

AUSTRALIAN CENTRE FOR GEOMECHANICS

CSIRO | The University of Western Australia | Joint Venture

MGR 2019

Proceedings of the First International Conference on Mining Geomechanical Risk

9–11 April 2019 | Perth, Australia



EDITOR Johan Wesseloo

Mining Geomechanical Risk 2019

Proceedings of the First International Conference on Mining Geomechanical Risk

9–11 April 2019, Perth, Australia

Editor

Johan Wesseloo

Australian Centre for Geomechanics, The University of Western Australia, Australia

ACG AUSTRALIAN CENTRE FOR GEOMECHANICS

CSIRO | The University of Western Australia | Joint Venture

Copyright

© Copyright 2019. Australian Centre for Geomechanics, The University of Western Australia. All rights reserved. No part of this publication may be reproduced, stored or transmitted in any form without the prior permission of the Australian Centre for Geomechanics, The University of Western Australia.

Disclaimer

The information contained in this publication is for general educational and informative purposes only. Except to the extent required by law, the Australian Centre for Geomechanics, The University of Western Australia make no representations or warranties express or implied as to the accuracy, reliability or completeness of the information stored therein. To the extent permitted by law, the Australian Centre for Geomechanics, The University of Western Australia exclude all liability for loss or damage of any kind at all (including indirect or consequential loss or damage) arising from the information in this publication or use of such information. You acknowledge that the information provided in this publication is to assist you with undertaking your own enquiries and analyses and that you should seek independent professional advice before acting in reliance on the information contained therein. While all care has been taken in presenting this information herein, no liability is accepted for errors or omissions. The views expressed in this publication are those of the authors and may not necessarily reflect those of the Australian Centre for Geomechanics, The University of Western Australia.

The papers contained in this publication are for general information only, and readers are cautioned to take expert advice.

Top front cover photo Copyright © 2019 Rio Tinto.

Top back cover photo courtesy of SNF ChemQuest.

Production team: Garth Doig, Christine Neskudla, Josephine Ruddle and Stefania Woodward, Australian Centre for Geomechanics.

ISBN 978-0-9876389-1-5



Australian Centre for Geomechanics
The University of Western Australia
35 Stirling Highway (M600)
CRAWLEY, WESTERN AUSTRALIA
AUSTRALIA 6009
Telephone: +61 8 6488 3300
info-acg@uwa.edu.au
www.acg.uwa.edu.au

ABN 37 882 817 280

Australian Centre for Geomechanics

The Australian Centre for Geomechanics (ACG) was formally established in 1992 as a University of Western Australia research centre in order to promote research excellence and continuing education in geomechanics, with particular emphasis on its application to the mineral and energy extraction sections of Australia's resources industry.

The Australian Centre for Geomechanics is an unincorporated Joint Venture involving:

- CSIRO Mineral Resources
- The University of Western Australia — Civil, Environmental and Mining Engineering

The ACG draws together staff knowledge, experiences and expertise from within the two groups forming the Centre and facilitates a multi-disciplinary approach to research and education in geomechanics. Research undertaken by the ACG attracts both national and global support and the outcomes of the projects are utilised to promote safer mining and environmental geomechanics practices, operating efficiencies and to meeting community expectations for sustainable mining practices.

With the guidance of strong industry representation on the Board of Management, and close collaboration with senior representatives of the mining industry, research, training and further education activities are tailored directly to the needs of industry. The ACG Board expects the Australian Centre for Geomechanics to be the focal point for industry on geomechanics issues and to address the needs of industry through a collaborative interdisciplinary approach.

Online Repository of Conference Proceedings



Accessing geomechanical excellence

Since 2005, the ACG has published conference papers across the geotechnical mining spectrum, including: underground and open pit mining, paste and thickened tailings and mine closure. To make many of these papers more accessible for industry and academia, the ACG launched the Online Repository of Conference Proceedings in 2017. This repository aims to provide the mining geomechanics fraternity with open access, peer-reviewed conference papers that may assist readers to maintain and develop their skills, knowledge and capabilities.

Aside from allowing users to freely download many past and current conference papers, the site features many useful functions. This highly interactive and searchable repository provides importable citation information in various formats, links to the paper authors' profiles on ORCID, ResearchGate and LinkedIn, as well as the ability to share papers on social media.

The First International Conference on Mining Geomechanical Risk papers are available on the repository.

