **propagation**, **subsidence** and mine–surface interaction;
  - Ore **fragmentation**, flow and **draw** control;
  - **Seismic**, **hydrogeological** and operational **risk** management



Our Tools Make a Difference

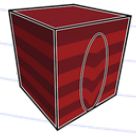
- ITASCA´s extensive experience as software developers has allowed us to **implement all aspects of caving analysis** within a variety of **proprietary tools**, such as
  - **FLAC3D or 3DEC** for 3D stress-strain analysis, including the IMASS constitutive model (Itasca Model for Advanced Strain Softening).
  - **Griddle** for 3D meshing and model construction.
  - **IMAT** for microseismic interpretation.
  - **MassFlow** for gravity flow analysis.
  - **MINEDW** for 3D numerical hydrogeology analysis.
  - **XSite** for hydraulic fracturing analysis.
- We also use third-party codes like **CAVESIM**, based on a cellular automata formulation.


FLAC3D

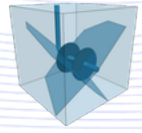

3DEC


Griddle


IMAT


MassFlow


MINEDW


XSite

ITASCA Consulting

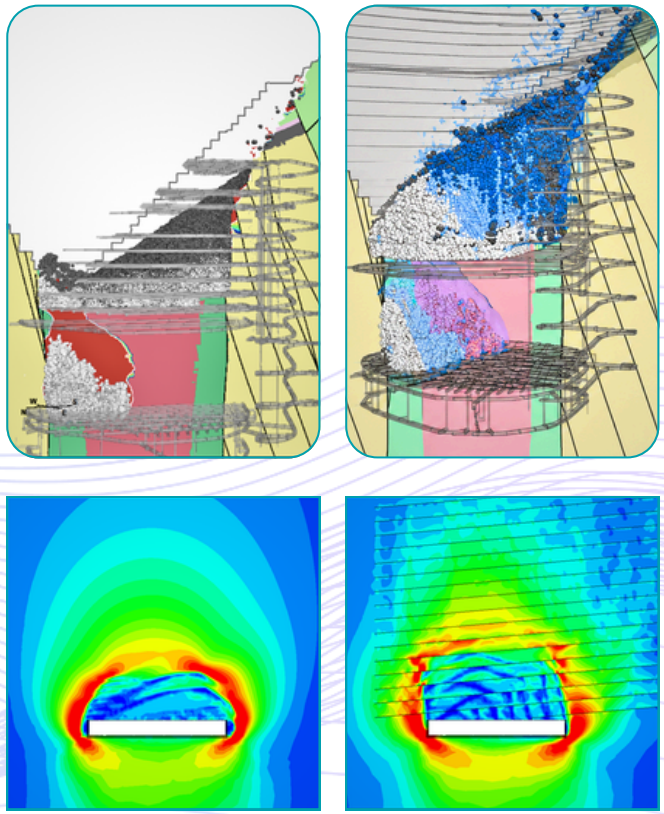
Contents

Caveability and Mine-Scale Geomechanics

The **fundamental questions** in cave mining are whether the orebody **is going to cave** and, if so, **how**? The ability to **forecast cave propagation** by understanding the evolving size and shape of seismogenic, yielded, and mobilized zones associated with caving **is critical to the mine design**. This establishes a **critical hydraulic radius** and sheds light on the **potential for hang-ups** and air gap formation.

Some of the tasks that go along with this subject include:

- Caveability assessments for initiation and propagation of caving, including the role of geological structures, strength degradation and stress paths via **IMASS** constitutive model.
- Development of **3D numerical models** to assess in-situ and induced **stresses**, damage zones, and rock mass **degradation**.
- Analysis of **rock mass preconditioning** via hydraulic fracturing to ensure propagation. Use of codes such as **XSite** to define a preconditioning strategy.
- Prediction of **cave stalling** and/or **intermittent caving** with their undesired side-risk of airblast.
- Identification of **high-risk zones** affecting production levels, infrastructure, and long-term **mine layout**.



