ACG AUSTRALIAN CENTRE FOR GEOMECHANICS

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Joint Venture

BIENNIAL REPORT 07-08

contents

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COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION AUSTRALIA
Division of Exploration and Mining

CURTIN UNIVERSITY OF TECHNOLOGY
Western Australian School of Mines

THE UNIVERSITY OF WESTERN AUSTRALIA
Department of Civil and Resource Engineering

highlights 2007-2008

As industry continues to evolve at a rapid rate, many mining professionals are asked to find new ways of enhancing their performance and contributions. During the last two years the ACG has developed relevant and specialised training products and publications that assist industry personnel to advance their skills, knowledge and capabilities. Our state-of-the-art research projects effectively respond to industry's needs by undertaking innovative research that provides ongoing benefits and viabilities instead of 'quick-fix' solutions.

FACILITATING COORDINATED RESEARCH, TECHNOLOGY TRANSFER AND IMPROVED EDUCATION AND TRAINING IN THE GEOMECHANICS DISCIPLINES

Mine Seismicity and Rockburst Risk Management

Research conducted during Phase III of the ACG's leading project witnessed the development of several new tools for the pro-active assessment of seismic hazard, excavation vulnerability and the potential for rockburst damage which enables the management of seismic risk.

High Resolution Seismic Monitoring in Open Pit Mines

This unique research project looks at the potential and the operational constraints of open pit seismic monitoring. This is particularly relevant as many operations increase their mine's economic depth with several rock slopes being mined in excess of 500 m — elevating safety and economic risk.

An Effective Stress Approach to Mine Backfill

This new research project examines an approach for curing cemented paste backfill under effective stress. This potentially allows operators to benefit from savings in cement quantities without introducing the additional risk of paste instability.

Tailings – From Concept to Closure

This exciting and new ACG training DVD provides guidance to personnel involved in the management and operation of tailings storage facilities.

Rockburst – Unleashing Earth's Energy

This new geotechnical hazard awareness training DVD explains the phenomenon underlying mine seismicity and rockbursts in a simple and easy to follow way.

Challenges in Deep and High Stress Mining

The ACG's latest publication features 75 papers selected from those presented at the three international seminars on deep and high stress mining.

10th International Seminar on Paste and Thickened Tailings

Paste 2007 looked at the advances in the preparation, transportation and deposition of paste. It also examined the important part that paste technology plays in incremental rehabilitation and its impact in mine closure.

International Symposium on Rock Slope Stability in Open Pit Mining and Civil Engineering

Nearly 200 mining and civil engineering professionals attended this symposium reflecting industry's keen interest in the novel and rapidly evolving slope monitoring and design technologies.

Fourth International Seminar on Deep and High Stress Mining

This series of seminars documents and disseminates the latest technologies and experiences in deep and high stress mining.

First International Seminar on the Management of Rock Dumps, Stockpiles and Heap Leach Pads

Almost 80 mine operators and owners, as well as academics, consultants and researchers explored the significant developments in the design, operation and management of rock dumps.

First Southern Hemisphere International Rock Mechanics Symposium

SHIRMS brought together more than 220 rock mechanics researchers and practitioners from the main areas of earth sciences to exchange ideas and lessons learnt, and to develop further collaboration and synergies.

chairman's foreword

Mr Ian Suckling
chairman

During 2007–2008, the ACG continued to flourish as the mining industry experienced a period of frenetic activity.

The risks faced by the industry through this period of growth reinforced the importance of the first part of the ACG's mission; "to add value to and create a safer environment within the Australian minerals industry", and created a strong appetite for the second part; "improved education and training in the geomechanics disciplines, combined with coordinated research and technology transfer."

As geotechnical engineering continued to grow in importance, due to the opening of new mines; the intrinsic geotechnical challenges of mature mines as they expand, deepen and age; and the industry's continuing pursuit of safer, more environmentally stable operations, the demand for the ACG's services grew commensurately.

The ACG's small but outstandingly productive and energetic team took on an ambitious schedule of international events during 2007 and 2008, and succeeded in delivering symposia and seminars of the highest quality. 2007 saw the ACG deliver the Tenth International Seminar on Paste and Thickened Tailings; the 2007 International Symposium on Rock Slope Stability in Open Pit Mining and Civil Engineering; and the Fourth International Seminar on Deep and High Stress Mining. 2008 included the First International Seminar on the Management of Rockdumps, Stockpiles and Heap Leach Pads, and the well-attended First Southern Hemisphere International Rock Mechanics Symposium.

These efforts were in addition to conducting a substantial number of more focussed short courses, seminars and workshops as the Centre engaged in increasing the training, education and professional development of those in various roles in the mining industry — from operator to geotechnical specialist. To this end, the ACG team also published excellently finished proceedings of many ACG events, as well as those of other associated groups. The Centre also produced a geotechnical hazard awareness training DVD for underground metalliferous mine workers entitled, *Rockburst – Unleashing Earth's Energy*, and a training DVD for tailings storage facilities titled, *Tailings – From Concept to Closure*.

The ACG's numerous research projects included important work on seismic monitoring, squeezing ground and mine backfill. The strength of industry sponsorship for ACG's projects is a continuing tribute to the calibre of the researchers involved and to the importance and usefulness of their work. The ACG's Mine Seismicity Risk Analysis Program (MS-RAP) software has been further developed as a part of the *Broadening the Application of Seismic Monitoring in Underground Mines* project, Phase III of the ACG's leading research project Mine Seismicity and Rockburst Risk Management. MS-RAP is being used by a number of sponsors' mines in Australia and overseas to assist in the analysis and management of their respective seismic risks.

In 2008, further recognition of the merits of ACG's work, and in particular that of ACG's estimable director, Yves Potvin, came in the form of the award of Western Australia's Inventor of the Year – Ready for Market category, for the development of HEA Mesh™, a high energy absorption mesh that shows great promise in assisting miners to cope with extreme ground conditions.

In 2007, the chairmanship of the ACG Board of Management passed to me following Andrew Grubb's successful tenure. In this role, I have benefitted from the work and guidance of Mark Adams as a fellow industry representative, and saw the Board strengthened in late 2008 with the addition of newer members Chris Stone, BHP Billiton Nickel West and Richard Butcher, Barrick Gold of Australia. I am also grateful for the guidance of members from the ACG's joint venture partners, notably Steve Harvey of CSIRO, Paul Dunn from Curtin University and Carolyn Oldham from The University of Western Australia. Dr Oldham replaced Professor Mark Bush, who made a valuable contribution to the governance and direction of the ACG.

The breadth and intensity of activity saw the ACG's resources stretched through 2007 and 2008. By attending to the quality of its work through this period the ACG team further enhanced its international reputation in underground geomechanics, built on its work in environmental geomechanics, and positioned

itself to continue the growth of its open pit geomechanics work.

This would not have been possible without the diligence and direction of Yves Potvin, and the sustained hard work of his admirable team. As a consequence of their work the ACG has built a sound foundation on which to base its future activities in pursuit of its mission.

Many mines are facing harder times than was the case in 2007/2008, but the ACG will continue to play an important role in advancing the safety, productivity and sustainability of the industry, and will continue to rely on its close relationship with the industry for its direction and funding.

Mr Ian Suckling – chairman

ACG Board of Management: Paul Dunn, Western Australian School of Mines, Curtin University of Technology; Yves Potvin, ACG; Steve Harvey, CSIRO Exploration and Mining; Ian Suckling, Newmont Asia Pacific; Mark Adams, Barminco Ltd; David Smith, The University of Western Australia; and Chris Stone, BHP Billiton Nickel West

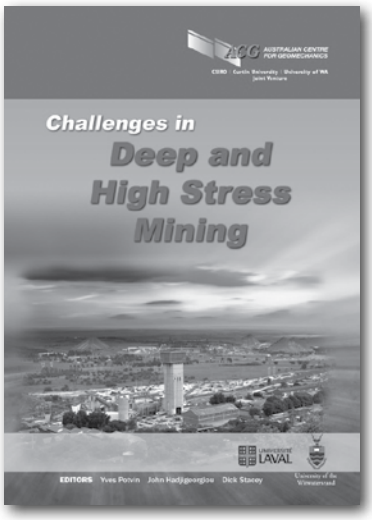
SHIRMS 2008 was attended by more than 220 rock mechanics practitioners and researchers from the civil, mining, fundamental and petroleum industries

director's report

Professor Yves Potvin
director

As the global mining industry enjoyed unprecedented growth in 2007 and 2008, the Australian Centre for Geomechanics experienced exceptional demand for its products and services. This burst of activity enabled the Centre to make significant progress towards achieving its long-term vision to be an international leader in the three main areas of geomechanics: underground, environmental and open pit.