Setting a high standard for technology transfer and accessibility, this valuable online resource will continue to develop and grow with future ACG geomechanical mining events.

papers.acg.uwa.edu.au

Technical Reviewers

The dedicated efforts of the peer reviewers have resulted in the high quality of the technical programme and the papers compiled for this publication. The editor thanks the following people who contributed their time and expertise as reviewers of manuscripts for the proceedings of the First International Conference on Mining Geomechanical Risk held in Perth, Australia. A technical and critical review of each paper was undertaken by a minimum of two reviewers for the production of this volume.

M Adams
Newcrest Mining Limited, Australia

R Armstrong
SRK Consulting (South Africa) (Pty) Ltd, South Africa

AC Atkins
Alex Atkins & Associates Pty Ltd, Australia

H Basarir
The University of Western Australia, Australia

FRP Basson
Newmont Mining Corporation, Australia

P Boeg-Jensen
Luossavaara-Kiirunavaara AB (LKAB), Sweden

J Boshoff
Golder Associates Pty Ltd, Australia

BS Brown
Bruce Brown Consulting Pty Ltd, Australia

A Carneiro
The University of Western Australia, Australia

C Chester
Newcrest Mining Limited, Australia

L-F Contreras
The University of Queensland, Australia

D Cumming-Potvin
Australian Centre for Geomechanics, Australia

A Day
Oceanagold, Australia

I de Bruyn
SRK Consulting (Australasia) Pty Ltd, Australia

PM Dight
Australian Centre for Geomechanics, Australia

MJ Dunn
Evolution Mining Ltd, Australia

AB Fourie
The University of Western Australia, Australia

S Gover
Golder Associates Africa (Pty) Ltd, South Africa

M Grenon
Université Laval, Canada

ECF Hamman
AngloGold Ashanti Australia Ltd, Australia

BK Hebblewhite
UNSW Sydney, Australia

C Holland
Société Des Mine De Syama S.A (SOMISY S.A), Australia

WC Joughin
SRK Consulting (South Africa) (Pty) Ltd, South Africa

GJ Keyter
SRK Consulting (South Africa) (Pty) Ltd, South Africa

L Linzer
SRK Consulting (South Africa) (Pty) Ltd, South Africa

F Malan
University of Pretoria, South Africa

J Mayer
SRK Consulting (UK) Ltd, UK

J McGaughey
Mira Geoscience Ltd., Canada

A Meintjes
SRK Consulting (South Africa) (Pty) Ltd, South Africa

P Morissette
Agnico Eagle Mines Ltd., Canada

IG Morkel
Australian Centre for Geomechanics, Australia

J Muaka
Australian Centre for Geomechanics, Australia

AR Penney
AMC Consultants Pty Ltd, Australia

Y Potvin
Australian Centre for Geomechanics, Australia

D Reid
The University of Western Australia, Australia

B Simser
Sudbury Integrated Nickel Operations, Canada

S Spottiswoode
South Africa

TR Stacey
University of the Witwatersrand, South Africa

SR Tierney
Australian Centre for Geomechanics, Australia

J van Rensburg
Klohn Crippen Berger, Australia

J Venter
AngloGold Ashanti Australia Ltd, Australia

N Vermeulen
Jones & Wagener (Pty) Ltd, South Africa

D Walker
SRK Consulting (Australasia) Pty Ltd, Australia

J Wesseloo
Australian Centre for Geomechanics, Australia

SDN Wessels
Rio Tinto Iron Ore, Australia

Preface

On 25 January 2019, a tailings dam failure occurred in Brazil with devastating consequences. The terrible loss of life, over 300 fatalities to date (reut.rs/2TPmurt), is a stark reminder of how important the careful management of geomechanical risks are. For underground and open pit rock mechanics, the exposure to the public is comparatively limited and the risk to life contained to the workforce, and the management of workforce exposure is effective in managing safety risk. The management of financial risk, however, requires different approaches. It is my opinion that within the broader mining community, geotechnical risk is often underappreciated and not always properly quantified.

One of the challenges faced by the industry is the fact that, at the highest levels, the management of mining geomechanical risk is the responsibility of managers from non-scientific or engineering backgrounds with little or no appreciation of the uncertainty and variability intrinsic to geomechanics. In many mining companies, mining engineers and geomechanical engineers are under-represented or completely absent from higher management levels.

In all areas of geomechanics, the uncertainty and variability that engineers need to deal with necessitates a rigorous process of quantification or, in the very least, the mandate to robustly qualify likelihoods and consequences. There appears also to be a large gap between the state-of-the-art and the state of general practice when it comes to the qualification and quantification of geotechnical risk.