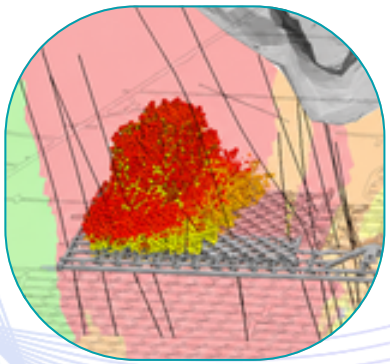
Infrastructure Stability and Serviceability

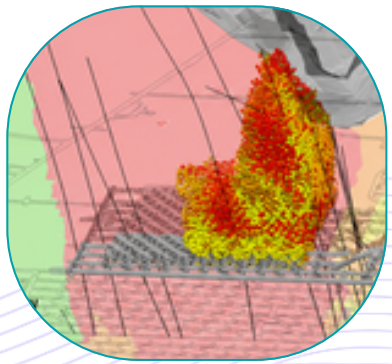
The main goal when designing the **infrastructure** for a caving project is to make sure that it will **remain stable** and serviceable under the entire **lifespan** of its caving activity.

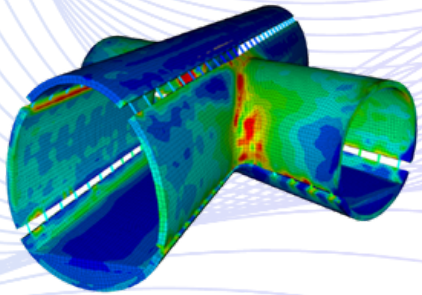
In this regard, **critical factors** usually accounted for in ITASCA´s analysis include: characteristic parameters that define **rock mass behavior**, **structural geology** components such as major faults and rock mass fabric, **footprint shape**, production **draw schedule** and mine site **stress field** characterization.

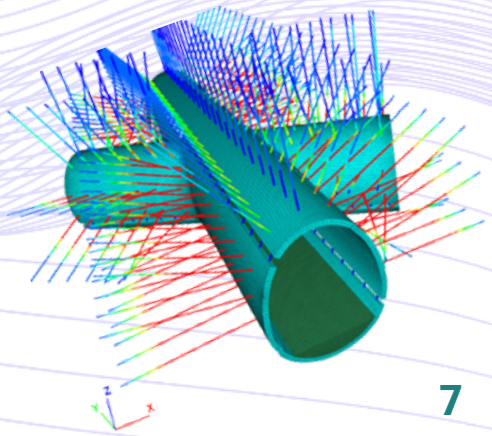
Through the **adequate use of numerical models,** ITASCA addresses the relevant aspects that **control the behavior** of caving infrastructure, such as**:**

- **Optimization** of undercut, drawbell, and extraction-level **layouts**, including pillar designs and spacing.
- Assessment of **sequencing** options (undercut advance, draw strategy) on stability, convergence, and serviceability of drifts and related excavations.
- Ground **support design** and numerical verification for undercut and extraction levels, shafts, and critical excavations.









