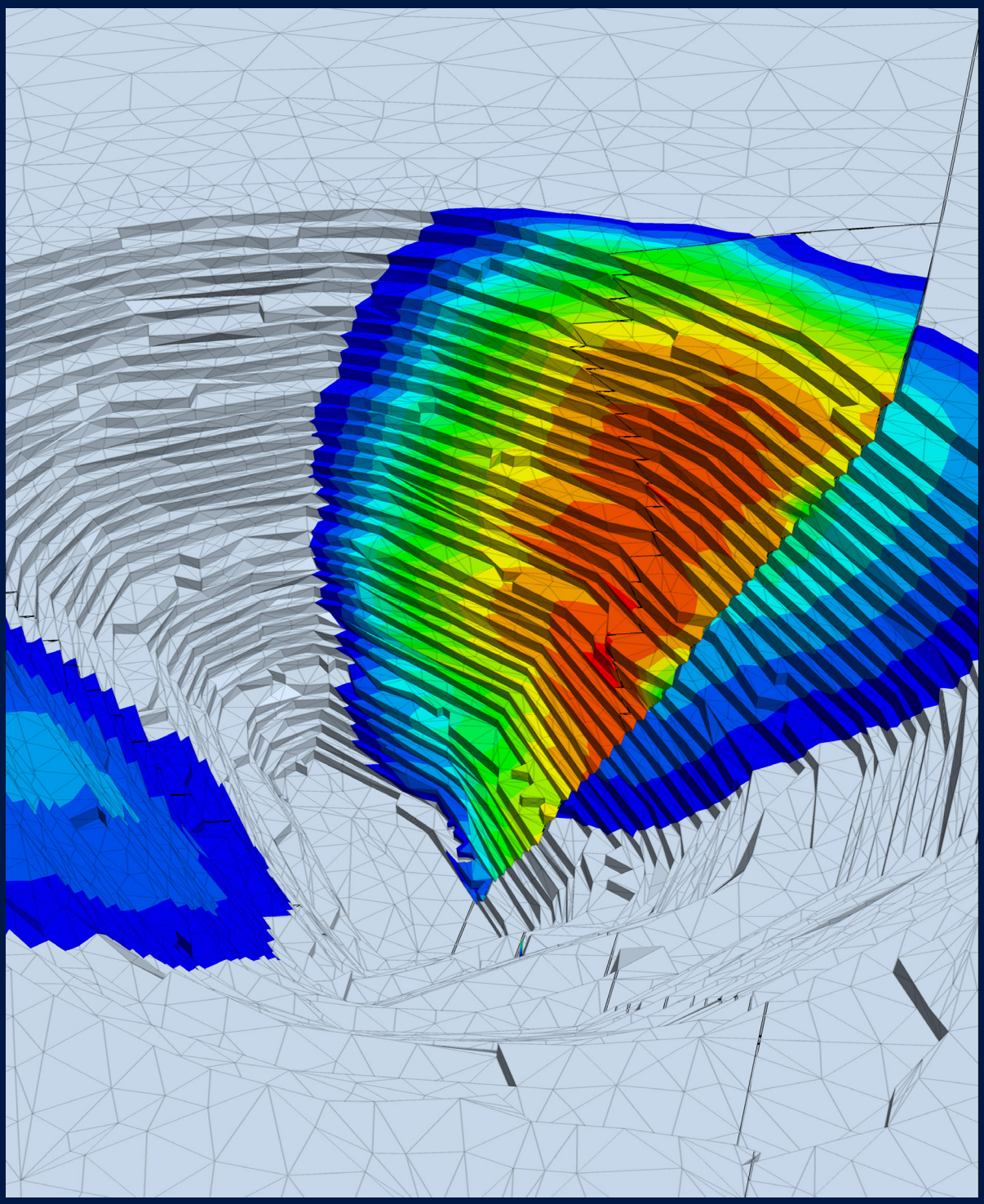
ITASCA™

40 YEARS

Mine Slope Services and Statement of Qualifications



ICG21-SOQ-SLOPE-02

GEOMECHANICS • HYDROGEOLOGY : CIVIL • MINING • ENERGY

"Forward Thinking Engineering and Science"

ITASCA

CONTENTS

Itasca "the true source"

In 1832, an expedition to the Upper Mississippi by Henry Rowe Schoolcraft and William T. Boutwell discovered the source of the Mississippi River; Lake Itasca, an amalgamation of Latin syllables meaning the true source.

ITASCA INTERNATIONAL

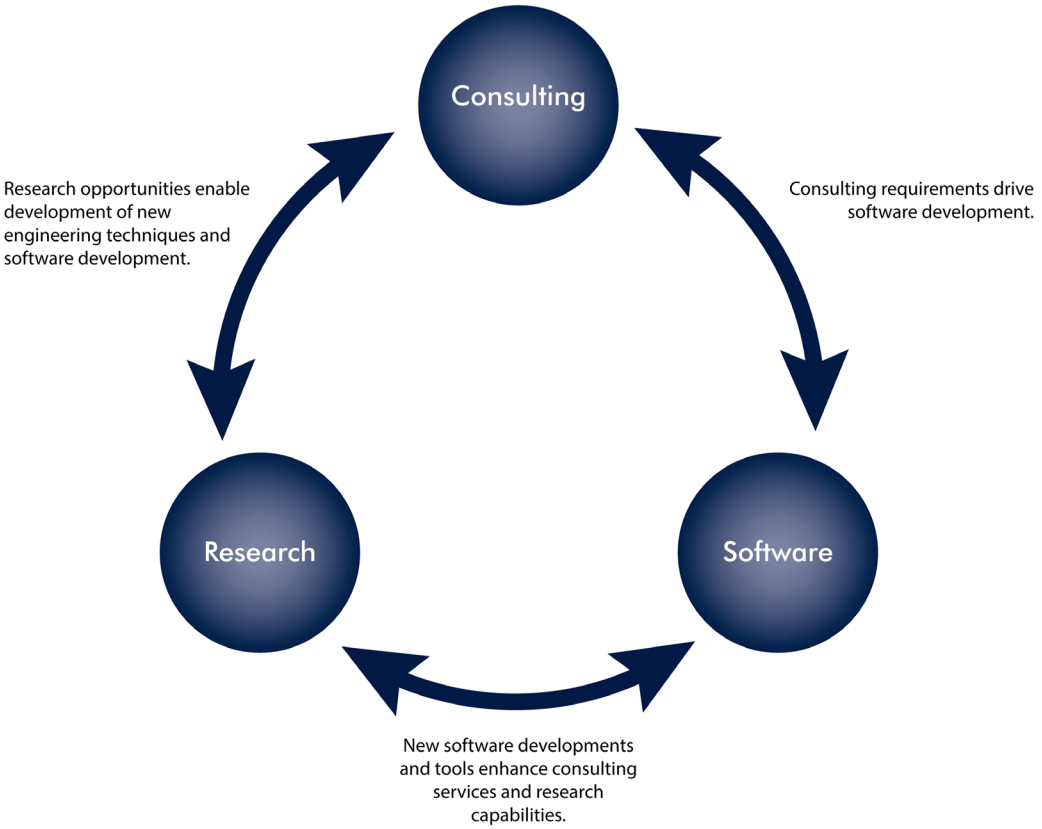
Itasca International Inc. is an engineering consulting and software development company founded in Minneapolis, Minnesota with 10 main offices worldwide. Itasca specializes in solving complex geomechanical, hydrogeological and microseismic issues in mining, civil, oil & gas, energy and manufacturing. Itasca works directly with industry, government, research and education institutions and as a specialist to other consulting engineering firms.

Founded in 1981, Itasca has gained practical and technical knowledge of world-class mining challenges and solutions. Itasca is staffed by leading engineers in the fields of rock mechanics, hydrology, hydrogeology, geochemistry, mining engineering and software engineering. Our experienced staff work on projects ranging from practical field solutions to design issues to applications of Itasca modeling tools for solving difficult or unusual problems, including a wide range of mining methods (from large open pits to deep underground operations) and materials (from soil and engineered materials to soft and hard rock).

Itasca understands the logistical constraints that often are encountered in solving engineering problems. Therefore, we believe in using the most appropriate levels and methods of engineering investigation that examine both technical and economic factors in order to provide practical solutions using the most suitable and best-available technology.

Use of numerical simulation software is an integral part of our consulting. Our state-of-the-art numerical modeling programs are among the most widely used and respected tools of their kind. Development of our advanced numerical simulation software sets Itasca apart from other geotechnical and mining consulting firms. Itasca benefits from the dynamic interplay between our consulting, software development and contract research activities.

Our software is developed and proven with real-world problem solving driven by our consulting work.



Itasca's consulting and research evolves our software, which in-turn provides more advanced tools for us to use towards solving complex problems for our clients.

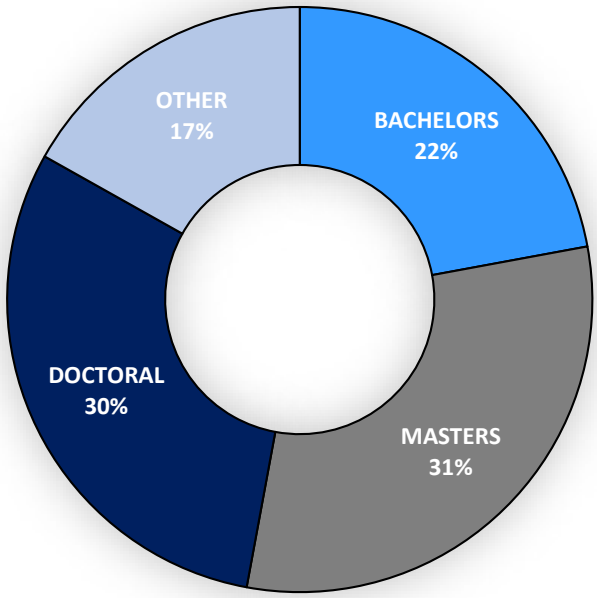
Our engineers and software developers have a proven track record of innovation, leading to new strategies and tools to better understand the complex environments in which mines exist.

With a large portion of our engineers possessing advanced degrees and mining experience, Itasca has been selected as the lead research group for three important mining consortia:

- Large Open Pit (LOP);
- Mass Mining Technology (MMT); and
- Hybrid Stress Blast Model (HSBM).

Each of these projects brought together international mining companies that pooled their resources to tackle problems of common interest.

Itasca also fosters education and university research worldwide though the Itasca Education Program (IEP) and Itasca Teaching Program (ITP), which offer our software free to qualified students and lecturers.