For this reason, the Australian Centre for Geomechanics (ACG) is hosting the First International Conference on Mining Geomechanical Risk (MGR 2019). The aim of the conference is to provide a forum to discuss the methods used to design for geotechnical risk and those used to manage these risks; to identify shortcomings; and to close the gap between the state-of-the-art and the state-of-practice. With this conference, we are bringing together underground rock engineers, rock slope engineers and tailings engineers with the aim of learning from each other on the common theme of geomechanical risk.

These proceedings comprise of 36 papers written by authors from nine countries. We are grateful to these authors for collectively writing this important body of work. The review process is extremely important to ensure the quality of such proceedings – we are thankful to each of the reviewers for their efforts. My personal thanks to the ACG team who has organised this event, managed the paper submission and review process and produced the proceedings. I also acknowledge the important contribution of the event sponsors.

There is no doubt in our minds that this conference topic is an important one, and we plan to organise future conferences on this theme.

These proceedings are also freely available from the ACG Online Repository of Conference Proceedings, courtesy of Open Access Sponsor, SRK Consulting. The papers can be accessed by scanning the QR code or from papers.acg.uwa.edu.au/mgr2019

Associate Professor Johan Wesseloo
Editor and Conference Chair

Conference Sponsors

The Australian Centre for Geomechanics proudly acknowledges the generous contribution by the principal, major, and open access sponsors of the First International Conference on Mining Geomechanical Risk.

PRINCIPAL SPONSOR

BHP

MAJOR SPONSORS

Evolution MINING

MAPTEK™

NEWCREST MINING LIMITED

REUTECH MINING

OPEN ACCESS SPONSOR

srk

Table of Contents

iii Australian Centre for Geomechanics

v Technical Reviewers

vii Preface

ix Conference Sponsors

KEYNOTE ADDRESSES

3 Understanding, managing and communicating geomechanical mining risk
J Hadjigeorgiou, University of Toronto, Canada

21 What are the real risks for tailings facilities?
BS Brown, Bruce Brown Consulting Pty Ltd, Australia

31 Major hazards associated with cave mining: are they manageable?
G Flores-Gonzalez, Newcrest Mining Limited, Australia

47 Risk-based access control at Mount Isa Copper Operations
GS Potgieter, AB Grubb, Mount Isa Mines Limited, A Glencore Company, Australia

61 Geotechnical risk-informed decision-making in mining
JF Lupo, Newmont USA Limited, USA

MANAGEMENT AND GEOTECHNICAL RISK

71 Challenges with use of risk matrices for geohazard risk management for resource development projects
M Porter, M Lato, BGC Engineering Inc., Canada; P Quinn, BGC Engineering Inc., Belgium; J Whittall, BGC Engineering Inc., Canada

85 Combining expert opinion and instrumentation data using Bayesian networks to carry out stope collapse risk assessment
R Mishra, R Kiuru, L Uotinen, M Janiszewski, M Rinne, Aalto University, Finland

97 Improving board assurance of technical and operational risks in mining
AC Atkins, Alex Atkins & Associates Pty Ltd, Australia; M Ritchie, Professional Auditor, Australia

111 Economic significance of geotechnical uncertainties in open pit mines
R Jele, MJ Dunn, Evolution Mining Ltd, Australia

127 Using qualitative risk assessment as a leading indicator for geotechnical risk in mining
ECF Hamman, J Venter, AngloGold Ashanti Australia Ltd, Australia

RISK MANAGEMENT, MONITORING AND INTEGRATION

159 InSAR tools for risk assessment over mine assets
JL Morgan, TRE Altamira, Australia; D Colombo, F Meloni, TRE Altamira, Italy

171 Using an integrated monitoring platform to communicate geotechnical risk to project stakeholders
WJ Conrad, AM Neuwirt, Canary Systems, Inc., USA

181 Seismic exclusions and re-entry from a risk perspective
SR Tierney, KR Woodward, J Wesseloo, Australian Centre for Geomechanics, The University of Western Australia, Australia

195 A practical safety risk model for monitoring program design
J Venter, ECF Hamman, AngloGold Ashanti Australia Ltd, Australia

205 A measured risk approach to managing the design and operation of a tailings storage facility
JP Coffey, JD Plunkett, Rio Tinto Iron Ore, Australia