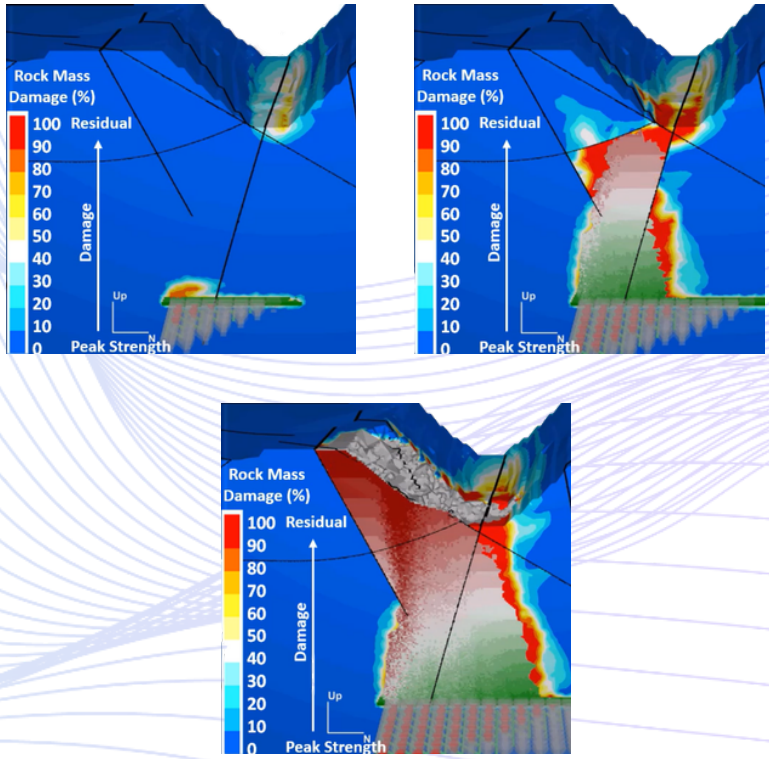
Cave Propagation, Subsidence and Mine–Surface Interaction

Along with the analysis of caving occurrence, it is also important to estimate the **cave propagation rates** and to define the **extent of cave limits**. Mining-induced subsidence is an inevitable artifact of underground ore extraction, to the point that **proper planning** of a cave mining project **must assess the impact of ground movements on surface** buildings and facilities and determine the necessary **stand-off distances** for the siting of mine shafts and other infrastructure.

In the case of **transition from open pit to cave mining**, the subsidence effect can have a **destabilizing** effect on the existing **slopes**, which must be taken into account to plan mining method migration or **coexistence**.

Some of the usual activities involved in this subject are:

- Modelling of **cave back evolution**, cave **propagation**, and **breakthrough** to overlying levels or surface.
- **Subsidence prediction** and impact assessment for **pits**, **infrastructure**, and **environmental** stakeholders.
- **Interaction** studies between **caves** and major **underground excavations** (shafts, access drives, major pillars).



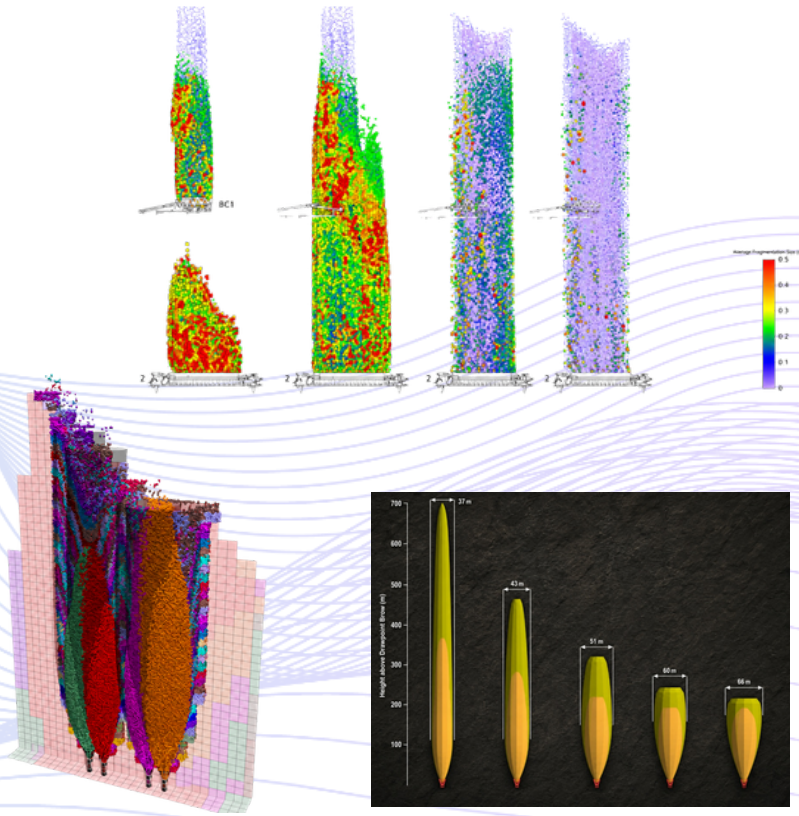
Ore Flow, Fragmentation and Draw Control