In addition to practical experience, two-thirds of Itasca personnel have advanced degrees in engineering, science or computer programming.

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10 main **consulting offices** in 9 countries, and **software agents** based in another 11 countries, focused on servicing the global mining, civil, and energy industries.

MINING SERVICES

Itasca's global experience and expertise in geomechanics, hydrogeology and microseismics are employed by our clients to select the mining method, sequence and ground support that will maximize ore recovery, excavation stability and operational safety while minimizing development costs and maximizing ore recovery.

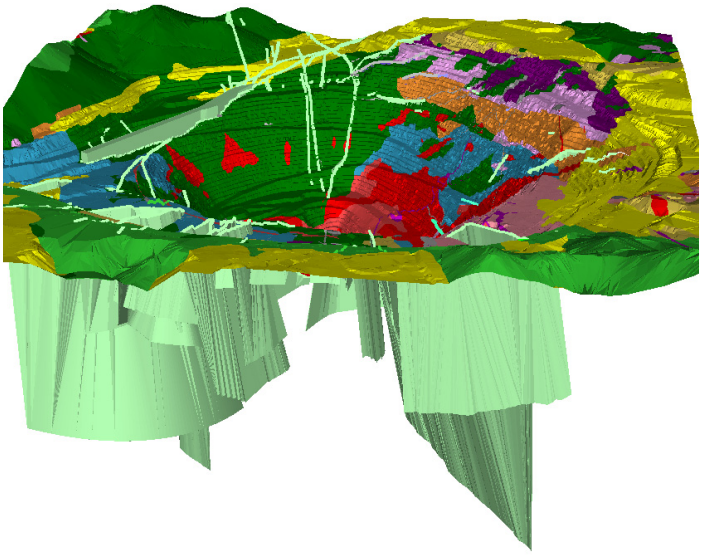
Itasca has analyzed the behavior of excavations in all types of rock and at all scales, from individual boreholes and access tunnels to the complete sequencing of the largest underground mines and deepest open pit mines in the world. Individual projects often require analyses over a wide range of scales due to the complex interaction between the overall mine advance, in-situ stresses and the loading conditions experienced on the scale of critical infrastructure.

Itasca is a recognized leader worldwide in geomechanical numerical modeling of complex mining environments. While this remains our core focus, Itasca's capabilities extend beyond this as a complete mining engineering service provider, as shown in the next sections.

Although Itasca has a reputation for numerical modeling, our consultants are out in the field every day assessing site conditions and characterizing the structural geology and rock mass data crucial for good engineering solutions.

Structural Geology and Rock Mass Characterization

In order to develop a robust structural geology model, Itasca assesses the existing data in collaboration with our clients to assess any gaps, and then applies a number of techniques as appropriate. These can include lineament analysis, precise structural mapping (outcrop, open pit and underground), drill core logging, televiewer analysis and stereophotos.



Datamine plot of a structural fault model with pit geology.

Rock mass strength estimation is required in order to predict the excavation response at the mine site. Obtaining accurate rock mass strengths requires an understanding of the intact rock and joint properties of each geotechnical unit and the in-situ stress state. Itasca can facilitate, interpret and apply both field/laboratory strength testing and in-situ stress measurements. We use traditional engineering approaches including mechanical, empirical and numerical to estimate rock mass strengths, and have pioneered innovative numerical techniques such as Synthetic Rock Mass (SRM) simulations. This approach allows our consultants to model rock mass behavior for any given range of anisotropies, scales, properties and conditions, giving Itasca an understanding of rock mass that is second-to-none.

Site Investigation 2012

Project Description

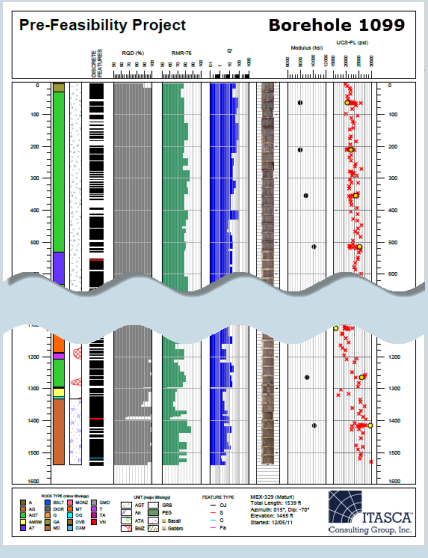
Itasca was asked to conduct a geotechnical field program for the prefeasibilty study of a mine. The site investigation involved data collection and analysis for rock mass characterization.

Itasca's Contribution

The field program included geomechanical core logging, point load testing and analysis of down hole acoustic televiewer (ATV) logging data from exploration boreholes. Geomechanical core logging data and point load strength testing data were used to empirically estimate rock mass quality using both the Q' system and RMR system. Itasca performed quality checking of ATV logging data as well as an assessment of various logged parameters on a global and local basis. From the ATV logs, Itasca identified borehole breakouts to investigate in-situ stress orientation. A fracture frequency comparison was conducted to identify possible bias between ATV logging and geomechanical logging.

Outcomes

Itasca used core logging data and ATV logging data to identify distinct domains in the area of interest to produce summary statistics and graphics showing global and local distributions of Q' and RMR. Borehole breakouts provided an estimate of the principal horizontal stress magnitude and direction. Fracture frequency comparison of core and ATV logging showed a slight bias in the core logging.



Summary of bore hole logging data.

ITASCA

Geomechanical Slope Stability and Design of Pit Slopes

Itasca specializes in the assessment of slope stability and design of pit slopes on bench, inter-ramp and global mine scales. Itasca performs slope, instrumentation and remediation design at many of the world's largest open pit mines. Our expertise in slope stability is not limited to open pit slopes. We also routinely analyze the static and dynamic stability of waste dumps, leach piles, and tailings dams.

Specific services provided include:

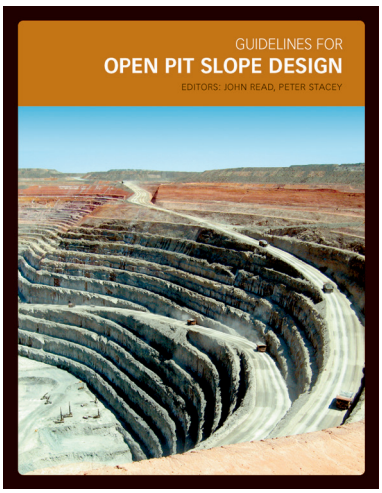
- geotechnical mapping and assessment of rock mass structure and in-situ properties for use in design,
- dewatering and coupling of the dewatering program to geotechnical stability of the slopes,
- blast design,
- specification of instrumentation for monitoring slope movements,
- numerical modeling for assessment of stability and design, and
- specification of slope remediation programs.

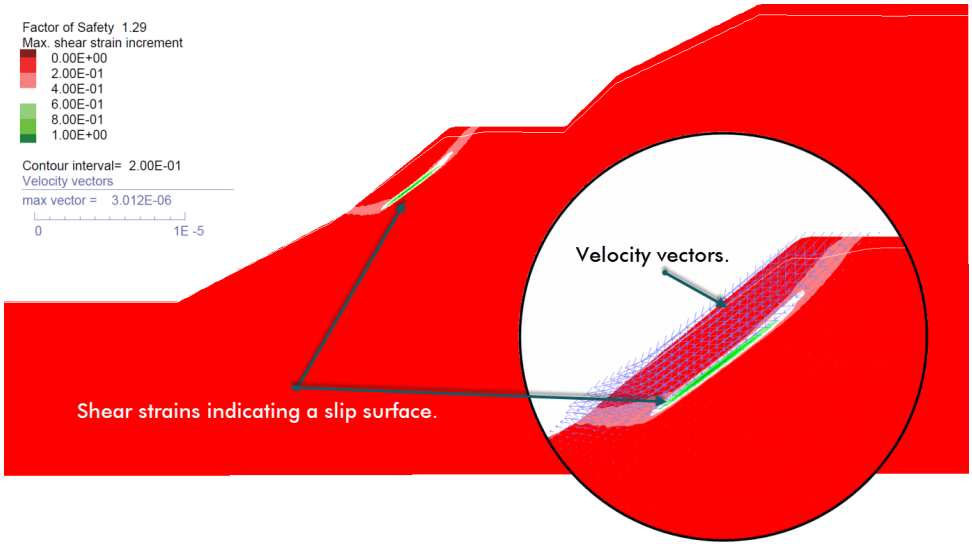
Itasca is particularly well-known for examining difficult problems involving slope instabilities and remediation methods. Itasca pioneered the use of accurate and efficient methods to determine safety factors using numerical methods that use the shear-strength reduction (SSR) technique, which allows failure surfaces to develop naturally; an important advantage over more traditional limit-equilibrium solutions that are restricted to prescribed failure surface geometries (circular, log spiral, segmented, etc.). SSR can also be extended to estimate failure probabilities, which are important in formalized risk assessment.

Itasca engineers use a range of approaches to design and analyze mine slopes, ranging from analytical methods, empirical data and numerical modeling. Itasca is recognized as a world-leader in the development and application of geomechanical and hydrogeological computer simulations. *FLAC* and *FLAC3D* are often used for soil or highly fractured rock slopes and simple groundwater analyses. For more comprehensive groundwater flow analysis we typically use *MINEDW*,

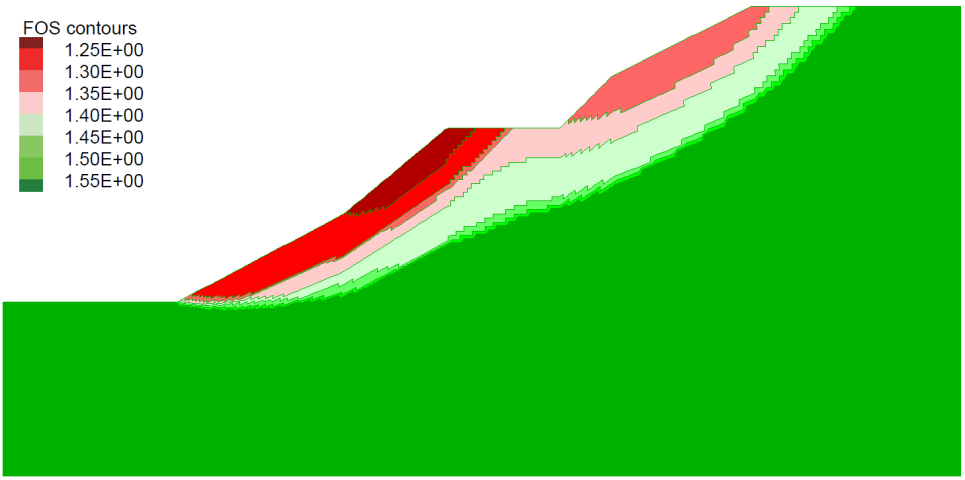
although other software such as MODFLOW-SURFACT and FEFLOW are sometimes used where appropriate. *UDEC* and *3DEC* are used for slope assessments where large-scale geologic structures impact slope movements. *PFC2D* and *PFC3D* are also used in conjunction with jointing and faults where rock bridging is of particular importance or to assess rock mass strength over a range of mine scales. *SLOPE* model is based on *PFC*, but with simplified physics and a dedicated slope stability interface to expedite analyses. *KATS* evaluates probabilistic or statistical way, using a single automated process, the behavior of a large number of systems belonging to a structural domain and various orientations and geometries of slope, can analyze, corroborate or optimize a design based on results such as loss distributions backbreak, spilling length, effective bench face angle, etc..

