SLOPE STABILITY 2020

ACG AUSTRALIAN CENTRE FOR GEOMECHANICS

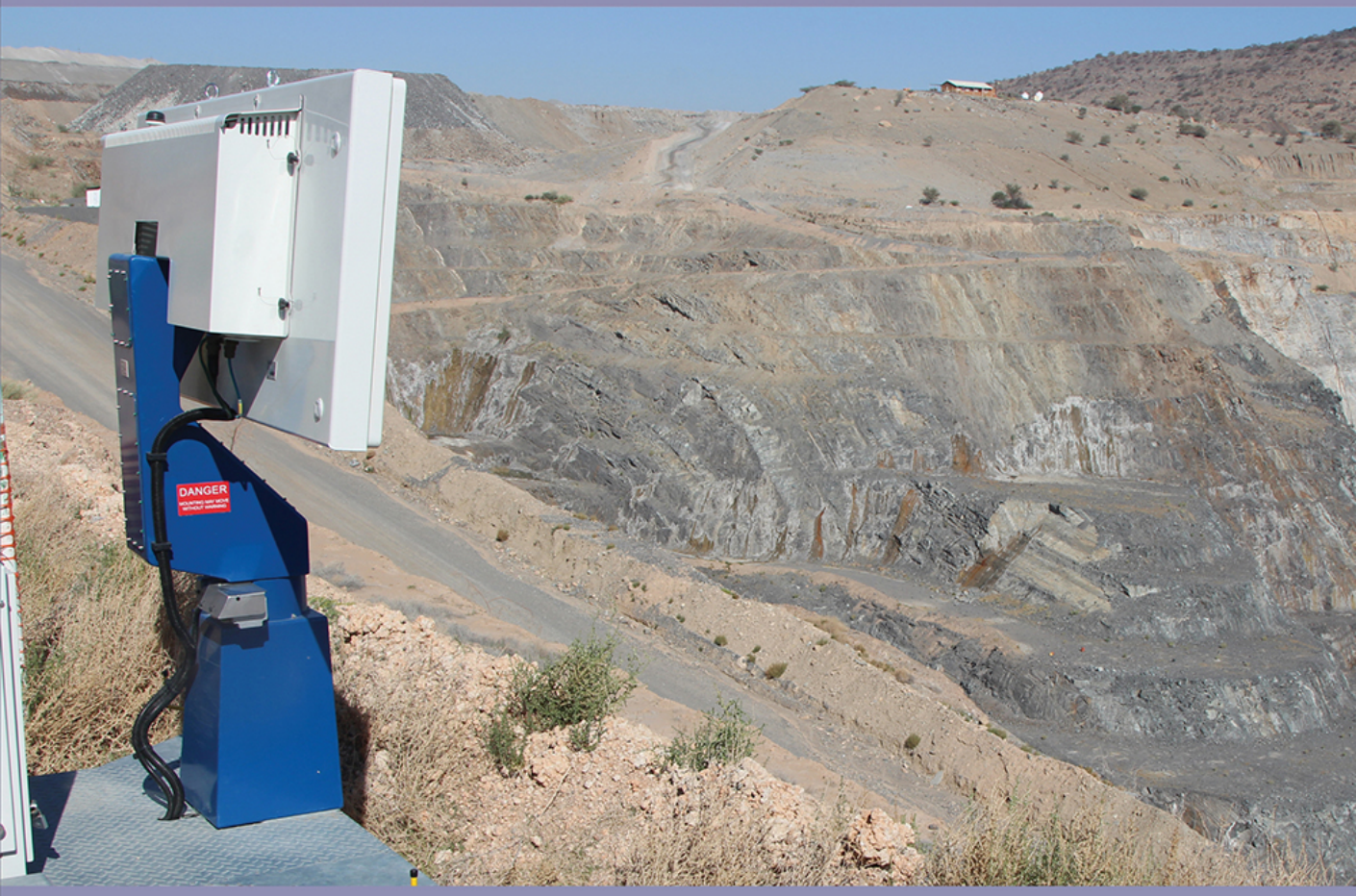
CSIRO | The University of Western Australia | Joint Venture

Slope Stability 2020

Proceedings of the 2020 International Symposium on Slope Stability in Open Pit Mining and Civil Engineering

12–14 May 2020

Volume One



EDITOR Phil Dight

Slope Stability 2020

Proceedings of the 2020 International Symposium on Slope Stability in Open Pit Mining and Civil Engineering

12–14 May 2020

Volume One

Editor

Phil Dight

Australian Centre for Geomechanics, Australia

ACG AUSTRALIAN CENTRE FOR GEOMECHANICS

CSIRO | The University of Western Australia | Joint Venture

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, makes 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 herein. 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.