Better **understanding of the flow** means better **control of the cave**—leading to **safer**, more efficient, and more **predictable production** in block and panel caving operations.

Through **reliable flow assessment**, ITASCA engineers can anticipate **draw rates**, interaction between **drawpoints**, **dilution** entry, **hang-ups**, air gaps, and uneven material movement. **This supports the correct positioning, spacing, and sequencing of drawpoints**, as well as the design of extraction levels, undercut layouts, and material handling systems.

Our services in this area include:

- Evaluation of **drawpoint spacing** and draw **strategies** to balance recovery, dilution, and geomechanical constraints.
- Support for **draw control systems** through quantitative predictions of **flow patterns**, **mixing**, and **grade** distribution.
- **Primary** and **secondary fragmentation** assessments and **flow modelling** of caved rock (e.g., MassFlow, CAVESIM) to understand draw behavior and hang-up potential.



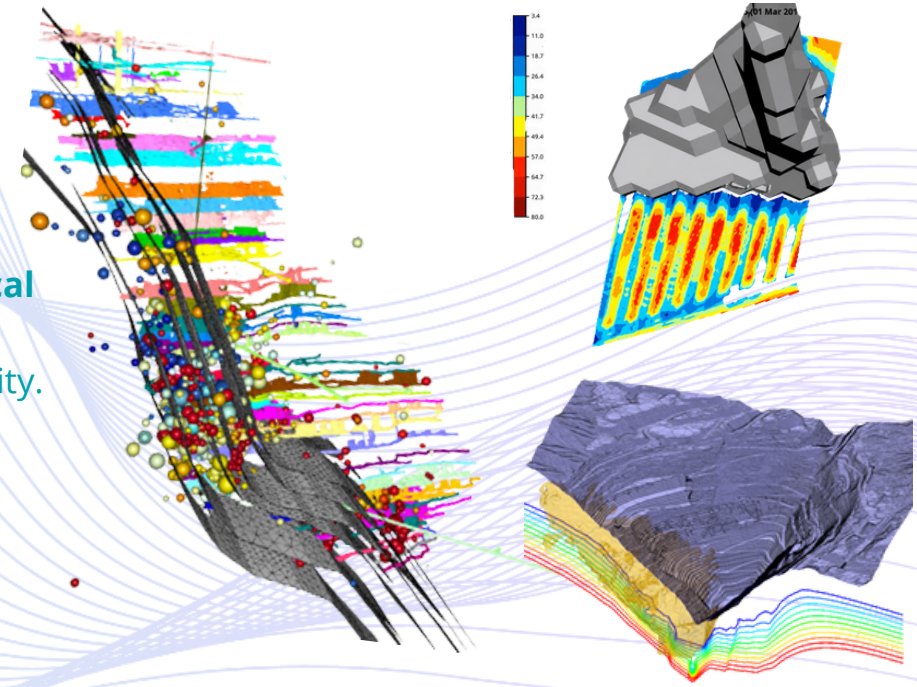
Seismic, Hydrogeological and Operational Risk Management

Integrating seismic, hydrogeological, and monitoring data with numerical models is **essential for managing risk** in cave mining. As the cave propagates, these data help **track** stress changes, pore pressure, deformation, cave growth, subsidence, and infrastructure **response**.

By **linking** real-time observations with calibrated models, ITASCA engineers can **validate** assumptions, **detect** early warning signs, **update** forecasts, and **apply controls** before risks escalate. This improves **safety**, cave **performance**, production **reliability**, and **protection** of critical mine infrastructure.