Itasca is the lead researcher for the Large Open Pit (LOP) project and has been instrumental in the publication of **Guidelines for Open Pit Slope Design**, a comprehensive and modern reference for the best-practices slope design processes and tools that are available for mine design. (Click on the cover image below for more information.)





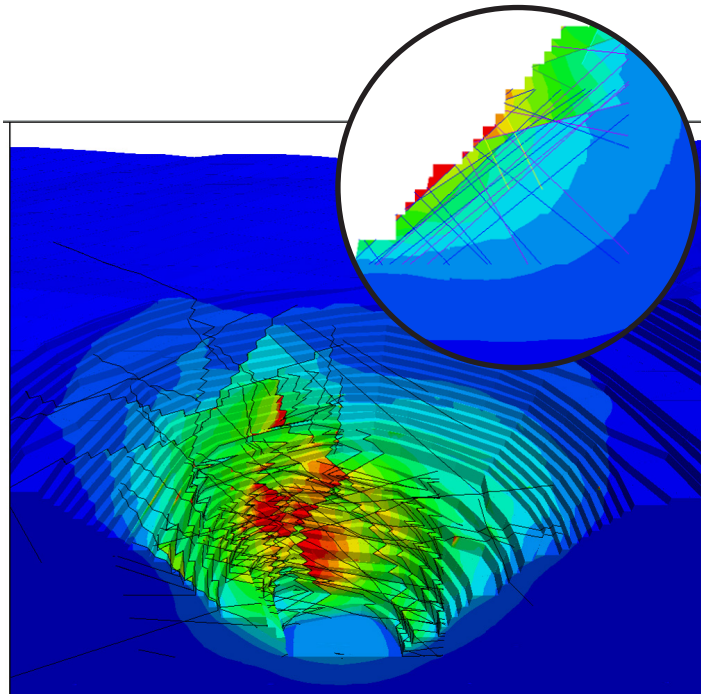
FLAC model using the SSR method to estimate the Factor of Safety (1.29) of a slope. Shear bands and velocity vectors indicate the location and extent of the yielding.



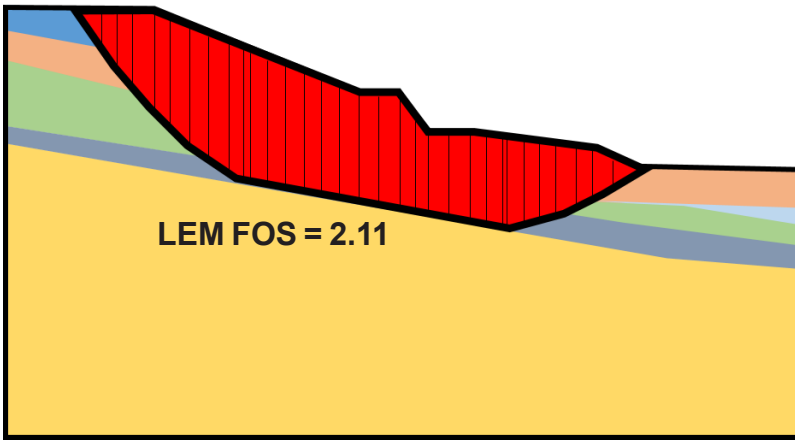
The SSR method permits *FLAC* to evaluate multiple scenarios in order to generate a contour of Factors of Safety for the slope.

Failure Mechanisms

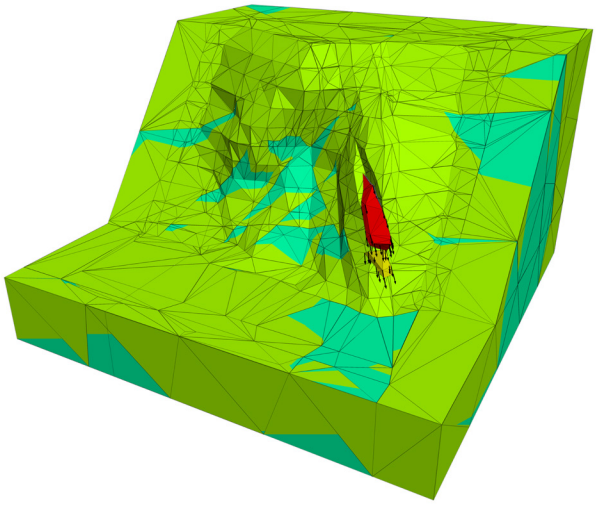
From soil slopes and waste piles to deep open pits in hard rock, Itasca engineers have a wide variety of experience with all types of slope failure mechanisms and the tools and work flows to analyze them.



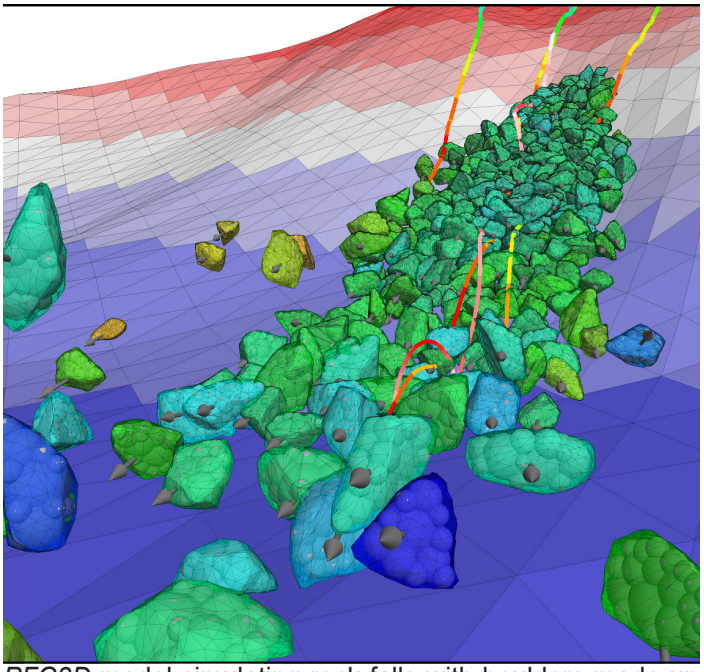
3DEC model of a large open pit with large scale structures displays a more complex mechanisms. All contours indicate displacements. The circular insert shows a section of the slope.



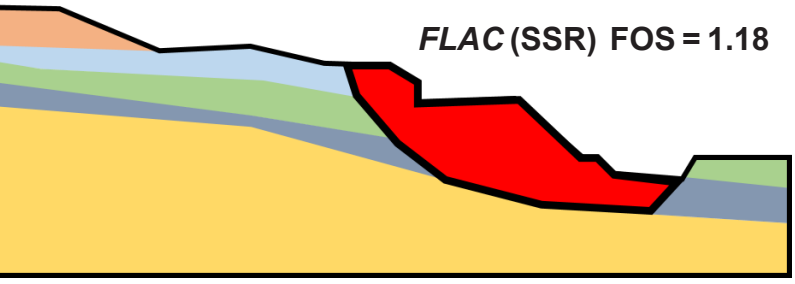
For a large, complex slope, LEM indicated a FoS of 2.11 and *FLAC* (SSR) predicted a FoS of 1.18. The difference was due to the *FLAC* SSR slip surface localizing in the lower part of slope, accounting for soil moving down slope.



3DEC model indicating a large wedge sliding out from the slope.



PFC3D model simulating rock falls with boulders made up of bonded particles slide down a slope.

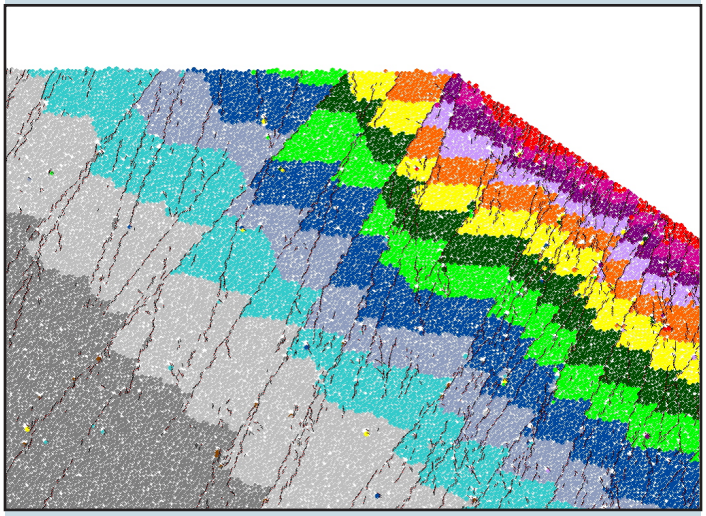


Large Open Pit 2006

Project Description:
Itasca was invited by the Large Open Pit (LOP) Project, a consortium of mining companies, to participate in a challenge to predict the failure mechanism of a slope at an unidentified open pit after several mining sequences. Geotechnical properties, dimensions, stresses and joint and fault data were all provided.

Itasca's Contribution:
This was the first large-scale application of Itasca's Synthetic Rock Mass (SRM) technology, developed as part of the Mass Mining Technology (MMT) Project, using our *PFC2D* software. SRM models the intact rock as bonded particles and the rock mass by removing bonds that are intersected by a representative Discrete Fracture Network (DFN). The models included of 7 fault sets (2890 faults) and 2 joint sets (37,335 joints).

Outcomes
The *PFC2D* model correctly predicted the dominant failure mechanism (toppling and rock sliding) and global depth of yielding experienced at the mine site, Chuquicamata. In the following plot, colors and dark lines indicate horizontal displacements and joints opening up or undergoing shear, respectively.