Front cover photograph courtesy of Reutech Mining.

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

ISBN 978-0-9876389-7-7

Australian Centre for Geomechanics
The University of Western Australia
35 Stirling Highway (M600)
CRAWLEY, WESTERN AUSTRALIA
AUSTRALIA 6009
Telephone: +61 8 6488 3300
publications-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 not-for-profit 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 2020 International Symposium on Slope Stability in Open Pit Mining and Civil Engineering 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

Australian Organising Committee

PG Andrews *Gold Fields Australia Pty Ltd, Australia*

S Arndt *Dassault Systèmes GEOVIA, Australia*

PM Dight *Australian Centre for Geomechanics, Australia*

M Dunn *Debswana, Australia*

M Elmouttie *CSIRO Energy, Australia*

D Gaudreau *Newmont Australia, Australia*

J Hall *AQ2 Pty Ltd, Australia*

C Holland *BHP, Australia*

AP Maconochie *GeoTek Solutions Pty Ltd, Australia*

S Narendranathan *GHD Pty Ltd, Australia*

M Pascoe *Rio Tinto, Australia*

J Ruddle *Australian Centre for Geomechanics, Australia*

E Sweeney *MEC Mining, Australia*

J Venter *AngloGold Ashanti Limited, Australia*

D Walker *SRK Consulting, Australia*

O Watson *Newmont Australia, Australia*

F Weir *PSM, Australia*

International Advisory Committee

M Brown *SRK Consulting (UK) Limited, UK*

S Cooper *First Quantum Minerals Ltd, Spain*

A Creighton *Rio Tinto, Australia*

T da Costa *Vale S.A., Brazil*

PM Dight *Australian Centre for Geomechanics, Australia*

PJH de Graaf *Anglo American, De Beers Group of Companies, Australia*

AB Fourie *The University of Western Australia, Australia*

JM Galera *Subterra Ingenieria, Spain*

J Lupo *Newmont Asia Pacific, USA*

D Martin *University of Alberta, Canada*

J Sjöberg *Itasca Consultants AB, Sweden*

P Terbrugge *SRK Consulting (South Africa) (Pty) Ltd, South Africa*

E Widzyk-Capehart *University of Chile, Chile*

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 2020 International Symposium on Slope Stability in Open Pit Mining and Civil Engineering. A technical and critical review of each paper was undertaken by a minimum of two reviewers for the production of these proceedings.