Underground geomechanics has traditionally been an area of strength for the Centre. In 2008, we completed the third phase of our "Mine Seismicity and Rockburst Risk Management" project and attracted sufficient funding to secure a fourth phase. The project has become a true international research effort with world-class mines such as Codelco El Teniente, LKAB Kiruna and Xstrata Kidd Creek joining our group of sponsors. Our international underground geomechanics activities also included the organisation of the well-attended Fourth International Seminar on Deep and High Stress Mining, where the ACG publication entitled *Challenges in Deep and High Stress Mining* was launched.



The ACG's newest publication is the most complete and current source of deep and high stress mining knowledge and technologies

A second area of traditional strength for the Centre is environmental geomechanics. Under the leadership of Professor Andy Fourie, a significant new research project was created, "An Effective Stress Approach to Mine Backfill". The very popular international series of seminars on paste and thickened tailings continues to tour the world, with a stop in Perth in 2007. Since 2005, the ACG has been producing the proceedings for these seminars annually. The international seminar series on mine closure, for which the Centre also produces the proceedings annually, generated strong attendance in Chile, 2007 and in South Africa in 2008. In mid 2008, Professor Fourie joined the Civil and Resource Engineering department at The University of Western Australia, but will remain involved in many of the ACG's activities. The ACG will endeavour to fill the environmental geomechanics position in the near future.

The third key area of the Centre's geomechanics activities is open pit. In addition to our regular open pit geomechanics courses, the ACG hosted the 2007 International Symposium on Rock Slope Stability in Open Pit and Civil Engineering. In 2008, we also completed our research project on "High Resolution Seismic Monitoring in Open Pit Mines" and are looking forward to continuing our research in this area. Open pit geomechanics is an area where we would like to expand our activities to better cater for industry needs and to achieve our long-term vision of advancing mine safety. We have taken a major step towards realising this vision with the appointment of Professor Phil Dight to lead the open pit geomechanics area.

Over the last two years the ACG has considerably strengthened its publication team and now has the capacity to produce between four and six proceedings and books annually. We also produce one mine worker training DVD every year and have established a strong revenue stream from the sales of our reference and training products. Coming off two years of intense research and further education and training activities, the Centre is enjoying a strong financial position. We can draw income from a number of activities including research, courses and events, affiliate memberships, sponsorships and of course, reference and training products.

As the signs of a global slow-down of the mining industry have become imminent towards the end of 2008, the ACG will be looking to consolidate its position and activities in the coming months. Our aim is to remain focussed on industry needs while identifying new opportunities.

Professor Yves Potvin – director

The ACG has made significant advances in environmental geomechanics research and education

The Centre's open pit geomechanics activities promote greater levels of safety and productivity by transferring the knowledge of how pit slopes behave to the people who need it the most — mine workers

mine seismicity and rockburst risk management project

Since its commencement in 1999, the goal of the ACG's renowned Mine Seismicity and Rockburst Risk Management research project has been to advance the application of seismic monitoring in the mining industry to quantify and mitigate the risk of mine seismicity and rockbursting. This has seen close involvement at research sponsors' sites by undertaking detailed site seismic analysis, testing or experimental work and providing seismic system technical support and advice as required.

Phase III of the ACG mine seismicity project entitled, *Broadening the Application of Seismic Monitoring in Underground Mines* commenced in January 2006 under the leadership of Daniel Heal. In mid 2008, Dan left the ACG and the role of project leader was taken up by Johan Wesseloo. Major contributions were also made by Yves Potvin, Paul Harris, Marty Hudyma and Peter Mikula. The project relies heavily on the data from sponsor sites. Interaction with the engineers at the mine sites and contributions of geotechnical engineers from sponsor sites are an integral part of the project's ongoing success.

The project consisted of several sub-projects, some focussed on the further development and application of existing tools and techniques at different sites under a variety of conditions, while others focussed on the development of new techniques and analysis methods as well as filling important gaps in the current state of knowledge. These included the implementation of the regional seismic monitoring network, dynamic support classification with the use of in situ data and blast tests, and the investigation into seismicity related to cave mining.

Several of the project results were published in conference and journal papers. The project's deliverables also improved the usability, navigation and features of the MS-RAP software program. A summary of the project outcomes was tabled at the sponsors meeting held in May 2008. The Seismic Risk Management Plan was well received and the sponsors decided that the document should be made available to the broader mining community via the ACG website.

Numerous additions and refinements were made to the MS-RAP software during this phase — the most notable addition being the implementation of the Rockburst Damage Potential system, minenode attachments and custom fields, as well as a prototype rockburst database.

Phase III sponsors

Acknowledgements

Funding for this project was through the Mine Seismicity and Rockburst Risk Management research project at the Australian Centre for Geomechanics. Phase III of this research project was financially supported by:

Major sponsors

Barrick Gold of Australia Ltd
BHP Billiton Nickel West Pty Ltd
Independence Group NL
Minerals and Energy Research Institute of WA
Norilsk Nickel Australia Pty Ltd
Perilya Ltd

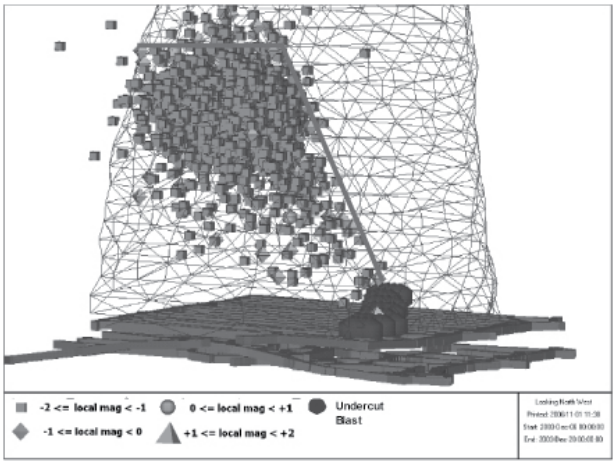
Minor sponsors

Allstate Explorations NL, Beaconsfield Mining JV
Agnico-Eagle Mines Ltd
AngloGold Ashanti Australia Ltd
Codelco Chile, Division El Teniente
Harmony Gold Australia Ltd
Kalgoorlie Consolidated Gold Mines Pty Ltd
Kirkland Lake Gold Inc.
Newcrest Mining Ltd
Newmont Asia Pacific
OZ Minerals Golden Grove Mine
Xstrata Copper Kidd Creek Mine
Xstrata Zinc Canada, Brunswick Mine

Phase IV objectives

Mine seismicity is not only a hazard but also a valuable source of information about rock mass behaviour and its response to mining. This information is not fully utilised and more development will benefit the industry both financially and in terms of safety. Phase IV of this project entitled *Advancing the Strategic Use of Seismic Data in Mines* aims to advance the strategic use of seismic data and to develop an increased understanding of seismicity's response to mining. As with Phase III, the project will further develop existing tools and techniques and address the following topics:

- Determination of dynamic support capacity.
- Developing analysis techniques for the integrated interpretation of seismic and other geotechnical data for cave management.
- The quantification of rock mass degradation.
- The assessment of long-term seismic risk.
- Investigating the interaction between regional seismicity and mine scale seismicity.