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Third Party Review

Itasca provides Third Party Reviews aimed at providing an independent and critical review of slope stability analyses performed by practitioners and other consultants. Reviews typically consist of three phases.

(1) Initial Information Review and Site Visit

Itasca reviews all existing and relevant technical documentation, which should include mine plans with pit wall geometry, lithology of the surrounding rock mass and some information on geomechanical properties (including stiffness and strength), rock mass classification and fracturing in the pit walls (including natural and blasting-induced fractures) and previous reports regarding pit stability.

Itasca engineers next visit the mine site and discuss any questions resulting from the information review. A brief site report is issued following the site visit, focused on a "green/red flag" high level summary of the critical findings.

(2) Geomechanical and Hydrogeological Review

Itasca will collect, organize and review the existing data for the mine, including previous assessments by staff and consultants. This task is for both rock mechanics and hydrogeological investigations, reports and assessments. Included in this review, as needed, is an interview of mine staff, subcontractors and consultants.

Critical information considered includes dewatering and depressurization plans, observed and anticipated modes of rock slope failure as a function of season, and the factors of safety for the various modes and mine sectors. The key hydrogeological factor that affects the slope stability is the pore pressure distribution behind the slopes. Because groundwater conditions in the slope may be affected by the regional groundwater flow condition, Itasca will, as necessary, review the regional geologic conditions based on the available data, such as precipitations, surface recharges, regional structures, and groundwater extraction.

(3) Independent Assessment

Based on the review, Itasca may conduct an independent assessment of the hydrogeology and rock mechanics of the pit walls.

The rock mechanics assessment focuses on stability assessments based on the pore water pressures, rock mass characteristics, and small- and large-scale discontinuities. Stability assessments will be via statics-based kinematics and deformation-based methods.

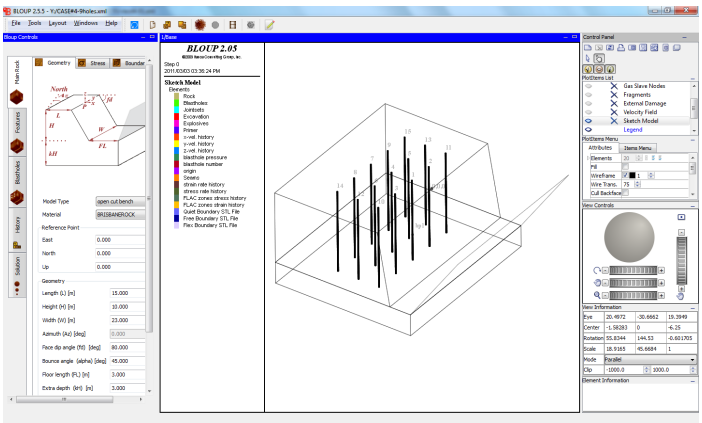
Under hydrogeology, Itasca will assess the future pore pressure distribution for the future mining plan. The phreatic surface of the pit wall will be constructed based on a combination of observed groundwater levels, analytical solutions, groundwater flow models, and Itasca's experience.

Blast Design

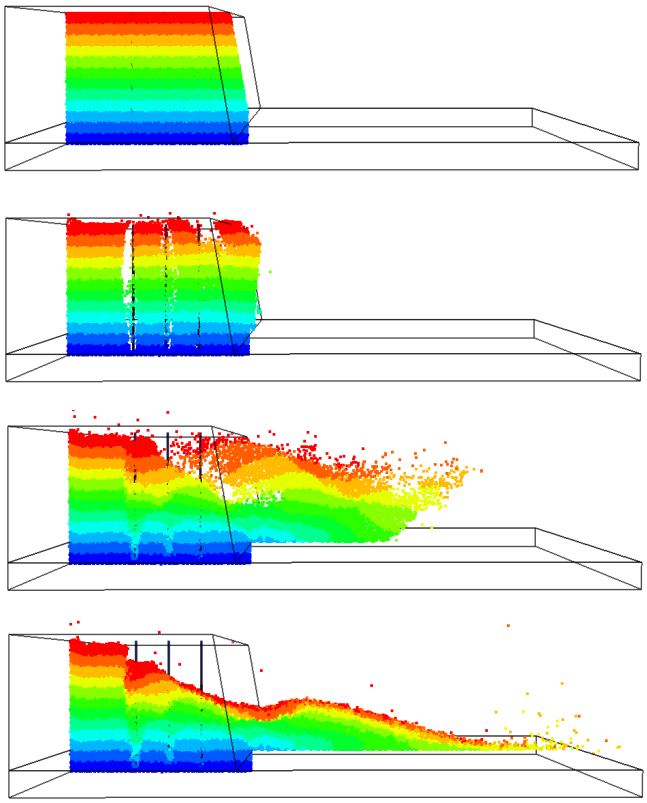
Itasca provides consulting services for:

- Drilling and blasting engineering;
- Stope surface and pit wall design;
- Blast optimization:
  - Fragmentation;
  - Muckpile profile;
  - Throw;
  - Vibrations;
  - Wall control;
- Large-scale destress blasting.
- Design monitoring systems so that performance can be assessed and optimized.

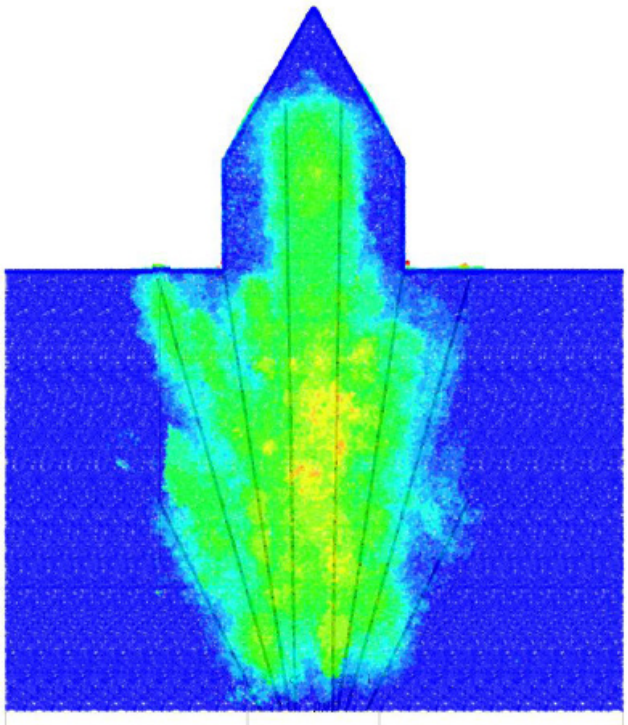
In addition to conventional analytical and empirical methods, Itasca has developed proprietary tools for blast analysis as part of the HSBM consortium that can be used to understand blasthole-to-blasthole interaction, optimize fragmentation and throw, and minimize undesirable damage (e.g., smooth blasting for wall control). This unique blasting simulator is capable of modeling a variety of geometries. Blasthole patterns and explosives loading may be defined individually or as groups (patterns). *Blo-Up* simulation results include final muckpile profile, fragment velocities, blasthole gas pressure and fragmentation and material distributions. Although *Blo-Up* is not available commercially, Itasca does use it in consulting work.



Blo-Up simulates explosive detonation, dynamic shock wave propagation and interaction, rock fragmentation and muck pile formation.



Blo-Up simulation showing a section through a 3D bench and subsequent muck pile.



A sublevel caving (SLC) module has been added to *Blo-Up* for ring blasting simulation.

Blast Design 2013

Project Description

The aim of this work was to preserve the integrity of the final pit walls remaining after a blast in adverse, highly fractured, geological conditions. The aim is widely geomechanical and aims to ensure the stability of the wall by controlling damage from the last blast.

The main objective in this context is neither fragmentation nor the profile/position of the muck pile, but to minimize the damage caused by the detonation gases and vibration levels.

Itasca's Contribution

In extremely adverse geological conditions with very pronounced discontinuities that are persistent, closely spaced, mechanically weak and misdirected , the basic principle to control the wall behind the shot is to minimize the amount of pressurized detonation gas injected into the fracture network.

Outcomes

When faced with extreme geological conditions, it is recommended to

- Lower the splitting factors in the pre-split holes.
- Use smaller diameter holes that are drilled closer together, with a blast hole angle similar to the final wall.
- Avoid over-confining charges in the final shot by ensuring that:
  - Effective burdens are not excessive, and/or
  - Charges are not too weak, and/or
  - The detonation sequence is not overly fast.

Highly variable wall conditions.

HYDROGEOLOGY

Itasca hydrogeologists have extensive experience in assessing key hydrogeologic issues related to surface and underground mining operations and projects, including:

- Groundwater inflow to mine workings for determining pumping and handling requirements;
- Pore-pressure distributions for assessing underground infrastructure and slope stability;
- Pore-pressure reduction methods;
- Prediction of moisture content for evaluating mud-rush potential; and
- Prediction of water quality for meeting regulatory discharge limits.

In addition to conventional data collection, field investigation and field monitoring, Itasca is unique in that our hydrogeologists and geomechanical engineers work closely together to account for the influence of mining over time in both hydrogeological and geomechanical models. Nearly all of the work involves three-dimensional transient groundwater flow simulations.

Itasca's models have simulated the temporal propagation of the enhanced permeability efficiently and realistically within the extent of disturbed rock due to mining. Itasca has constructed three-dimensional groundwater flow models to predict both inflow and pore-pressure distribution for dozens of mining projects.

Geochemistry

Itasca geochemists are experienced in predicting the water quality of mine water. Itasca investigates the effects of fine caved materials on the enhanced leaching of chemicals from caved material to groundwater, the water quality of potential pit lakes including open pits or transition from the open pits to underground workings, and the temporal/spatial distribution of key chemical components.

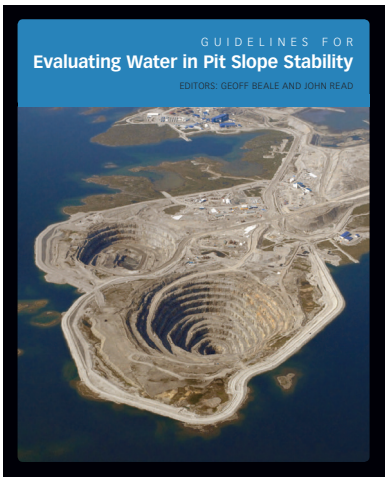
MINEDW

Itasca's *MINEDW* is commercially available

groundwater flow software that is specifically designed to simulate complex mining-related groundwater conditions. In contrast to the general industry modeling practice, which requires many intermittent yearly models, *MINEDW* models are computationally efficient and robust, reducing overall modeling costs and avoiding complex management of modeling files and data. *MINEDW* three-dimensional groundwater flow models are capable of simulating enhanced permeability around the mine and over the life of the mine using a single transient model simulation. The calculated two- and three-dimensional pore pressures from *MINEDW* can be imported seamlessly into Itasca's suite of geomechanical software for use in geomechanical stability analyses requiring a minimal amount of time, on the order of minutes. For example, a Chuquicamata Open Pit and Block Cave groundwater flow model required only one transient simulation to calibrate past open-pit operation calibration, starting in 1970, through to the end of block caving. The entire running time for this simulation (on a regular desktop) was less than one day.