M Abdulai
Gold Fields Australia Pty Ltd, Australia

R Almenara
Newmont Corporation, USA

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

S Arndt
Dassault Systèmes GEOVIA, Australia

N Baczynski
Prime Geotechnics, Australia

F Basson
Newmont Australia, Australia

T Beingessner
Teck Resources Ltd., Canada

N Boldrini
IDS GeoRadar, Italy

P Brenchley
EMR Golden Grove Pty Ltd, Australia

M Brown
SRK Consulting (UK) Limited, UK

O Buzzi
The University of Newcastle, Australia

A Cabrejo
GroundProbe North America, USA

C Carranza-Torres
University of Minnesota, USA

I Clark
GEONET Consulting Group, Australia

S Coetsee
Reutech Mining, South Africa

LF Contreras
SRK Consulting, Australia

T da Costa
Vale S.A., Chile

J Danielson
BGC Engineering Inc., Canada

I de Bruyn
SRK Consulting, Australia

PJH de Graaf
Anglo American, De Beers Group of Companies, Australia

E de Sousa
DHI Water and Environment Pty Ltd, Australia

M Desjardins
De Beers Canada Inc., Canada

G Dick
BGC Engineering Inc., Canada

PM Dight
Australian Centre for Geomechanics, Australia

J Dixon
Fortescue Metals Group Ltd, Australia

R Dixon
Rio Tinto, Australia

R Dufour
DHI Peru SAC, Peru

M Dunn
Debswana, Australia

A Duran
PSM, Australia

M Elmouttie
CSIRO Energy, Australia

K Esmaeili
University of Toronto, Canada

P Farina
Geoapp S.R.L., Italy

JM Galera
Subterra Ingenieria, Spain

D Gaudreau
Newmont Australia, Australia

S Ghaychi Afrouz
Virginia Tech University, USA

A Giacomini
The University of Newcastle, Australia

J Graaf
Gold Fields Australia Pty Ltd, Australia

I Gray
Sigra Pty Ltd, Australia

M Grenon
Université Laval, Canada

R Gresswell
GHD Pty Ltd, Australia

J Hall
AQ2 Pty Ltd, Australia

ECF Hamman
AngloGold Ashanti Limited, Australia

LJ Hayman
Rio Tinto, Australia

C Heaven
Glencore, Australia

D Holden
3vGeomatics Inc., Canada

C Holland
BHP, Australia

GC Howell
SRK Consulting (South Africa) (Pty) Ltd, South Africa

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

B Jeffcoat-Sacco
The University of Western Australia, Australia

T Johnson
Red Rock Geotechnical, Australia

E Jones
MineGeoTech Pty Ltd, Australia

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

S Kacavenda
GHD Pty Ltd, Australia

S Karekal
University of Wollongong, Australia

K Koosmen
PSM, Australia

J Leighton
3vGeomatics Inc., Canada

J Li
BHP, Australia

P Lombard
GHD Pty Ltd, Australia

L Lorig
Itasca Consulting Group Inc., USA

D Lucas
Mining One Pty Ltd, Australia

R Macciotta Pulisci
University of Alberta, Canada

AP Maconochie
GeoTek Solutions Pty Ltd, Australia

KT Mandisodza
Cartledge Mining and Geotechnics, Australia

N Marshall
SRK Consulting (UK) Limited, UK

J Mathis
Zostrich Geotechnical, USA

A McQuillan
Rocscience Inc., Australia

G More O'Ferrall
Kansanshi Mining PLC, Zambia

J Morkeh
Rio Tinto, USA

S Narendranathan
GHD Pty Ltd, Australia

D Noon
GroundProbe Pty Ltd, Australia

D Oliveira
Jacobs Engineering Group, Australia

G Owusu-Bempah
Harmony Gold, Papua New Guinea

F Pothitos
Newcrest Mining Limited, Australia

Y Potvin
Australian Centre for Geomechanics, Australia

D Prado
SRK Consulting, Australia

M Raynor
SRK Consulting (UK) Limited, UK

S Read
GNS Science, New Zealand

R Rimmelin
BHP, Australia

B Roache
Mining One Consultants Pty Ltd, Australia

A Robotham
BHP, Australia

ME Robotham
Rio Tinto, Australia

B Ross
The University of Arizona, USA

D Ross
BHP, Australia

M Rougier
Golder, Canada

M Royle
SRK Consulting (Canada) Inc., Canada

K Rozlapa
AQ2 Pty Ltd, Australia

M Ruest
Goldcorp, Canada

W Sarunic
Xstract Mining Consultants, Australia

E Saunders
SRK Consulting (Canada) Inc., Canada

P Saunders
GroundProbe, Australia

MF Scholz
Piteau Associates Engineering Ltd., Canada

J Seery
Bastion Geotechnical Pty Ltd., Australia

J Sjöberg
Itasca Consultants AB, Sweden

P Stacey
Stacey Mining Geotechnical Ltd, Canada

TR Stacey
University of the Witwatersrand, South Africa

E Sweeney
MEC Mining, Australia

C Swindells
Consultant, Australia

P Terbrugge
SRK Consulting (South Africa) (Pty) Ltd, South Africa

H Thomas
University of the Witwatersrand, South Africa

R Thomas
Absolute Geotechnics Pty Ltd, Australia

A Vakili
Mining One Consultants Pty Ltd, Australia

J Venter
AngloGold Ashanti Limited, Australia