Tracking of cave front through seismic activity

Phase IV sponsors

Acknowledgements

Phase IV of this research project is financially supported by:

Major sponsors

Barrick Gold of Australia Ltd
BHP Billiton Nickel West Pty Ltd
Lightning Nickel Pty Ltd
LKAB

Minor sponsors

Agnico-Eagle Mines Ltd
Allstate Explorations NL, Beaconsfield Mining JV
AngloGold Ashanti Australia Ltd
Codelco Chile, Division El Teniente
Goldfields, St Ives Gold Mine
Kirkland Lake Gold Inc.
Newcrest Mining Ltd
Newmont Asia Pacific
Perilya Ltd
Xstrata Copper Kidd Creek Mine
Xstrata Nickel (Cosmos Nickel Project)
Xstrata Zinc Canada, Brunswick Mine

Dr Johan Wesseloo
project leader

high resolution seismic monitoring in open pit mines

The past decades have seen open pit operations mining to deeper levels. Several rock slopes are being mined in excess of 500 m, with some slopes having reached heights of greater than 900 m. There are now several open pit mines which have been designed between 800 and 1000 m in depth. This trend has seen an increased stress environment and a greater uncertainty about the mechanical behaviour of slopes. In turn, this has elevated mine worker safety and productivity risks. To better identify, understand and mitigate the potential geomechanical hazards associated with slope stability failure, the ACG initiated a research project entitled, High Resolution Seismic Monitoring in Open Pit Mines, in 2004.

Funded and supported by project sponsors BHP Billiton Nickel West Pty Ltd, MERIWA and Xstrata Black Star open cut mine, this project aims to demystify the complexities surrounding slope stability by examining the potential as well as the operational constraints of seismic monitoring in open pit mines.

Traditionally, slope monitoring methods measure the displacement of the slope face. This provides no information on the mechanism that drives deformation or damage. In contrast, microseismic monitoring focusses on the assessment of damage, damage accumulation and localisation occurring in the rock mass at small strains, and is both a mechanistic and proactive monitoring approach. Microseismicity has the potential to provide an early warning of developing failures and enhance the understanding of stress induced failure mechanisms in rock slopes. With current developments in the modelling of rock masses, microseismic data can generate unique opportunities for calibrating and enhancing these models.

In February 2007, Johan Wesseloo was appointed project leader (formerly led by Gordon Sweby). Since then Dr Wesseloo has been researching microseismicity in open pit mines based on the data obtained from the two sponsor sites: BHP Billiton's Mt Keith operations and Xstrata Black Star open pit (Mt Isa). The Mt Keith operation comprises an open pit nickel mine. The pit bottom at the end of 2004 was about 355 m deep with mining to the North of the array taking the pit bottom in that area from 155 to 320 m between January 2005 and November 2007 (i.e. the monitoring period).

Xstrata's Black Star open pit is a lead-zinc mine located at Mt Isa. The pit bottom at the end of 2007 was about 120 m deep with the current plan depth exceeding 540 m. The Black Star seismic system recorded very little seismicity and the data obtained from the system could not be used in a detailed analysis for this project study.

Although the study of the spatio-temporal distribution of microseismicity was hampered by the frequent and long periods of data loss, there appears to be some change in the seismicity over the monitoring period. Recorded seismicity does not show any distinct clustering in localisation or time and is similar throughout the monitored volume. This, along with the apparent northward movement of the seismogenic zone as mining progresses to the northern part of the pit, indicates that monitored seismicity is a result of the rock mass response to changes in stress resulting from the mining activity.

In-depth analysis of the seismic data at Mt Keith operations has shown that the rock mass fractures and accumulated damage occurred at stress levels below the rock mass strength generally assigned to the rock mass. The mechanism of this damage accumulation is an extensional fracturing process. The numerical modelling approaches generally used in open pit design do not account for this mechanism. Further, it is suggested that this mechanism fundamentally alters the understanding of the step-path failure.

Although some of the hardware limitations preventing the use of microseismicity monitoring in open pits have been overcome, the effective use of this technology in open pits is still faced with several challenges. Access to the slopes is often restricted to areas surrounding the ramps and crests. As the system is typically rigid, while the mining environment is prone to constant change, an installation may be short lived if installed from a location within the pit and small changes in the mine plan are made. This is particularly the case in mines subject to cutbacks. Small events need to be measured and, as a result, the inter-sensor spacing needs to be less than an equivalent underground system in order to measure and reliably locate these events. Due to the comparatively low stress environment, seismic signals are weak and signal-to-noise ratios are high. Experience at the sponsor sites showed

that more noise than events are triggered resulting in a large data set having to be manually filtered to remove the non-events. The weakness of the events also results in data often being difficult to process resulting in poorer than desired location accuracy.

It has been shown that the principles of seismic system design developed for underground mining are generally applicable to the open pit environment. However, as attenuation increases, with a decrease in stress and increase in the frequency content of the seismic wave, sensor spacing needs to be less than what underground experience recommends.

Based on the experience developed in this pilot project, it is recommended that slope monitoring using microseismicity (MS) and acoustic emission (AE) be aimed at failures of different scales as safety and productivity is negatively affected by smaller as well as larger failures. This would be considered a tactical response combined with a strategic response. There are many instances in open pits where smaller volume higher frequency MS/AE monitoring could be used to identify failure development. An example would be where geometry of the structures indicates kinematic admissibility as slope deformation monitoring is not sensitive enough to detect slope dilation. Focussing on small failures would also provide a faster return to sponsors on the value of MS monitoring. Using seismic monitoring in both the higher MS and lower AE ranges is considered feasible to develop an understanding of the progressive/cumulative degradation of the near surface rock mass resulting from excavation and blasting. In the present study it is inferred that larger fractures will be located closer to the pit wall. It is apparent that many slope failures will be in this altered zone. This work could then be combined with more sensitive surface monitoring using photogrammetry, and in the wall monitoring of deformation.

Further work is required to understand the failure mechanisms. It is recommended that a laboratory study be undertaken using AE and the centrifuge to examine aspects of the brittle extensional dilative failure in a controlled environment. This would supplement the field work.

Examination of the Cohesion-Hardening-Friction-Softening material behaviour with extensional failure in discrete fracture networks in numerical models would offer the best opportunity to understand the failure mechanisms from a numerical perspective. This must be coupled with more routine measurement of the stress state around open pits.

The next phase of this project is under development by Phil Dight, who joined the team in 2008.

Acknowledgements

This research project is financially supported by:

Major sponsors

BHP Billiton Nickel West Pty Ltd

Minerals and Energy Research Institute of WA

Xstrata Nickel

Installation of the seismic system

an effective stress approach to mine backfill

The ACG, in collaboration with The University of Western Australia, commenced this industry funded project in July 2007 to investigate ways to improve the safety and reduce the cost of cemented paste backfilling.

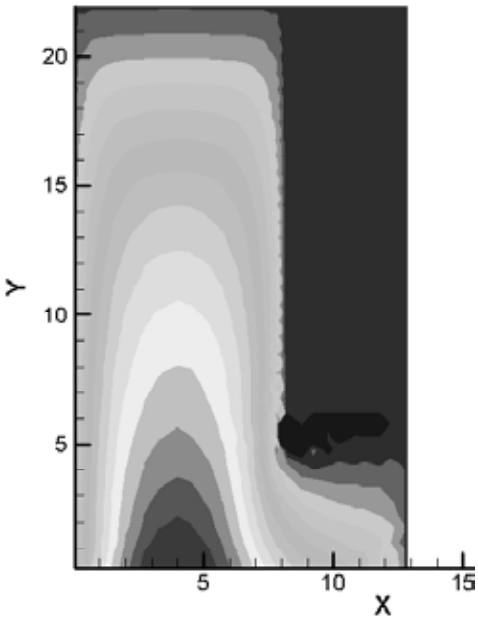
The project was initiated after a clearly defined gap in knowledge was identified. Although the Bronzewing disaster attracted a great deal of media coverage over the years, what is less well known is that failures of pastefill barricades occur with unsettling regularity every year, all around the world. Failures of these barricades compromise the safety of underground workers. The uncertainties as to how to quantify barricade loads (and thus design them properly) has probably hampered the uptake of cemented paste backfill (CPB), despite the numerous advantages provided by the technology.