LOP

As part of the Large Open Pit (LOP) project, Itasca has been instrumental in the publication of **Guidelines for Evaluating Water in Pit Slope Stability**, a comprehensive account of the hydrogeological procedures that should be followed when performing open pit slope-stability design analyses. (Click on the cover image below for more information.)



6Hydrogeology 2013

Project Description

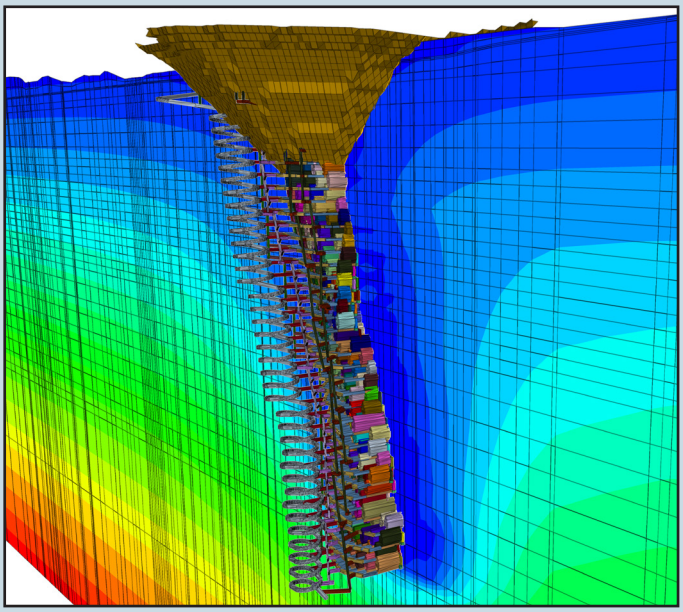
A combined mining method of open pit mining, open benching and sublevel retreat (SLR) is proposed for a steeply dipping pipe-shaped deposit in Guyana. Highly foliated sericitic schist bound the orebody on two sides extending along strike beneath the Cuyuni River. Of potential concern was the increased hydraulic conductivity created along these foliated bands due to mining-induced disturbance or relaxation.

Itasca's Contribution

Two numerical models were created in conjunction such that the staged results could be coupled, providing a more appropriate approximation of pore water pressure distribution (*MINEDW*) to the mechanical model (*FLAC3D*), and providing the hydrogeologic model updated zones of higher permeability.

Outcomes

Results of the coupled modeling indicate that rock mass disturbance is not likely to propagate along the weaker foliated schist found on either side of the orebody during SLR mining. No material increase in water inflow into the mine openings was modeled for the proposed mining plan. The open benching and SLR method were shown to be an acceptable and economic mining method for the deposit. These results were used to help determine the water management systems designed within the mine.



Cross-section of pore-pressure distribution of a *MINEDW* model with multiple open pits and underground mining.

MINE SLOPE EXPERIENCE

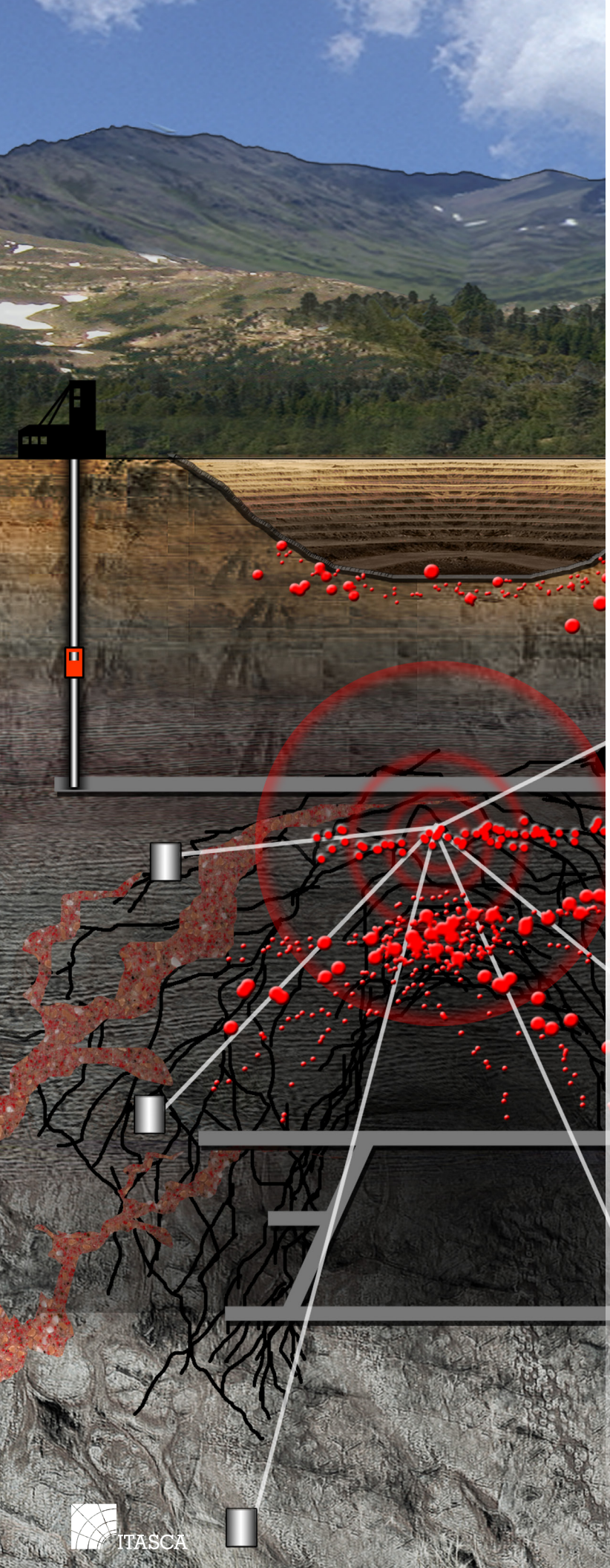
Itasca has been at the forefront of mine slope design, simulation and back-analysis for more than 20 years, pioneering the development of a number of industry leading tools for the assessment of geotechnical domains and rock mass strength and the design of bench, inter-ramp and overall mine slopes.

These tools have been applied at dozens of operations and projects worldwide and have been validated through direct comparison of observed and predicted behaviors. Itasca also relies on a number of experiential guidelines and empirical relations for slope design that have been developed by Itasca and other experts based on a large number of case histories.

Itasca engineers work directly with mining companies and other consultants in all phases of design, ramp-up, operation and closure in order to provide advice and make predictions aimed at providing safety, optimizing recovery, and managing risk. Once in operation, Itasca can provide guidance on the implementation of blasting, dewatering, depressurization, and monitoring (including slope movement, stress, pore pressures, and microseismics).

Select surface and open pit clients are listed in the adjacent table.

MINE/LOCATION	CLIENT	MINE/LOCATION	CLIENT
Mantos Blancos Mine, Chile	Anglo American	Jwaneng, Botswana	Debswana
Sishen Mine, South Africa		Damtshaa, Botswana	
Kolomela Mine, South Africa		Battle Mountain, USA	Echo Bay Mines
Cerro Vanguardia, Argentina	Anglogold Ashanti	Ranger, Australia	Enery Resources Aus
Cresson and Victor Mines, USA		Toquepala and Cuajone Mines, Peru	Grupo Mexico
Geita-Nyankanga, Tanzania		Century, Australia	MMG Ltd.
Esperanza Project, Chile	Antofagasta Minerals	Sepon, Laos	MMG Ltd.
Fedorov's Tundra, Russia	Barrick	Cadia Hill Mine, Australia	Newcrest
Turquoise Ridge, USA		Lone Tree, USA	Newmont Mining Corporation
Mount Whaelback and Orebody 5, Australia	BHP Billiton	Twin Creeks, USA	Newmont Mining Corporation
Escondida Mine, Chile		Gold Quarry - Nine Point Slope, USA	Newmont Mining Corporation
Radomiro Tomic Mines, Chile	Codelco	Gold Quarry, USA	Newmont Mining Corporation
Chuquicamata Mine, Chile		Vista 7, USA	Newmont Mining Corporation
Collahuasi Mine, Chile	Collahuasi Mining Co.	Padddington Mine, Australia	Norton Goldfields
Victor, Canada	De Beers Canada	Macraes Open Pit, New Zealand	Oceanagold
Gahcho Kué, Canada		Grasberg Mine, Indonesia	P.T. Freeport
Fort à la Corne, Canada		Tom Price, Australia	Rio Tinto
Premier, South Africa	De Beers Consolidated Mines	West Angelas, Australia	Rio Tinto
Finsch, South Africa		Jericho Mine, Canada	Tahera Diamond Corp.
Voorspoed, South Africa		Lemont and McCook Mines, USA	Vulcan Materials Co.
AK6, Botswana		Tintaya and Antapaccay, Peru	Xstrata
Mulepe, Angola		Ernest Henry Mine, Australia	Xstrata
Orapa, Botswana	Debswana	C1 Project, Brazil	Yamana Gold
Letlhakane, Botswana			



MICROSEISMIC ANALYSIS

Itasca specializes in providing commercial microseismic monitoring, processing and advanced analyses to the mining industry. Microseismic monitoring provides a unique insight into the fractures induced by mining operations, which has implications for:

- Early warning on localized induced damage to mine infrastructure;
- Performance of ground stability controls; and
- Effectiveness of rock fragmentation, preconditioning campaigns and caving projects.

Itasca has developed a series of novel services that enhance the information provided by existing microseismic assets to monitor the evolution of the fracturing processes, including the following.