J von Ruette
3vGeomatics Inc., Canada

D Walker
SRK Consulting, Australia

S Walker
Newcrest Mining Limited, Australia

O Watson
Newmont Australia, Australia

F Weir
PSM, Australia

J Wesseloo
Australian Centre for Geomechanics, Australia

F Wessels
Rio Tinto, Australia

J Whittall
BGC Engineering Inc., Canada

D Wines
Itasca Australia Pty Ltd, Australia

Preface

When a slope failure is imminent, geotechnical engineers and geologists are most often called on to manage the safety and assess the risk. Many people are able to use advanced monitoring systems to advise on timing, help calculate expected volume/s and consequential runout. There is no hiding from the issue. The frontline people show great leadership in what is a crisis; there is no blaming others. Acceptance of such a role takes great courage. Calling the shots with limited data makes for even greater risk management. The frontline people should be applauded. At the time of preparing this preface, the world is facing global catastrophe in the service industries in particular. However, our mines continue to operate. Calls to abandon/postpone this symposium were made by well-meaning people but often without the leadership skills to understand how to respond to a crisis. The ACG team quickly and efficiently moved to create a virtual symposium. Our authors supported the initiative with over 90% agreeing to continue with the symposium and retain their papers in the proceedings. To them I applaud your response to the crisis; slightly less people agreed to make a virtual presentation. That is courage. The issues that these authors wanted to present are at the forefront of crisis management. They are the leaders. I salute you all.

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/ss2020.

Professor Phil Dight, Australian Centre for Geomechanics, Australia
Editor and Symposium Chair

Symposium Sponsors

The Australian Centre for Geomechanics proudly acknowledges the generous contribution by the Principal and Major Sponsors of the 2020 International Symposium on Slope Stability in Open Pit Mining and Civil Engineering Online Event.

PRINCIPAL SPONSOR

REUTECH MINING

MAJOR SPONSORS

BHP

GEOBRUGG BRUGG Safety is our nature

GroundProbe

IDS GeoRadar

ITASCA™

Newmont™ AUSTRALIA

Table of Contents

iii **Australian Centre for Geomechanics**
v **Committees**
vii **Technical Reviewers**
xi **Preface**
xiii **Symposium Sponsors**

Keynote addresses

3 **BHP mine water management: an integrated approach to manage risk and optimise resource value**
C Ahumada Calderon, BHP, Australia

17 **Slope performance monitoring: system design, implementation and quality assurance**
R Sharon, Sharon Geotechnical LLC, USA

39 **Geomechanics of Australian open cut coal mining**
JV Simmons, Sherwood Geotechnical and Research Services, and The University of Newcastle, Australia

65 **Hydromechanical coupling concepts for mine slopes**
TD Sullivan, PSM, Australia

Safety and risk management

101 **Risk-based slope monitoring framework**
J Armstrong, Nevada Gold Mines, USA; R Sharon, Piteau Associates Ltd., USA; C Williams, B Ross, University of Arizona, USA

117 **Practical waste rock dump and stockpile management in high rainfall and seismic regions of Papua New Guinea**
N Bar, Gecko Geotechnics Pty Ltd, Australia; J Semi, M Koek, Ok Tedi Mining Limited, Papua New Guinea; G Owusu-Bempah, A Day, Harmony Gold Mining Company Limited, Papua New Guinea; S Nicoll, J Bu, Newcrest Mining Limited, Papua New Guinea

129 **New techniques for characterising damage in rock slopes: implications for engineered slopes and open pit mines**
D Donati, D Stead, Simon Fraser University, Canada; D Elmo, University of British Columbia, Canada; E Onsel, Simon Fraser University, Canada

145 **Economic consequences of geotechnical instabilities in open cut coal mines**
K Young, A Robotham, G Virk, BHP, Australia

155 **Regulation of open pit slope stability in Russia**
A Makarov, I Livinsky, V Spirin, SRK Consulting (Russia) Limited, Russia; A Pavlovich, Saint-Petersburg Mining University, Russia

165 **An overview of the slope monitoring program at the Serra Sul Iron Ore Project, S11D, northern Brazil**
MF Souza, E Friguetto, WJ Souza, AHCR Castro, Vale S.A., Brazil