It was established that the only method for understanding the evolution of stresses in a stope during filling was through understanding the process from an effective stress standpoint. Therefore, the initial task of the project was to utilise laboratory, field and numerical studies to develop a rational understanding of the CPB deposition process, including the time dependent interaction of fill accumulation, cement hydration and consolidation. One particularly interesting development included identifying a previously unreported phenomenon, relating to the reduction of pore pressure drop as a consequence of cement hydration, which results in vastly reduced barricade loads under certain circumstances.

Using this new knowledge, we have been able to explain the apparently anomalous pore pressure responses measured in backfilled stopes that have been reported by a number of research groups both in Australia and Canada. It turns out that the pore pressure responses are not anomalous at all, but entirely consistent with the behaviour explained through our research, which is a combination of hydration induced 'self-desiccation' and the increase in shear and bulk stiffness that occurs simultaneously. This work clearly shows that the pore pressure response in a filled stope, and the barricade load, can vary significantly, depending on the particular combination of fill material and binder used.

It has been understood for some time that the phenomenon known as 'arching', whereby shear stresses that develop between the backfill and the stope walls result in load-shedding to the walls, which in turn leads to a reduction in vertical, and hence in horizontal, stresses. However, what has not been properly grasped is that arching can only develop when there is some settlement of the backfill where significant effective stresses can develop, i.e. when there is some consolidation. Our numerical modelling has highlighted these aspects of arching.

These fundamental developments culminated in a rational approach for predicting the behaviour of CPB during placement. This includes a novel experimental approach for characterising the behaviour of CPB throughout the hydration process, as well as a numerical model that can couple this evolution of the material properties with the imposed boundary conditions to understand the process as a whole. Now that this understanding is well established, it is being applied to critical areas of uncertainty in design.

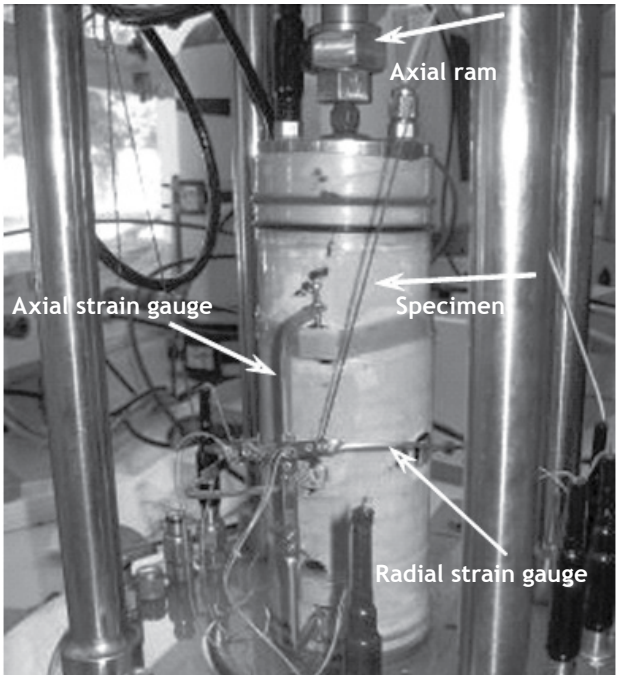


Output from the developed numerical analysis software Minefill-2D

Initially this theory was directed towards the application of barricade stresses during filling. Using the understanding developed, it was established that a number of characteristics, which may appear subtle, can actually significantly influence the resulting barricade stresses. For example, some of our

work on tailings having high talc content showed extremely slow hydration rates, resulting in very small pore pressure drops and thus high barricade loads.

Another aspect that this theory has been applied to is the often reported discrepancy between unconfined compressive strength (UCS) values measured in the laboratory and those measured on specimens recovered from backfilled stopes, i.e. field results. The field values almost invariably are higher than the laboratory results, but to date no satisfactory explanation for this discrepancy has been reported. As described in the publications listed in this report, the key issue is the effective stress under which a sample is cured. By replicating the effective stresses likely to occur in a backfilled stope and then curing samples under this value of effective stress, we have shown that laboratory and field results will be similar.



Laboratory testing

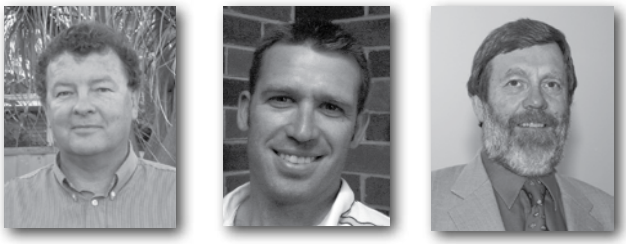
At present, work is focussing on extending our numerical model to three dimensions, so that fully representative geometries can be modelled, as well as undertaking additional field studies. Phase I of the project (the current phase) will end in June 2010. There are plans to continue the work with Phase II, which will concentrate on implementing the results of Phase I at sponsor sites and developing fill management techniques based on output from our improved design philosophy.

Field testing

Acknowledgements

Phase I of this research project was financially supported by:

Barrick Gold of Australia Ltd
BHP Billiton Nickel West Pty Ltd
Panoramic Resources Ltd



Phase I research project team: Andy Fourie, Matt Helinski and Martin Fahey

squeezing ground task force

Squeezing ground conditions pose a serious challenge for a number of underground mines. In the mining context, a practical definition for squeezing ground conditions is when the total displacement of an excavation or, more specifically, the drive closure reaches at least tens of centimetres within the life expectancy of a supported drive. In general, mine drives are designed to be in operation for up to two years. It is also implied that in squeezing ground conditions the resulting loads and displacements will be greater than the capacity of a 'stiff' support system. This often results in the significant failure of ground support and necessitates extensive rehabilitation work.

The "Squeezing Ground Task Force" was formed in 2007 by the Australian Centre for Geomechanics as a research initiative to faciliate a better understanding of squeezing ground conditions and how different mines manage these issues. The primary ground control aim of the mines dealing with squeezing ground is often to devise a ground support system and strategy that will enable them to complete mining locally, without having to go through expensive rehabilitation work. Some mines temporarily achieve this goal by a trial-and-error process, at least until the ground has worsened or until the stress increases. Many other mines operating in squeezing environments resign themselves to reducing the number of rehabilitation cycles to one or two.

The Squeezing Ground Task Force was a collaboration between the ACG, Professor John Hadjigeorgiou of Laval University, and industry partners BHP Billiton Nickel West Pty Ltd, Norilsk Nickel Australia Pty Ltd (previously Lionore Australia Pty Ltd), Gold Fields Australia Pty Ltd, Agnico-Eagle Mines Ltd and Xstrata Nickel Canada. In May 2008, the task force completed a state-of-the-art review of the squeezing ground problems in selected underground mines owned by the industry partners. Site visits were undertaken in July 2007 in Canada and in October 2007 in Australia. In total, four Western Australian mines (Maggie Hayes, Black Swan Nickel, Waroonga and Perseverance), and one Canadian mine (LaRonde) were visited by the Squeezing Ground Task Force. The Canadian leg of the visit included visits to two Xstrata Nickel mines: Craig and Fraser.

Canadian mines tend to use weld mesh as their main form of surface support

The comparison of the practices between the five mines involved in the Squeezing Ground Task Force allowed the task force to draw some pertinent conclusions. This investigation also challenged some of the conventional wisdom and has helped formulate some interesting questions that could eventually be addressed in future research.

The most obvious observation from the mine visits is the clear dichotomy between Australian and Canadian ground support practices. In terms of surface support, Australian mines are using an excessive amount of fibrecrete, while the Canadian mines rely primarily on weld-mesh, at times supplemented with mesh-straps. On the other hand, reinforcement practices in Australia are strongly driven by the installation technique, which are more mechanised, relying almost entirely on jumbos. From Task Force observations, a new research proposal to address squeezing ground problems is currently in preparation.