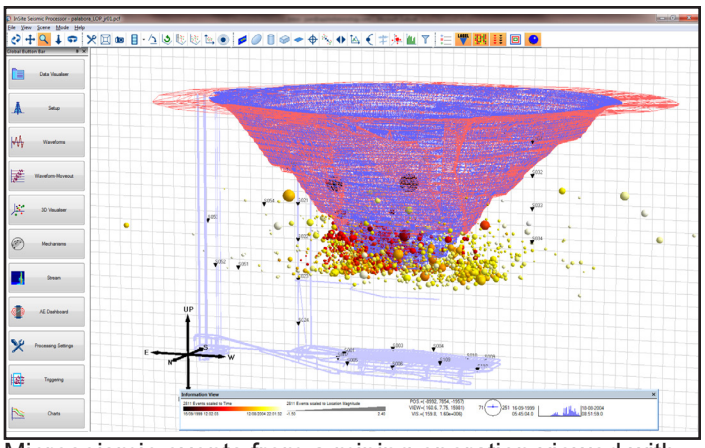
- Structural analysis of microseismic event distribution for imaging of induced or mobilized fracture geometry.
- Analysis of microseismic source parameters to identify fracturing modes and the fraction of newly opened and reactivated fractures.
- Temporal and spatial clustering of microseismic events to quantify damage accumulation and identify areas of localized fracturing.
- In-depth understanding of fracture mechanics through the integration of acquired data and Synthetic Rock Mass models.
- Fully featured, microseismic training courses focused on the principles behind the technology, processing algorithms and hands-on experience of using processing software.

InSite, Itasca's integrated tool for seismic data acquisition, signal processing and data management and visualization, is independent of the acquisition hardware used at the mine site. It can be integrated with most commercial hardware packages to perform real-time data capture and processing. Processing algorithms are developed continuously to meet the complexities of processing microseismic activity in challenging environments, such as high-noise operating mines, complex velocity structures or limited coverage sensor arrays.

Itasca provides sensor array and equipment design services and quality review. We provide an in-depth and objective analysis of the type and design required, including a three-dimensional site analysis to recommend the optimal positioning of a sensor array with quantitative assessment of its effect on monitoring sensitivities and accuracy. We provide advice on a comprehensive range of cost-effective seismic data acquisition systems and sensors, and facilitate vendor selection and installation. We have our own solutions in high-speed data acquisition for investigation of micro-fracturing.

Additional microseismic services provided include:

- Microseismic project management, array design, data hosting and integrated processing systems;
- Geophysics team for provision of complete processing service solution;
- Quality assurance of third-party microseismic processing results;
- Standard and advanced software tools for do-it-yourself processing; and
- Advanced database technologies for networking remote microseismic stakeholders.



Microseismic events from a mining operation viewed with *InSite*.

[7,8]Underground & Open Pit Interaction 2008/12

Project Description

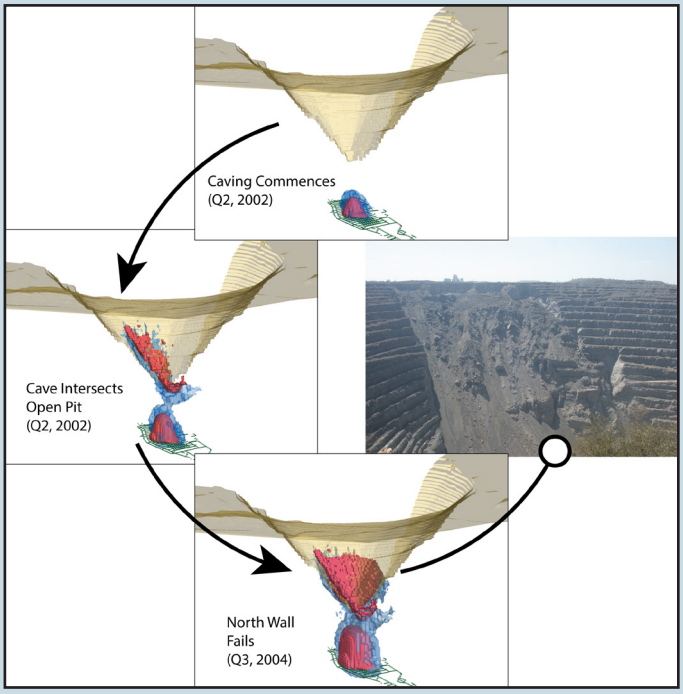
As the Palabora Mine (South Africa) transitioned from surface to underground mining, a large-scale failure occurred in the pit slope as a result of cave mining. This resulted in the dilution of ore reserves and instability in mine infrastructure. A microseismic (MS) monitoring system was in operation.

Itasca's Contribution

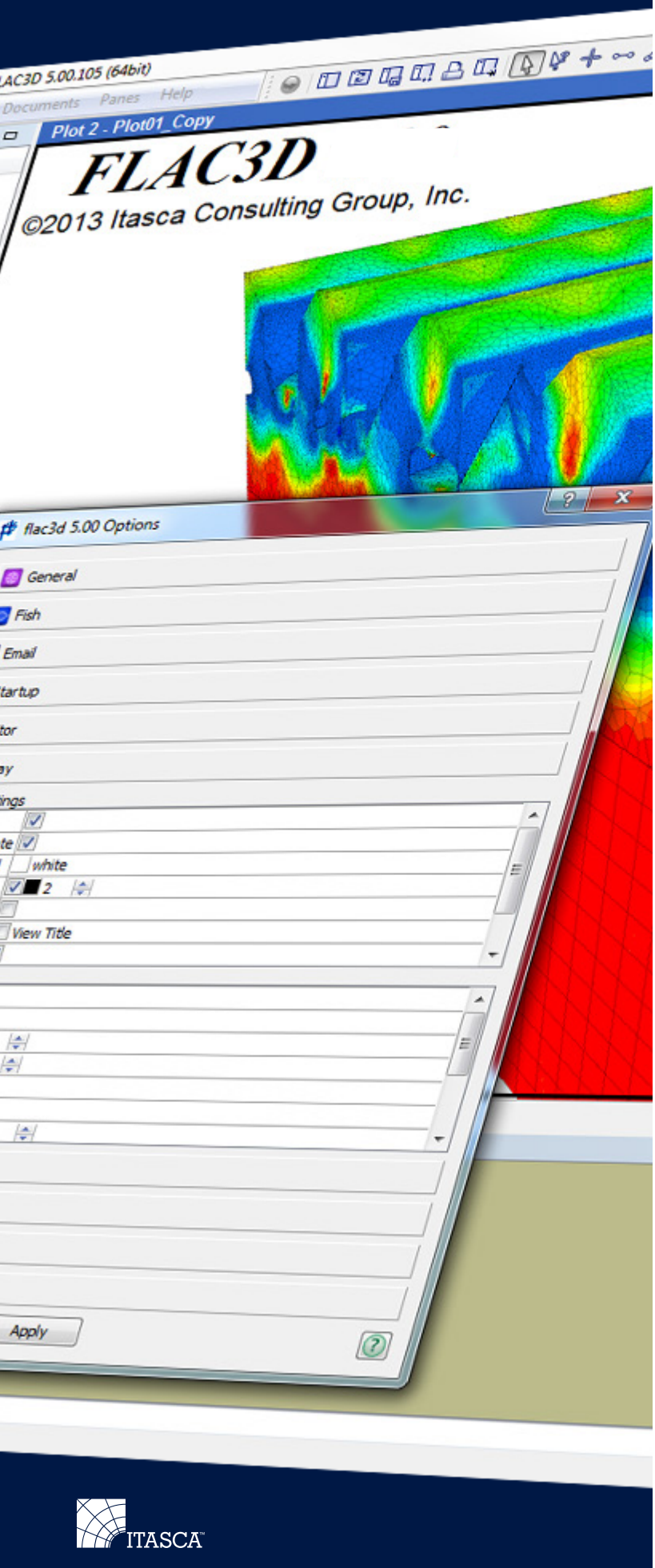
Synthetic Rock Mass (SRM) responses were developed for the rock mass domains at Palabora. Production was simulated and the advancing cave and north wall failure area was assessed.

Outcomes

Microseismicity strongly indicated the development of significant damage in the rock mass below the north slope in the months preceding its failure. *FLAC3D* models, due to higher stresses induced by the underground mining, describe very similar macro behavior to that observed in-situ. The combination of numerical analyses and SRM modeling with MS analyses provides a preliminary assessment of potential volumes of rock failure during caving operations to be completed prior to production start-up.



Development of the pit slope failure mechanism at the Palabora mine at various stages of production.



SOFTWARE SERVICES

Itasca first commercialized its software in 1985 when clients asked to have access to the software tools that our engineers used in their analyses. Itasca has pioneered and continues to innovate the application and development of numerical modeling software. Our software are among the most widely used and respected tools of their kind for analyzing and solving problems in geomechanics, hydrogeology, microseismic analysis, and other engineering fields. The result is a set of software that provides unparalleled speed, power, and proven capability for handling engineering problems ranging from traditional design work to understanding the most complex natural phenomena encountered in some of the most challenging environments.

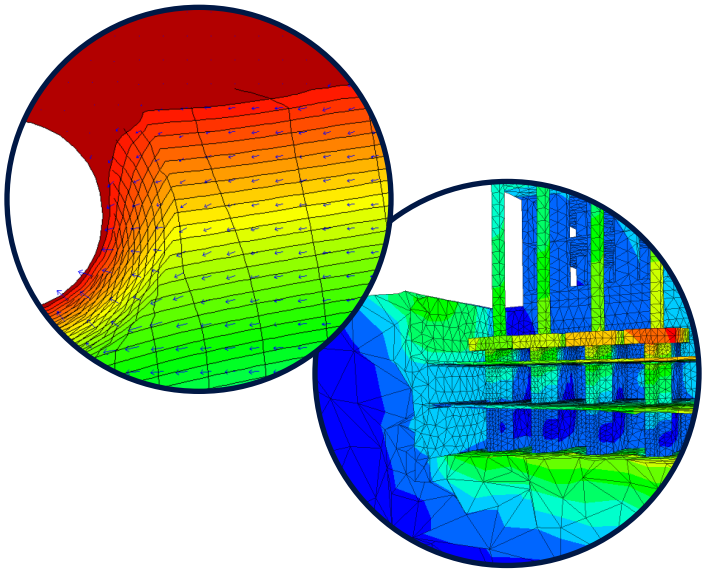
Itasca programs are used for design of major mining and civil construction projects, design of nuclear waste repositories, and oil reservoir treatment programs and have been used in a large portion of rock mechanics research projects worldwide. More than 4,000 mining and civil construction companies, consultants in rock and soil mechanics, and university and government researchers use these programs worldwide.

Itasca software programs include the two- and three-dimensional continuum programs *FLAC* (including *FLAC/Slope*) and *FLAC3D*, the two- and three-dimensional discontinuum programs *UDEC* and *3DEC*, the two- and three-dimensional particle-flow simulation programs *PFC2D* and *PFC3D*, the three-dimensional, finite-element groundwater flow code *MINEDW*, the integrated seismic data acquisition, processing, management and visualization software *InSite* for seismological studies, and the three-dimensional code *DFN.lab* for simulating 3D DFNs for engineering and research problems.