219 Data-driven geotechnical hazard assessment: practice and pitfalls
WJ McGaughey, Mira Geoscience Ltd., Canada

233 Calibration of a seismic hazard assessment tool using velocity fields and geotechnical data
Y Abolfazlzadeh, L Smith-Boughner, Z Anderson, ESG Solutions, Canada; A Jalbout, Goldcorp Inc., Canada; A Mataseje, ESG Solutions, Canada

245 Calibrating and testing of the forecasts of seismic hazard for planned mining sequences
DA Malovichko, Institute of Mine Seismology, Australia

QUANTITATIVE APPROACHES TO DESIGN

261 Production-associated risk factors of seismicity in the Kiirunavaara mine
J Vatcher, Itasca Consultants AB, Sweden; M Bošković, Luossavaara-Kiirunavaara Aktiebolag (LKAB), Sweden; J Sjöberg, Itasca Consultants AB, Sweden

273 Construction of a damage risk model for footwall drifts
J Andrijasevich, H Basarir, The University of Western Australia, Australia; J Wesseloo, Australian Centre for Geomechanics, The University of Western Australia, Australia

RISK MANAGEMENT FROM A CORPORATE PERSPECTIVE

291 Key considerations when developing a risk management framework for tailings facilities
AG Gagnon, Lundin Mining Corporation, Canada

299 Geotechnical risk in mining methods and practice: critical issues and pitfalls of risk management
BK Hebblewhite, UNSW Sydney, Australia

MANAGEMENT OF LARGE AREAS WITH LIMITED RESOURCES

311 Managing geotechnical risk in multi-pit operations
SDN Wessels, R Dixon, Rio Tinto Iron Ore, Australia

323 Geohazard risk management for linear transportation
M Lato, BGC Engineering Inc., Canada; P Quinn, BGC Engineering Inc., Belgium; M Porter, S Newton, BGC Engineering Inc., Canada; R Dixon, SDN Wessels, L Wessels, Rio Tinto Iron Ore, Australia; D Sirois, M Leveque, Iron Ore Company of Canada, Canada

337 Use of the excavation compliance indicator at the Oyu Tolgoi copper–gold mine, Mongolia
A Juldyz, Oyu Tolgoi LLC, Mongolia

QUANTITATIVE RISK-BASED DECISION-MAKING

353 Geotechnical value quantification through real options
J Venter, ECF Hamman, AngloGold Ashanti Australia Ltd, Australia

373 Geotechnical risk analysis for the closure alternatives of the Chuquicamata open pit
L-F Contreras, SRK Consulting (South Africa) (Pty) Ltd, South Africa; E Hormazabal, SRK Consulting (Chile) S.A., Chile; R Ledezma, M Arellano, Codelco, Chile

DATA DRIVEN RISK ASSESSMENT

391 Quantifying uncertainty in mining geomechanics design
MJ Dunn, Evolution Mining Ltd, Australia

403 The role of the geotechnical model for rapid integration in managing operational geotechnical risk
MC Brockman, KMR Gosche, DJ Du Plooy, AngloGold Ashanti Australia Ltd, Australia

419 Getting back to basics: risk fundamentals applied to the geotechnical engineering of tailings storage facilities
JP Coffey, N Susic, Rio Tinto Iron Ore, Australia

429 Probabilistic stability analyses for sedimentary deposits
A Duran, Pells Sullivan Meynink Pty Ltd, Australia

443 Review of the practical effectiveness of thin spray-on liners based on information from suppliers and observations from the mining industry
MJ Kanda, TR Stacey, University of the Witwatersrand, South Africa

CASE STUDIES

461 Development of the Mine Geotechnical Risk Index
S Narendranathan, M Cheng, GHD Pty Ltd, Australia

475 Geotechnical design and uncertainty in residual soil slopes
KT Mandisodza, MJ Dunn, Evolution Mining Ltd, Australia

493 Managing geohazard risk during mineral exploration at remote locations in rugged terrain and tropical environments
J Whittall, BGC Engineering Inc., Canada; P Quinn, BGC Engineering Inc., Belgium; M Lato, M Porter, BGC Engineering Inc., Canada; B Bowden, J Drew, M Croaker, Rio Tinto Exploration Pty Ltd, Australia

505 Managing decline deformation in an active sublevel caving operation
MJ Woods, S Fitch, J Doolan, DS Barnett, Newcrest Mining Limited, Australia

521 Proceedings Author Index