Acknowledgements

This research project was financially supported by:

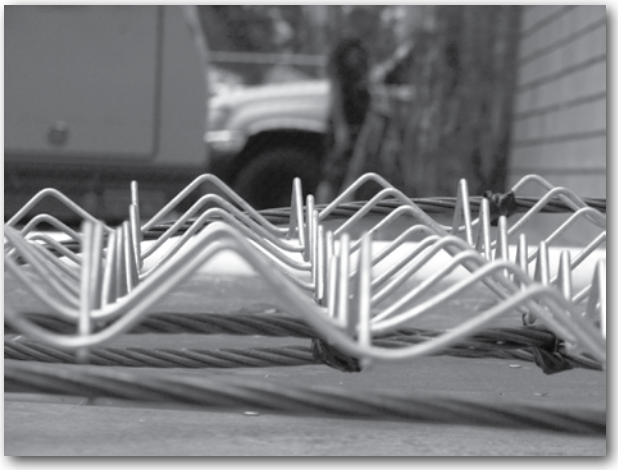
Agnico-Eagle Mines Ltd
BHP Billiton Nickel West Pty Ltd
Gold Fields Australia Pty Ltd
Lionore Australia Pty Ltd, Lake Johnston
Lionore Australia Pty Ltd, Black Swan Nickel

hea mesh™

One of the main tools used by mining companies to mitigate rockburst risk is the installation of dynamic resistant support systems. Ground support systems such as rockbolts, cable bolts, mesh and shotcrete are capable of absorbing a high quantity of energy.

Professor Yves Potvin initiated the High Energy Absorption (HEA) Mesh project in 2005. The ACG, in collaboration with Onesteel Reinforcing Pty Ltd, has developed a state-of-the-art support system to help mine workers respond more proactively to the hazards posed by mine seismicity and rockburst. The new HEA Mesh™ combines both strength and flexibility, providing a yieldable and high load support system, suitable for extreme mining conditions like high seismicity and squeezing ground.

HEA Mesh™ has a unique design that enables an efficient load share between surface support and reinforcement. It is a simple concept that involves the pre-fabrication of a cable lacing pattern over a commonly used 2.4 x 3 m sheet of mesh that has been crinkled, or is standard. As the rock surface moves in (wall closure) it pulls the crinkled or standard mesh which is contained by the cable web. As the cables are solidly attached to the bolts, the load is transferred to the bolts and shared between all bolts and the cable.



HEA Mesh™ is suitable for extreme mining conditions like high seismicity and squeezing ground

Underground mining testing and laboratory results

- Testing revealed that HEA Mesh™ can be installed with a jumbo as easily and rapidly as commercial sheet mesh.
- It has a high load bearing capacity up to 17 t.
- The mesh can accommodate significant deformation as the cable can stretch over its entire length.
- Laboratory tests have shown that a 2.4 x 3 m sheet can deform more than 800 mm before breaking a single wire or weld.
- Further testing and dynamic load tests using the simulated rockburst technique are planned in 2009.

Key features

- Mesh configuration, weight, wire thickness and size can be adjusted to meet most sites' unique ground support requirements. The mesh can be supplied as a 5 or 6 mm galvanised wire.
- HEA Mesh™ is supplied as crinkled or standard mesh sheets. The largest crinkle sheet mesh is 3 x 4 m. The largest plain flat sheet is 6 x 2.4 m.
- Applicable to extreme mining environments and underground tunnelling projects.

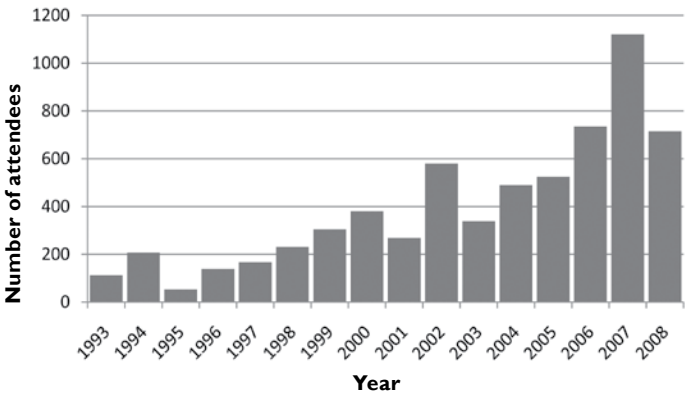
Yves Potvin was delighted to be awarded the Inventor of the Year 2008 award in the Ready for Market category.

The ACG is pleased to be acknowledged by the Department of Industry and Resources of Western Australia for its innovation in technology design.

geomechanics education and training courses

During 2007 and 2008, the ACG's further training and education programme attracted a record number of mining professionals. As a result of the unprecedented mining economic boom, many large, global mining companies and suppliers had a new workforce to train and educate. As a leading provider of specialist and advanced training and education for mining personnel and geotechnical practitioners in mining and environmental geomechanics, the ACG successfully supported industry to reach their business and training objectives. More than 1800 mining personnel attended ACG events during 2007 and 2008 (see graph below).

ACG event attendances 1993-2008



THE ACG'S GEOMECHANICS TRAINING AND EDUCATION PLATFORM PROVIDES A SOLID BASE FOR THE TRANSFER OF TECHNOLOGICAL DEVELOPMENTS AND PRACTICES BASED ON KNOWLEDGE GATHERED FROM LOCAL AND INTERNATIONAL SOURCES

2007 EVENTS

Risk Analysis and Economic Valuation of Mine Projects Course
Brisbane, Queensland, 3–5 April 2007

Rheology Workshop
Fremantle, Western Australia, 12 March 2007

10th International Seminar on Paste and Thickened Tailings
Fremantle, Western Australia, 13–15 March 2007

Advanced Ground Support in Underground Mines Course
Perth, Western Australia, 2–4 May 2007

Mine Water Management Seminar
Perth, Western Australia, 12–13 June 2007

Planning for Mine Closure Seminar
Perth, Western Australia, 14–15 June 2007

Blasting for Stable Slopes Course
Perth, Western Australia, 30–31 August 2007

Slope Stability Forum
Perth, Western Australia, 11 September 2007

International Symposium on Rock Slope Stability in Open Pit Mining and Civil Engineering
Perth, Western Australia, 12–14 September 2007

Hydraulic and Paste Backfill Seminar
Perth, Western Australia, 5 November 2007

Managing Seismic Risks in Mines Short Course
Perth, Western Australia, 6 November 2007

Fourth International Seminar on Deep and High Stress Mining
Perth, Western Australia, 7–9 November 2007

Practical Soil Mechanics in Mining Course
Perth, Western Australia, 4 December 2007

Total Tailings Management Seminar
Perth, Western Australia, 5–7 December 2007

2008 EVENTS

Planning for Stable Landforms Workshop
Perth, Western Australia, 4 March 2008

First International Seminar on the Management of Rock Dumps, Stockpiles and Heap Leach Pads
Perth, Western Australia, 5–6 March 2008

Geotechnical Engineering in Open Pit Mines Seminar
Perth, Western Australia, 6–8 May 2008

Coal Tailings Impoundments: Risks, Responses and Alternatives Seminar
Sydney, New South Wales, 14–15 May 2008

Blasting for Stable Slopes Course
Perth, Western Australia, 24–25 July 2008

Petroleum Geomechanics in the Value Chain Short Course
Perth, Western Australia, 14–15 September 2008

From Rock Mass to Rock Model Workshop
Perth, Western Australia, 15 September 2008

First Southern Hemisphere International Rock Mechanics Symposium
Perth, Western Australia, 16–19 September 2008

Development and Production Blasting in Underground Mines
Perth, Western Australia, 3–4 November 2008

Ground Support in Underground Mining
Perth, Western Australia, 5–7 November 2008

Tailings Management for Decision Makers
Perth, Western Australia, 3–4 December 2008

ON THE HORIZON

First International Seminar on Safe and Rapid Development Mining
Perth, Western Australia, 6–7 May 2009

Why are today's developments similar to those 30 years ago? Are the Canadian or Scandinavian mining industries developing faster than Australia? What role will automation play in future mines? The ACG looks forward to addressing these important issues at the First International Seminar on Safe and Rapid Development Mining.

www.srdm.com.au

Fourth International Conference on Mine Closure (to be held in collaboration with Centre for Land Rehabilitation, The University of Western Australia)
Perth, Western Australia, 9–11 September 2009