Itasca often performs custom modification or development of these programs for specific project or client needs. Development of all software is governed by input from Itasca's consulting practice. Consequently, clients are assured that these software are practical, efficient analysis tools with a proven record of solutions to real-world problems.

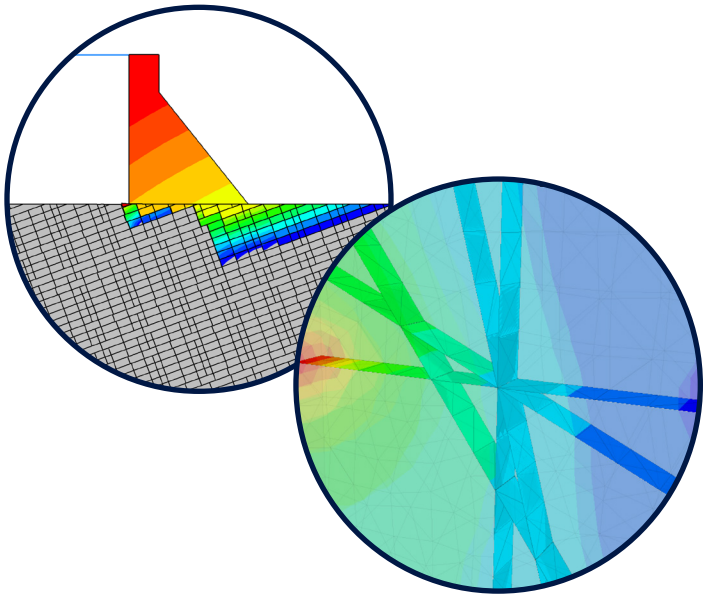
For more information or to download a free software demo, please visit: www.itascacg.com/software.

FLAC® – FLAC3D™



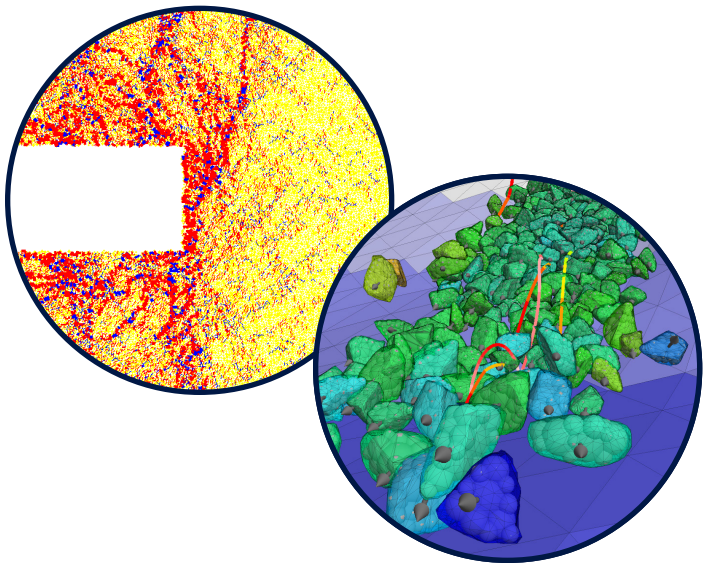
These are two- and three-dimensional explicit finite-difference programs for engineering mechanics simulations. These programs model the behavior of soil, rock, or other materials that are subject to plastic yielding. Materials are represented by a continuum of zones, which form a grid that is adjusted by the user to form the shape of the model to be simulated (e.g., tunnel, open pit, tailings dam, etc.). These programs are capable of simulating large strains (including unstable physical processes such as collapse), joints along which slip and/or separation can occur, groundwater flow, multiple excavation sequences (including backfilling), and dynamic processes and includes structural elements (e.g., liners, rock bolts, cables, beams, etc.).

UDEC™ – 3DEC™



Two- and three-dimensional distinct element codes for modeling discrete or jointed systems (e.g., rock mass, rock grains, hydro-electric dams on jointed rock foundations, masonry structures). Materials are represented by a network of blocks cut by discontinuities with surface (boundary) conditions. Blocks are able to rotate and slide along joints and joints can open or close. Blocks can be rigid or deformable (allowing yielding). The programs are capable of simulating large block displacements, groundwater flow along discontinuities, multiple excavation sequences, and dynamic processes and include structural elements (e.g., liners, rock bolts, cables, beams).

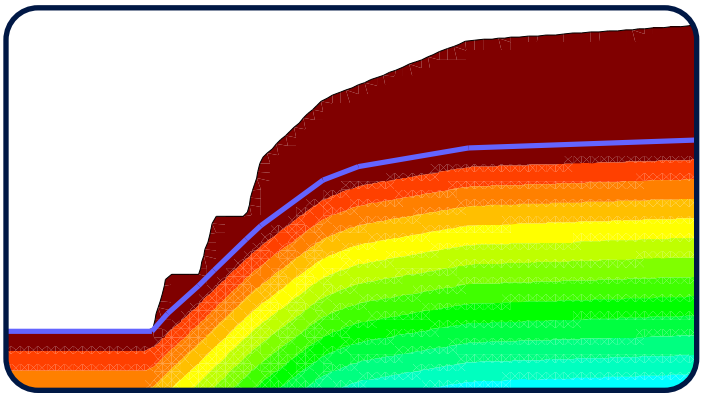
PFC Suite™



Two- and three-dimensional distinct element programs for modeling the movement and interaction of assemblies of arbitrarily sized circular or spherical particles. *PFC Suite* includes both *PFC2D* and *PFC3D*. The codes create an ideal environment for study of the behavior of synthetic materials, modeling bulk flow and materials mixing, studies of micro- and macro-damage (cracks) in solid bodies, including damage accumulation leading to fracture, dynamic breakage, and seismic response. *PFC2D* is also sold separately.

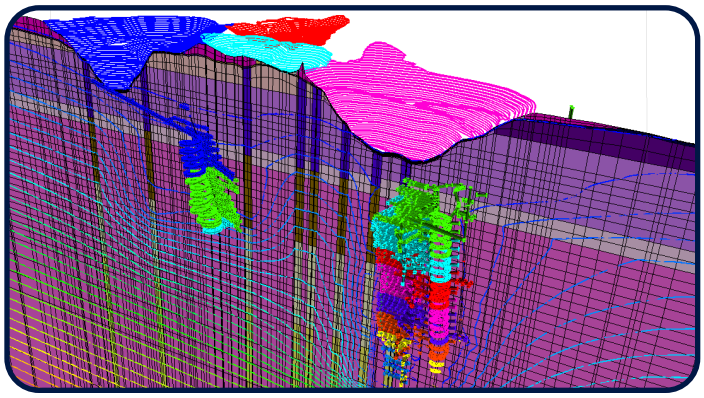
FLAC/Slope™

FLAC/Slope is a free, specialized version of *FLAC* designed specifically for slope stability factor-of-safety analysis. This code allows rapid generation of problem geometries and factor-of-safety calculation using the shear-strength reduction technique. One particular feature of this code is the ability to overlay DXF plots to speed model generation. Users can also specify water tables and pseudostatic earthquake loading.



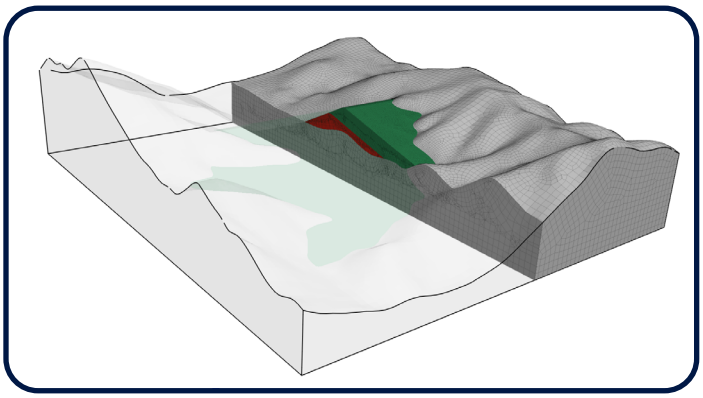
MINEDW™

Itasca's hydrogeological software has been specifically developed for simulating groundwater conditions. *MINEDW* (www.itascadenver.com/minedw) is very efficient in simulating complex geometry and spatial and temporal change of hydraulic conductivity of disturbed rock as the results of excavating. The simulated pore pressure distribution from *MINEDW* model can be readily imported into Itasca's geomechanical models.



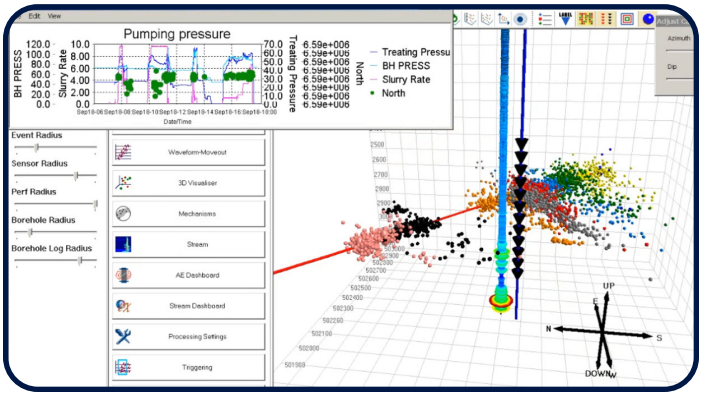
Griddle™

Griddle is a fully interactive, general-purpose mesh generation plug-in for the *Rhinoceros* 6.0 3D CAD software (www.rhino3d.com). *Griddle* can be used to remesh *Rhino* surface meshes to comply with precise size specifications and type (triangle or quad-dominant). Surface meshes can then be used as boundaries for *Griddle's* volume mesher, which produces high-quality tetrahedral or hex-dominant meshes. The volume meshes are ready for importing into most engineering analysis packages, including *FLAC3D* and *3DEC*.



InSite™

Itasca's integrated seismic data acquisition, processing, management, and visualization software for seismological analysis, ranging in scale from acoustic emissions in the laboratory through microseismics around underground excavations up to regional-scale earthquakes. The software is independent of acquisition hardware and can be integrated with hardware packages to perform real-time data capture and processing. *InSite* software is used by many international companies and organizations for in-house processing and management of microseismic data. *InSite* is available as *InSite-Geo*, *InSite-HF*, and *InSite-Lab* for geomechanical, hydraulic fracturing, and laboratory applications. *InSite-Lite* is also provided as a free microseimicity viewer.