177 **Trigger action response plan development and optimisation at the Bingham Canyon Mine**
KM Bakken, GK Chapin, MG Abrahams, Rio Tinto Kennecott Copper, USA

191 **Management of geotechnical hazards through embracing technology and innovative thinking**
KT Mandisodza, Evolution Mining Ltd, Australia

207 **InSAR investigation of sackung-like features and debris flows in the vicinity of Hawkesbury Island and Hartley Bay, British Columbia, Canada**
D Huntley, D Rotheram, P Bobrowsky, G Lintern, R MacLeod, C Brillon, Geological Survey of Canada, Canada

227 **Analysis of velocity and acceleration trends using slope stability radar to identify failure 'signatures' to better inform deformation trigger action response plans**
R Shellam, SRK Consulting (UK) Limited, UK; J Coggan, University of Exeter, UK

241 **Use of laser scanner technology as part of the slope stability risk management strategy at Letšeng diamond mine**
N Lefu, Letšeng Diamonds (Pty) Ltd, Lesotho; V Nokwe, Maptek, South Africa

255 **Managing ice walls and other operational challenges while optimising Victor Mine late stage opportunities**
M Rougier, Golder, Canada; PJH de Graaf, Anglo American, De Beers Group of Companies, Australia; M Desjardins, De Beers Canada, Inc., Canada; M O'Leary, Mount Polley, Canada (formerly De Beers, Canada); N Yugo, Independent Consultant, Canada (formerly De Beers, Canada); B Kilbride, De Beers Canada, Inc., Canada

265 **Evolution and management of large-scale instability: a case study from Ok Tedi**
G Kennedy, D Casagrande, PSM, Australia

281 **InSAR in the clouds: satellite-based monitoring at Grasberg Mine**
JM Leighton, 3vGeomatics Inc., Canada; M Sullivan, Freeport McMoRan, Indonesia

293 **Brumadinho Dam InSAR study: analysis of TerraSAR-X, COSMO-SkyMed and Sentinel-1 images preceding the collapse**
D Holden, S Donegan, A Pon, 3vGeomatics Inc., Canada

307 **Post-shearing data collection with enhanced network smart markers**
T Beingessner, R Yost, Teck Resources Limited, Canada; S Steffen, D Whiteman, Elexon Mining, Australia; AM Thomas, M Royle, SRK Consulting (Canada) Inc., Canada; E Widzykcapehart, University of Chile, Chile

319 **Risk management and alarming based on a new atmospheric correction algorithm for ground-based radars**
A Cabrejo, GroundProbe Pty Ltd, Colombia; P Bellett, G Stickley, GroundProbe Pty Ltd, Australia; R Silva, Y Gunaris, J Pérez, Compañía Minera Doña Inés de Collahuasi, Chile

339 **The use of strain threshold in slope stability trigger action response plans**
S Coetsee, Reutech Mining, South Africa; R Armstrong, P Terbrugge, SRK Consulting (South Africa) (Pty) Ltd, South Africa

353 **i²MON: development of an integrated monitoring system for the detection of ground and surface displacements caused by coal mining**
D Schröder, K Zimmermann, S Bock, DMT GmbH & Co. KG, Germany; J Klonowski, Mainz University of Applied Sciences, Germany

367 **Influence of the hydrothermal alteration rocks on the stability of an open pit mine of the south of Peru: a case study**
S Castro, C Huaman, Anddes, Peru

383 **Case study: analysis of a highwall toppling failure and development of a successful mine re-entry plan using RS2, RocFall and Dan-W at a coal mine in Canada**
C Clayton, A Jackson, J Price, Tetra Tech Canada Inc., Canada; A Bidwell, Teck Coal Limited, Canada; D Elmo, The University of British Columbia, Canada

399 **Geotechnical risk management for Victor Mine closure**
M Desjardins, De Beers, Canada; PJH de Graaf, Anglo American, De Beers Group of Companies, Australia; G Beale, Piteau, UK; M Rougier, Golder, Canada

415 **BHP Western Australia Iron Ore geotechnical open cut slope design system: a simple pragmatic process for slope risk decisions**
A Haile, D Ross, A Maldonado, M Neyaz, C Rajbhandari, BHP, Australia