The ACG is pleased to welcome Mine Closure 2009 back to Perth. In 2009, we again look forward to actively progressing the economic and socially acceptable closure of mines at this traditionally well-attended event.

www.mineclosure2009.com

Second International Symposium on Block and Sublevel Caving
Perth, Western Australia, 20–22 April 2010

The strong attraction of some mining companies to cave mining methods in recent years is driven by the typical low cost and high productivity of these methods. The ACG looks forward to hosting the second symposium of this series in Australia.

www.caving2010.com

International Seminar on the Reduction of Risk in the Management of Tailings and Mine Waste
Perth, Western Australia, 6–10 September 2010

Whether the mining industry is in a boom period or a downturn, the universal truth is that there is rarely money to be made from tailings management. The reality is that it is invariably solely a cost to a company. This new ACG seminar will tackle the full range of issues that constitute risks in the management of mining wastes, particularly tailings and waste rock.

www.minewaste2010.com

BALANCE SHEET AS AT 31 DECEMBER 2008

	2008 A$	2007 A$	2006 A$
Cash	1,333,727	1,259,536	795,260
Receivables	4,036	7,900	11,021
Total current assets	1,337,763	1,267,436	806,281
Plant and equipment	71,435	64,918	80,600
Total non-current assets	71,435	64,918	80,600
Total assets	1,409,198	1,332,354	886,881
Creditors and borrowings	1,630	1,064	8,606
Provisions (leave liabilities)	208,723	202,540	128,538
Total current liabilities	210,353	203,604	137,144
Net assets	1,198,845	1,128,750	749,737
Shareholder's equity			
Partner contributions	243,980	243,980	243,980
Retained profits/acc (losses)	954,865	884,770	505,757
Total shareholder's equity	1,198,845	1,128,750	749,737

The balance sheet should be read in conjunction with the accompanying notes.

PROFIT AND LOSS FOR THE YEAR ENDED 31 DECEMBER 2008

	2008 A$	2007 A$	2006 A$
Income			
Affiliate membership fees	72,000	60,000	60,545
Sponsorship environmental position	0	100,000	100,000
Project administration	106,409	42,792	63,154
Project income – staff time	194,623	79,668	102,027
Project income – reimbursements	13,311	9,040	21,813
Event fees and sponsorships	884,862	1,433,824	1,110,927
Publications and training materials	208,189	169,524	141,664
Publications sponsorships	0	10,000	39,000
Government grants	30,000	0	0
Interest	16,077	15,050	0
Profit on trade-in of vehicle	0	0	0
UWA student and research allocation	59,557	30,013	65,921
Industry funded special projects	78,605	62,275	46,860
Total income	**1,663,633**	**2,012,186**	**1,751,911**
Expenses			
Personnel	914,142	774,824	613,064
Personnel – relocation expenses	0	23,998	0
Provisions – personnel	208,723	202,540	128,538
Office space incl. furniture	42,948	37,423	32,035
Project related expenses	8,633	91,452	43,442
Events, training and royalties	448,680	432,852	363,262
Travel, conferences and MV allowances	24,960	24,661	21,657
Operating overheads incl. printing	90,390	70,080	51,209
Professional services	18,000	18,000	15,300
Depreciation	12,258	12,130	17,573
Loss on trade-in of vehicle	29,321	12,442	20,757
Printing of books	0	45,640	33,759
Student related expenses incl. special projects	19,798	12,117	116,023
Total expenses	**1,817,853**	**1,758,159**	**1,456,619**
Net profit (loss)	**-154,220**	**254,027**	**295,292**
Opening retained earnings	379,774	125,747	-169,545
Closing retained earnings	**225,554**	**379,774**	**125,747**

The profit and loss account should be read in conjunction with the accompanying notes.

STATEMENT OF CASHFLOWS
Year Ended 31 December 2008

	2008 A$	2007 A$	2006 A$
Cash flow from operating activities			
Receipts from customers	1,651,420	2,000,256	1,748,833
Payments to suppliers and employees	-1,566,985	-1,538,588	-1,285,649
Government grants	0	0	0
Interest received	16,077	15,050	0
Net cash flows from/(used in) operating activities	100,512	476,718	463,184
Cash flows from investing activities	0	0	0
Acquisitions of plant and equipment	-29,321	-12,442	-25,069
Net cash flows from/(used in) investing activities	-29,321	-12,442	-25,069
Cash flows from financing activities			
Partners contributions	0	0	0
Net cash flows from (used in) financing activities	0	0	0
Net increase/(decrease) in cash held	71,191	464,276	438,115
Add: Opening cash brought forward	1,259,536	795,260	357,145
Closing cash carried forward	1,330,727	1,259,536	795,260

The statement of cash flows should be read in conjunction with the accompanying notes.

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENTS AT 31 DECEMBER 2008

1 Summary of Significant Accounting Policies

The financial statements have been prepared in accordance with the historical cost convention. Cost in relation to assets represents the cash amount paid or the fair value of the asset given in exchange.

The financial statements have been made out in accordance with applicable accounting standards.

The accounting policies adopted are consistent with those of the previous year unless otherwise specified.

(a) Depreciation

Depreciation is provided on a straight line basis on all tangible fixed assets, other than freehold land, at rates calculated to allocate their cost or valuation less estimated residual value, against the revenue derived over their estimated useful lives.

As of 2007, in line with The University of Western Australia's policies, equipment purchases of less than $5,000 in value are no longer recorded as an asset. The at cost plant and equipment value was amended accordingly in 2008.

(b) Income Tax

Tax effect accounting procedures are not applied as the Australian Centre for Geomechanics is a tax free research and education centre run on a not for profit basis.

(c) Income Recognition

Government grants are recorded as income when received.

Membership fees are recognised as income in line with the membership period covered in the subscription.

(d) Employee Entitlements

Provision is made for long service leave and annual leave estimated to be payable to employees on the basis of statutory and contractual requirements. Vested entitlements are classified as current and non-current liabilities.

The contributions made to superannuation funds by the entity are charged against profit.

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENTS AT 31 DECEMBER 2008 (continued)

	2008 A$	2007 A$	2006 A$
2 Operating Profit/(Loss)			
a. The operating profit/(loss) before income tax is arrived at after charging/(crediting) the following items			
Depreciation – plant and equipment	12,258	12,130	17,573
Provision for employee entitlements	208,723	202,540	128,538
b. Included in the operating profit/(loss) are the following items of operating revenue			
Affiliate membership fees	72,000	60,000	60,545
Industry funding environmental position	0	100,000	100,000
Industry funding special projects	78,605	62,275	46,860
Project administration and staff time	310,307	131,500	186,994
Course fees and sponsorships	892,762	1,433,824	1,110,927
Publications and training materials	208,189	169,524	141,664
Interest – other persons/corporations	16,077	15,050	0
Profit on sale of vehicles	0	0	0
Industry sponsorships for publications	0	10,000	39,000
UWA student and research allocation	59,557	30,013	65,921
Government grants	30,000	0	0
Total revenue	1,667,497	2,012,186	1,751,911
3 Receivables			
Other debtors	4,036	7,900	11,021
Partners receivables	0	0	0
Total receivables	4,036	7,900	11,021
4 Plant and Equipment			
At cost	96,839	176,620	176,097
Provision for depreciation	-25,404	-111,702	-95,497
Total plant and equipment	71,435	64,918	80,600

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENTS AT 31 DECEMBER 2008 (continued)

		2008 A$	2007 A$	2006 A$
5	**Creditors and Borrowings (current)**			
	Trade creditors and accruals	1,630	1,064	8,606
6	**Provisions (current)**			
	Employee entitlements	208,723	202,540	128,538
7	**Partner Contributions**			
	CSIRO opening/closing balance	60,320	60,320	60,320
	WA School of Mines opening/closing balance	60,320	60,320	60,320
	UWA Geomechanics opening/closing balance	60,320	60,520	60,520
	UWA Geology	60,320	60,320	60,320
	DMP* (previously DoIR) opening/closing balance * contribution mainly provided in-kind	2,500	2,500	2,500
	Total partner contributions	243,980	243,980	243,980
8	**Statement of Cash Flows**			
	Reconcilitation of net profit/(loss) to the net cash flow from operations			
	Net profit/(loss)	-154,220	254,027	295,292
	Changes in assets and liabilities			
	– Other debtors	3,864	3,121	17,406
	– Trade creditors and accruals	566	-7,542	-16,382
	– Employee entitlements provision	208,723	202,540	128,538
	Depreciation	12,258	12,130	17,573
	Loss on sale of vehicles	29,321	12,442	20,757
	Net cash flow from operating activities	100,512	476,718	463,184

We gratefully acknowledge the support of Mr Ian Thorson – Faculty Accountant, The University of Western Australia, who provided support in the preparation of the asset register.

publications

The Australian Centre for Geomechanics provides industry with an excellent source of geomechanical knowledge through our event proceedings, research reports and relevant industry publications. In response to industry need for high quality, comprehensive and state-of-the-art information, the ACG produces peer and technically reviewed symposium and seminar proceedings.