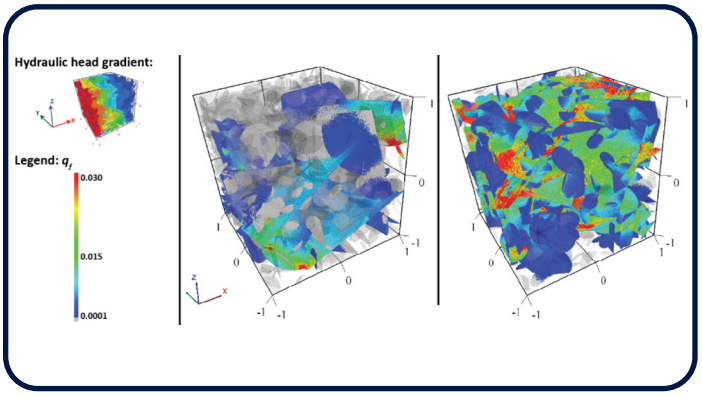
KATS

Kinematic Analysis Tools for Slopes (*KATS*) is a tool aimed at assessing instabilities caused by daylighting wedges and planar failures formed when different structural sets interact with the orientation of a given slope. The main application of the code is the so-called bench-berm scale analysis, which is understood as a first step in the mining slope design process for moderate and competent rock masses. However, it is possible to perform a kinematic analysis in inter-ramp scale. Unlike other tools currently available, through a single automated process, *KATS* allows performing a probabilistic or deterministic assessment of the behavior of a large number of slope configurations defined by many structural domains and many orientations and geometries of the slope. The results from the analysis can be provided using a variety of parameters, such as loss of crest, spill lengths, bench face angle distribution, etc. All these results allow a geometric definition of the interramp (IRA) angles that achieve the acceptability criteria defined by the operation from the point of view of stability and safety of personnel and equipment.

DFN.lab™

DFN.lab is used for simulating fluid flow and trasport in 3D discrete fracture networks (DFNs) for engineering and research problems. *DFN,lab* is capable of:

- generating genetic models containing millions of fractures based on the physics of fracturing,
- compute stationary and transient flow with various boundary conditions in significantly large systems,
- characterize the DFN structure and hydraulic properties using novel statistics and graph methods



Software Customization

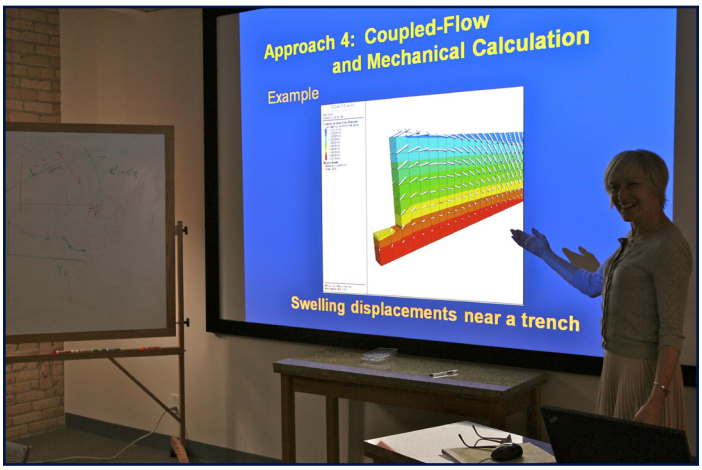
Itasca's software development is directed and refined by Itasca's consulting practice and client feedback. Itasca develops specialized material constitutive and contact models, *FISH* and Python functions, or even entirely novel simulation software in consultation with clients or as part of research collaborations. The software *REBOP* (cave mining), *Blo-Up* (blast design), *Slope Model* (slope stability), and *XSite* (hydraulic fracturing) were created in this manner and are used for both consulting and research.

For more information, please contact us at:

info@itascainternational.com

Training

Itasca offices worldwide routinely offer software training courses throughout the year.



You can find out which courses are currently available here:

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Custom engineering or software training courses can also be arranged at one of our offices or at your organization. Online web forms can be found at the following address.

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LEAD PERSONNEL, MINE SLOPES

Martin Brown
Itasca Chile SpA
Hydrogeology Manager,
Water Management Engineer
martin.brown@itasca.cl

Mr. Brown is a civil engineer who holds Diplomas in Water and Environmental Management from the University of Bristol (UK) has worked in the field of water and tailings management and dewatering systems for major mining operations and projects in Chile and South America for over 15 years, the last of which is for Itasca.

He has a diverse background in mining applied hydrogeology. For mining operations his experience includes planning and management of water resources and open-pit dewatering systems through 3D hydrogeological and pore pressure numerical models and support in the elaboration of environmental impact assessments. Has also been fluids transport manager with responsibility over tailings storage facilities, water supply systems and slurry pipelines. While in Itasca his experience includes elaboration of 3D hydrogeology numerical models for open-pit mines, assessment of dewatering systems and support in the elaboration of environmental permits related to groundwater management.

Christopher O'Connor
M.A.Sc.
Itasca Consulting Canada, Inc.
General Manager & Principal
Geomechanics Engineer
coconnor@itasca.ca

Mr. O'Connor is a mining engineer with a Master of Applied Science degree in Mineral Resource Engineering. He has worked in the mining field for over 20 years focusing on advanced numerical modeling and geomechanics. Mr. O'Connor has returned to Itasca after four years working at Glencore's Nickel Rim South Mine as the Senior Ground Control Engineer for the site.

Branko Damjanac
Ph.D.
Itasca Consulting Group, Inc.
Principal Engineer and
Geotechnical Engineer
branko@itascacg.com

Dr. Damjanac has experience in the design and analysis of underground and open pit mining excavations in both hard and soft rocks. He developed numerical models and methodologies for analysis of mine stability.

He has investigated mechanism of large-scale panel collapses in room-and-pillar trona mines. Developed a methodology to provide guidelines for safe mine design (extraction ratios, pillar sizes and panel spans) accounting for interaction between pillars and overburden. For large room-and-pillar salt mines analyzed mine-scale convergence rates due to salt creep and investigated the effect of creep and associated damage on long-term stability.

Participated in development of a novel numerical method for simulation of slope stability in fractured rock masses, with intended application to large open pit slopes. Investigated the mechanics and the effects of rock mass preconditioning by hydraulic fracturing for block caving operations.

Patricio Gómez
Itasca Chile SpA
General Manager,
Applied Geotechnical Engineer
patricio.gomez@itasca.cl

Mr. Gómez is a civil engineer who holds a Diploma in Geomechanics Applied to Mining from the University of Chile and has worked in the field of soil and rock mechanics for major mining projects in South America for over 35 years, 25 of which are for Itasca. He has a diverse background in mining applied geomechanics. On underground operations his experience includes assessment of mining methods and recommendation of mining sequences for block caving operations, stability analyses for underground chambers and ore-pass sectors, as well as the evaluation of ground-support methods, analysis of rock mass degradation, caveability analyses, and stress field calibration. His main area of expertise is geomechanics for open-pit mines, including slope design at several scales, stability assessments and back-analysis of slope failures and dynamic analysis of slopes under effects of earthquakes. Surface consulting projects include static and dynamic stability analyses and the liquefaction potential of tailings dams, water reservoirs and waste dumps in highly active seismic areas.

Houmao Liu
Ph.D., P. Eng.
Itasca Denver, Inc.
General Manager and
Principal Hydrogeologist
hliu@itascadenver.com

Dr. Liu has more than 25 years of project experience in mining hydrogeology, geochemistry, and groundwater flow modeling. He has worked on and directed numerous mining hydrogeology projects in southern Africa, South America, Turkey, North America, Russia, and East Asia. He has also been the Principal-in-Charge of Itasca's hydrogeologic projects for key mining companies such as Alrosa, De Beers, Cameco, Anglo American, Debswana, Doe Run, Freeport McMoRan, Rio Tinto, Goldcorp, and Codelco. These projects include mine dewatering, slope depressurization, water management of surface and underground mines, environmental impacts, and mine water quality. In addition, Dr. Liu has extensive experience in the code development of *MINEDW*, as well as more than 25 years of groundwater flow modeling experience using other commercial codes such as MODFLOW, MT3D, and FEFLOW. He also provides expert opinions for regulatory hearings and due diligence reviews and has taught numerous hydrogeologic courses.

Loren Lorig
Ph.D., P. Eng.
Itasca Consulting Group, Inc.
Itasca S.A.
Principal Mining Engineer
loren.lorig@itasca.cl

Dr. Lorig has more than 35 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. Dr. Lorig has worked extensively at some of the largest open pits in the world and currently is working on studies involving transition from open-pit to underground mining at sites around the world. He has served as a member of consulting and peer review boards for several large projects. He has conducted over 40 short courses, authored more than 50 technical articles and made ten keynote presentations. He is a Registered Professional Engineer in several U.S. states.

Glenn Sharrock
Ph.D., MAusIMM CP (Geotech)
Itasca Australia Pty. Ltd.
General Manager and Principal
Geotechnical Engineer
gsharrock@itasca.com.au

Dr. Sharrock's has 15 years industry experience in a wide range of rock mechanics positions such as Principal Geotechnical Engineer (Newcrest Mining NL), Rock Mechanics Engineer (Mt Isa Mines), Senior Geotechnical Consultant (AMC Consultants), Senior Lecturer in Geotechnical Engineering (UNSW) and Associate Professor - Caving Geomechanics (UQ). His last position was as Principal Geotechnical Engineer at Newcrest's Cadia East, Ridgeway Deeps, Ridgeway SLC and Telfer Mines. In addition to Newcrest, consulting experience includes Argyle, Perseverance, North Parks, Koffiefontein, Resolution, Goldex, Afton, Ekati, Perseverance Deeps, and Ridgeway Deeps (Lift 2).

Jonny Sjöberg
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Itasca Consultants AB
General Manager and Principal Engineer
jonny@itasca.se

Dr. Sjöberg is a rock mechanics engineer with experience in operations, research and consulting within mining and civil engineering. He holds a Ph.D. in the area of open-pit slope stability, and has worked on underground and surface mining projects in rock mechanics, civil engineering tunneling projects, stress measurements and various other numerical modeling projects. Dr. Sjöberg also is an Adjunct Professor in Rock Mechanics and Rock Engineering at Luleå University of Technology.

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ITASCA

40 YEARS

"More than **40** years of solving mining challenges through engineering and computer simulation."

Thank you for your interest in Itasca's services to the mining industry. Please let us know how we can assist you with your work.

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