Some activities in this field include:

- **Microseismic data processing** using tools such as IMAT (**I**tasca **M**ining **A**nalysis **T**oolbox).
- Groundwater and **coupled 3D hydro–geomechanical analyses** to evaluate inflows, depressurization strategies, and their impact on stability and caveability.
- **Monitoring integration and back-analysis** (convergence, microseismicity, production, inflows).
- **independent peer review** of major cave projects.



Key Personnel in Caving Geomechanics

Catalina Álvarez

Dr. Alvarez has extensive experience in numerical modeling related to rock mechanics, within the areas of caving (BC, SLC, etc.) and open-pit mining, considering advanced constitutive models (creep, strain softening, etc.). Her experience also includes the calibration of the regional stress field for operations in Chile, Peru, and the USA. Dr. Alvarez has also led static and dynamic stability analyses for tailings dams, reservoirs, and waste dumps.

Miguel Fuenzalida

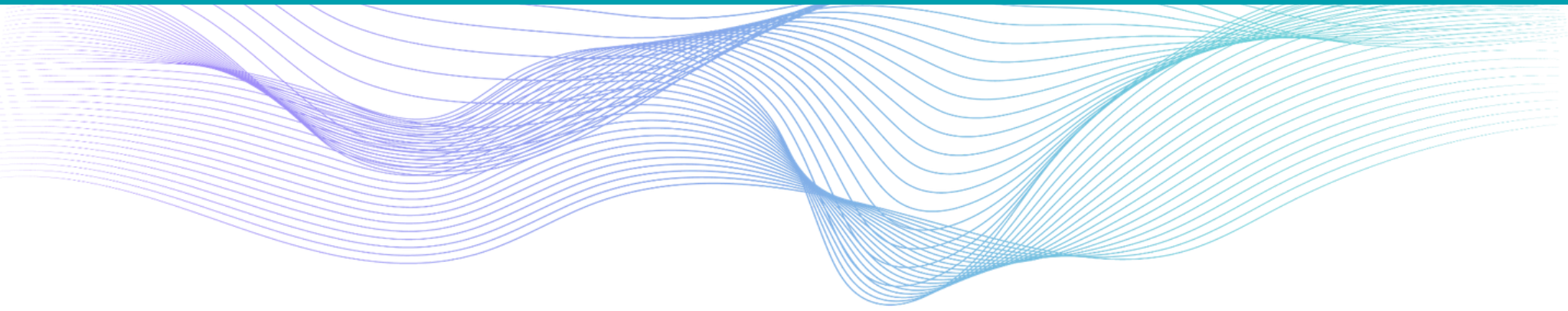
Miguel is a Principal Geomechanics and Mining Engineer with more than 14 years of experience in underground mining. He has deep technical expertise in sublevel, block, and panel caving, supporting worldwide projects from concept through feasibility. He has been actively involved in major international research initiatives, including the Mass Mining Technology (MMT) and Caving2040 consortia.

Loren Lorig

Dr. Lorig has more than 45 years of experience in engineering projects requiring specialized geomechanics consulting. His area of expertise is in the application of numerical models to provide solutions to stability, support and dynamics problems in civil and mining engineering. Currently, Dr. Lorig is working on studies involving transition from open-pit to underground cave mining at sites around the world.

Glenn Sharrock

Dr. Sharrock has over 20 years of experience in the industry, holding various positions in rock mechanics, including Principal Geotechnical Engineer (Newcrest Mining, Netherlands), Rock Mechanics Engineer (Mt. Isa Mines), Senior Geotechnical Consultant, Full Professor of Geotechnical Engineering (UNSW) and Associate Professor of Subsidence Geomechanics (UQ).



ITASCA

"We drive the evolution of engineering geology and geosciences to improve the world, collaboratively developing innovative solutions for challenging problems"

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