PROFESSOR YVES POTVIN (DIRECTOR)

Books (Editor)

Potvin, Y., Hadjigeorgiou, J. and Stacey T.R., Challenges in Deep and High Stress Mining, 2007, ISBN 978-0-9804185-1-4, Australian Centre for Geomechanics, Perth, 666 p.

Potvin, Y., Proceedings of the International Symposium on Rock Slope Stability in Open Pit Mining and Civil Engineering, Slope Stability 2007, September 2007, ISBN 978-0-9756756-8-7, Australian Centre for Geomechanics, Perth, 543 p.

Potvin, Y., Proceedings of the Fourth International Seminar on Deep and High Stress Mining, Deep Mining 07, November 2007, ISBN 978-0-9804185-2-1, Australian Centre for Geomechanics, Perth, 507 p.

Potvin, Y., Carter, J., Dyskin, A.V. and Jeffrey, R., Proceedings of the First Southern Hemisphere International Rock Mechanics Symposium, SHIRMS 2008, 16–19 September 2008, Perth, Australia, ISBN 978-0-9804185-5-2, Australian Centre for Geomechanics, Perth, Vol. 1: 716 p., Vol. 2: 641 p.

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Potvin, Y. and Slade, N., Controlling extreme ground deformation: learning from four Australian case studies. Re-printed in Challenges in Deep and High Stress Mining, Y. Potvin, J. Hadjigeorgiou and T.R. Stacey (eds), 2007, Australian Centre for Geomechanics, Perth, pp. 355–361.

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Hudyma, M.R., **Potvin**, Y. and Allison, D., Seismic monitoring of the Northparkes Lift 2 block cave – Part 1 Undercutting, Proceedings of the First International Symposium on Block and Sub-Level Caving, Cave Mining, 8–10 October 2007, Cape Town, South Africa, The South African Institute of Mining and Metallurgy, Johannesburg, pp. 303–333.

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PROFESSOR PHIL DIGHT (PROFESSOR OF GEOTECHNICAL ENGINEERING)

Proceedings of conferences, symposia and seminars

Dight, P.M. and Dyskin, A.V., On the determination of rock anisotropy for stress measurement, Proceedings of the First Southern Hemisphere International Rock Mechanics Symposium, SHIRMS 2008, Y. Potvin, J. Carter, A.V. Dyskin and R. Jeffrey (eds), 16–19 September 2008, Perth, Australia, Australian Centre for Geomechanics, Perth, Vol. 2, pp. 575–585.

PROFESSOR ANDY FOURIE (PRINCIPAL - ENVIRONMENTAL GEOMECHANICS)

Books (Editor)

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Helinski, M., Fahey, M. and **Fourie**, A.B., Numerical Modelling of Cemented Mine Backfill Deposition, Journal of Geotechnical and Geoenvironmental Engineering, ASCE, October 2007, pp. 1308–1319.

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MR DANIEL HEAL (PROJECT LEADER)

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DR JOHAN WESSELOO (PROJECT LEADER)

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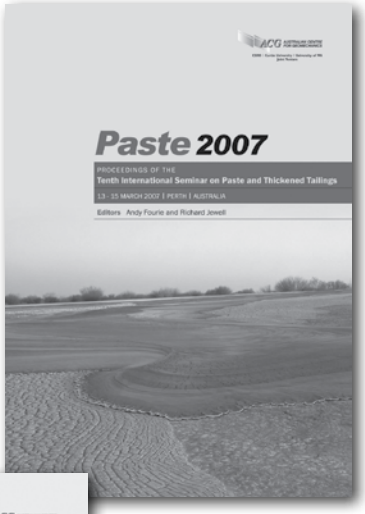
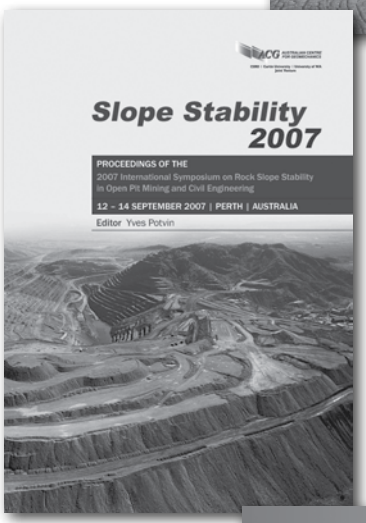
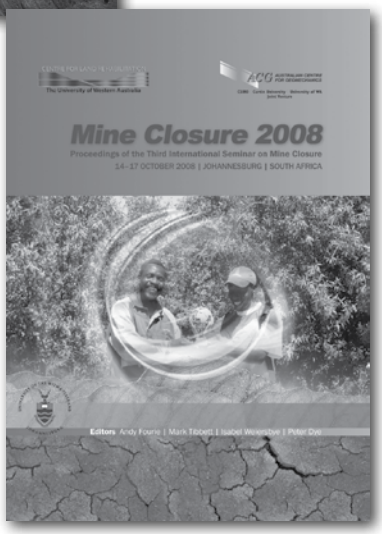






geomechanics training products

COLLABORATING WITH INDUSTRY TO DEVELOP STATE-OF-THE-ART TRAINING AND AWARENESS MATERIAL FOR MINE WORKERS

Recognising the vital importance of employee training and education to improve mine safety and production performance, the ACG's training platform is designed to enhance the competency, knowledge and skill base of the mining workforce.

TAILINGS - FROM CONCEPT TO CLOSURE

Best practices for tailings disposal - A training DVD for owners and operators of tailings storage facilities

It is frustrating that despite modern engineering, tailings storages continue to wreak havoc through failures or spillages. These failures may lead to stopping production, multi-million dollar clean-ups, some loss of life and potentially have a major impact on company credibility and share value. This new ACG training DVD, scripted by Andy Fourie, was launched in 2007. It is an essential training tool for all mines or processing plants that have tailings storage facilities (TSFs).

DVD content:

- TSF overview
- TSF operation
- Water management
- Monitoring and response
- Closure and rehabilitation

Project sponsors

- Barrick Gold of Australia Ltd
- BHP Billiton Nickel West Pty Ltd
- Newmont Asia Pacific
- Rio Tinto
- Worsley Alumina

ROCKBURST - UNLEASHING EARTH'S ENERGY

A geotechnical hazard awareness training DVD for underground mine workers

Following the rockfall incident at the Beaconsfield mine in Tasmania, Australia, it has become evident that the phenomenon of rockburst and seismicity in mines is poorly understood by the general population and, more importantly, by a large portion of the mining community.

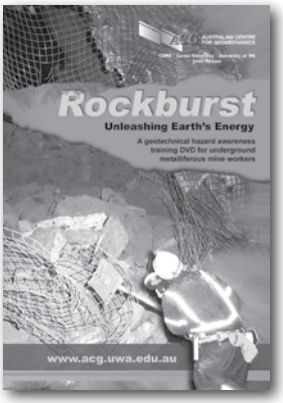
The ACG developed a state-of-the-art training DVD that explains the phenomenon underlying mine seismicity and rockburst in mines. Underground mine workers will be equipped with essential knowledge to understand this hazard, including understanding the difference between natural seismicity and mine induced seismicity, what makes a mine seismically active, the precursors, and how to control seismic hazards.

Content includes:

- What is a seismic event?
- What is a rockburst?
- Is there a precursor to large rockbursts?
- How to control the risk of rockburst?

Project sponsors

- Allstate Explorations NL, Beaconsfield Mining JV
- AngloGold Ashanti Australia Ltd
- Barrick Gold of Australia Ltd
- BHP Billiton Nickel West Pty Ltd
- Independence Group Lightning Nickel Pty Ltd
- Newmont Asia Pacific



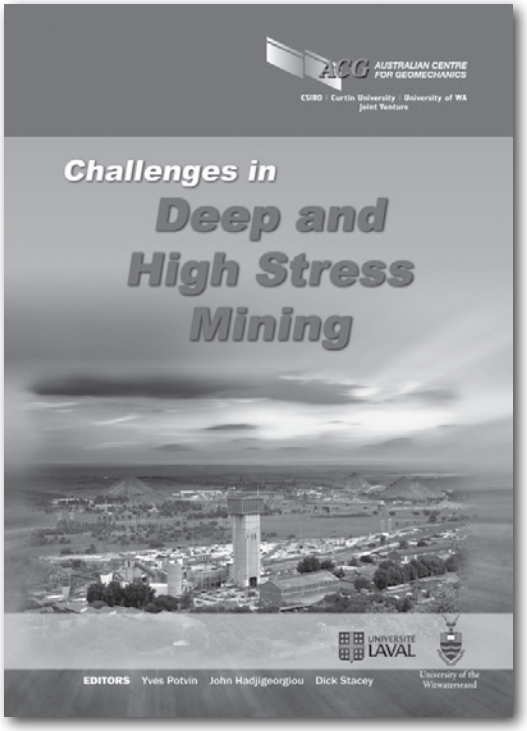
CHALLENGES IN DEEP AND HIGH STRESS MINING

The ACG's newest publication was launched at the Fourth International Seminar on Deep and High Stress Mining held in Perth in November 2007. The publication features the most relevant papers presented at the series of biennial international seminars on deep and high stress mining held in Perth (2002), Johannesburg (2004) and Quebec City (2006). One hundred and twenty papers were presented at the three seminars producing the most complete and current compilation of literature on this highly specialised subject. This unique resource aims to assist mine personnel dealing on a day-to-day basis with the challenges of mining in deep and high stress conditions.

Book sponsors

> Newmont Asia Pacific

> Xstrata Copper



THE ACG'S TRAINING AND FURTHER EDUCATION TOOLS WOULD NOT HAVE BEEN DEVELOPED IF IT WERE NOT FOR THE SUPPORT AND ENCOURAGEMENT OF VARIOUS MINING COMPANIES, RESEARCH ORGANISATIONS AND INDUSTRY SUPPLIERS. IT IS THIS COLLABORATIVE APPROACH THAT BOTH CONSOLIDATES AND VALIDATES ACG'S ROLE IN THE DEVELOPMENT OF SAFETY TRAINING TOOLS AND TECHNIQUES. THROUGH THIS SPIRIT OF COOPERATION, THE ACG CONTINUES TO WORK WITH MINING STAKEHOLDERS AND RESEARCH ORGANISATIONS TOWARD THE COMMON VISION OF CREATING A SAFER WORKING ENVIRONMENT WITHIN THE AUSTRALIAN AND OVERSEAS MINERALS INDUSTRIES.

acg membership

During 2007–2008, the Australian Centre for Geomechanics welcomed onboard Australian Tailings Consultants, BHP Billiton Nickel West Pty Ltd, Fero Strata Systems Pty Ltd, Rio Tinto Iron Ore and Snowden Mining Industry Consultants as the newest members of the Corporate Affiliate Programme. Corporate and technical affiliate members assist the ACG to provide research excellence, training and education in the geomechanics disciplines. These memberships are fundamental in alerting funding bodies of the need to support the Centre. Contributions by affiliates are used by the Centre to promote research excellence, education and training in geomechanics areas.

The ACG was delighted to have the following Corporate and Technical Affiliate Members for 2007–2008.

CORPORATE AFFILIATES

Argyle Diamonds Pty Ltd

AngloGold Ashanti Australia Ltd

Australian Tailings Consultants

Barrick Gold of Australia Ltd

BHP Billiton Cannington Pty Ltd

BHP Billiton Iron Ore Pty Ltd

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Kalgoorlie Consolidated Gold Mines Pty Ltd

Newmont Asia Pacific

PT Freeport Indonesia

Rio Tinto Iron Ore

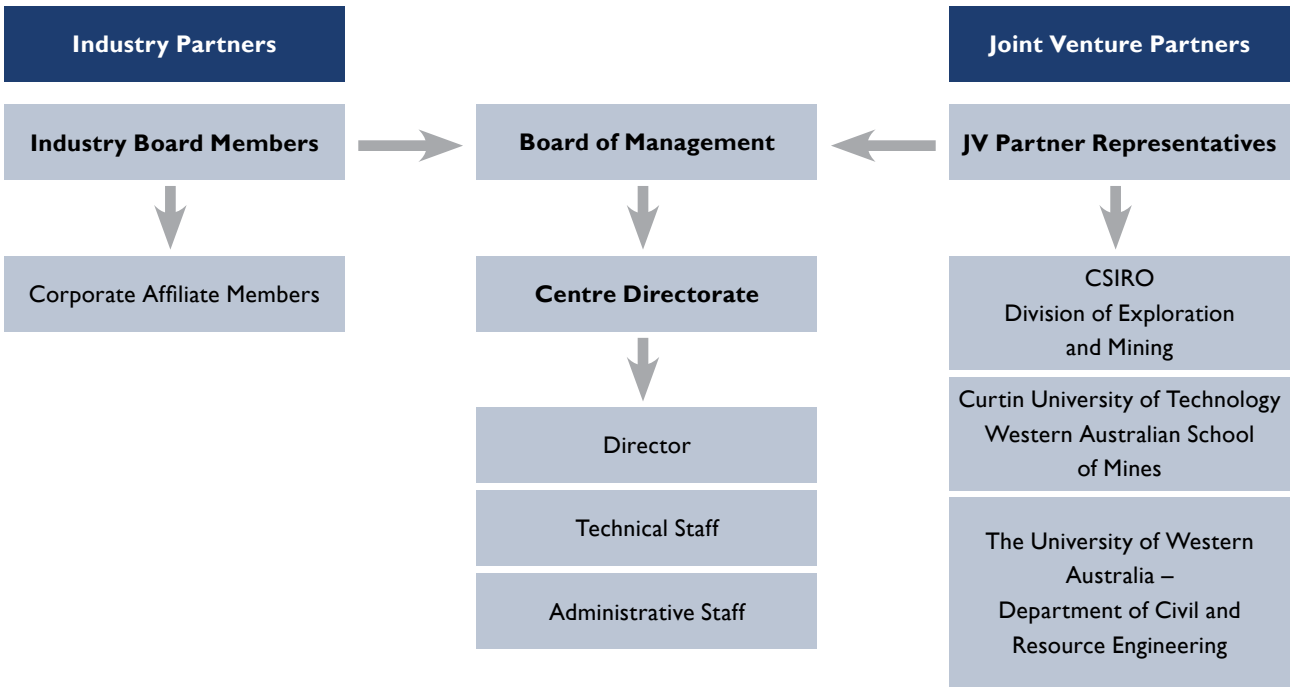
Snowden Mining Industry Consultants

SRK Consulting

TECHNICAL AFFILIATE

Mr M. Sandy (AMC Consultants Pty Ltd)

management structure



AUSTRALIAN CENTRE FOR GEOMECHANICS BOARD OF MANAGEMENT

The Australian Centre for Geomechanics Board of Management comprises of an independent chairman, director of the Centre and industry and joint venture partner representatives. The Board meets up to four times a year to present strategic direction for the Centre, review and approve activities and operations and to provide counsel.

Joint Venture Partner Representatives (3)

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(CSIRO DEM)

Professor Paul Dunn
(Curtin University of Technology – WASM)

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ACG AUSTRALIAN CENTRE FOR GEOMECHANICS

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