427 **Characterisation of a rock slope showing three weather-dominated failure modes**
M Roustaei, R Macciotta, M Hendry, J Rodriguez, University of Alberta, Canada; C Gräpel, Klohn Crippen Berger, Canada; R Skirrow, Alberta Transportation, Canada

439 **Monitoring and managing large deformation pit slope instabilities at a British Columbia copper mine**
G Dick, BGC Engineering Inc., Canada; S Nunoo, S Smith, Gibraltar Mines Ltd., Canada; W Newcomen, D Kinakin, I Stilwell, J Danielson, BGC Engineering Inc., Canada

Processing of geotechnical data and limit design

455 **Evolution of a geotechnical model for slope design in an active volcanic environment**
FM Weir, MJ Fowler, TD Sullivan, M Kobler, PSM, Australia; J Bu, Newcrest Mining Limited, Papua New Guinea

473 **Geotechnical evaluation of the east wall of the Cerro Corona Pit**
J Dueñas, G Becerra, R Ordoñez, Gold Fields, Peru; PG Andrews, Gold Fields Australia Pty Ltd, Australia

487 **Introducing G.RE.T.A. – an innovative geo-resistivimeter for long-term monitoring of earthen dams and unstable slopes**
G Tresoldi, Politecnico di Milano, Italy; A Hojat, Shahid Bahonar University of Kerman, Iran and Politecnico di Milano, Italy; L Zanzi, Politecnico di Milano, Italy; A Certo, LSI Lastem s.r.l., Italy

499 **Capturing/interpreting non-obvious slope controlling structures**
JI Mathis, Zostrich Geotechnical, USA

507 **Post-blast slope stability monitoring with slope stability radar**
P Saunders, GroundProbe Pty Ltd, Australia; JM Kabuya, ArcelorMittal Mining Canada, Canada; A Torres, GroundProbe, USA; R Simon, École Polytechnique de Montréal, Canada

523 **Combining structural data with monitoring data in open pit mines to interpret the failure mechanism and calibrate radar alarms**
P Farina, F Bardi, Geoapp s.r.l., Italy; L Lombardi, G Gigli, Università degli Studi di Firenze, Italy

535 **Characterisation of foliated rock masses using implicit modelling to guide geotechnical domaining and slope design**
E Saunders, A LeRiche, T Shapka-Fels, W Barnett, SRK Consulting (Canada) Inc., Canada

551 **The shear strength of bedding partings in shales of the Pilbara: the similarity of non-dilatational angles, mineralogy relationships, and nominal roughness**
A Maldonado, The University of Western Australia, Australia; PM Dight, Australian Centre for Geomechanics, The University of Western Australia, Australia

565 **Disrupting rock engineering concepts: is there such a thing as a rock mass digital twin and are machines capable of learning rock mechanics?**
D Elmo, University of British Columbia, Canada; D Stead, Simon Fraser University, Canada

577 **Tools for validating and creating reliable fault models**
J Danielson, D Kinakin, I Stilwell, BGC Engineering Inc., Canada

591 **Rock mass behaviour of deep mining slopes: a conceptual model and implications**
R Rimmelin, The University of Queensland and BHP, Australia; J Vallejos, University of Chile/Advanced Mining Technology Center, Chile

609 **Bayesian approach for the assessment of sufficiency of geotechnical data**
LF Contreras, SRK Consulting, Australia; M Serati, DJ Williams, The University of Queensland, Australia

625 **Utilising data science to test similarity of rock mass unit strength distributions in the Pilbara**
L J Hayman, Rio Tinto Iron Ore, Australia

637 **Assisting better decision-making of geotechnical slope design by using in-house software at BHP Iron Ore**
A Maldonado, A Haile, C Meegamarachchi, L Sasmita, BHP, Australia

645 **Mechanical and physical properties of chalk and impacts on mining operations and slope designs**
P Ebeling, Holcim Technology Ltd, Switzerland; A Iwanoff, BGW Geotechnik GmbH, Germany

657 **The effect of anisotropy orientation on the sedimentary rock strength estimated by point load testing strength, Pilbara, Australia**
X Gao, Rio Tinto Iron Ore, Australia

667 **Influence of particle size-shape correlation on the shear strength of scaled samples of coarse mine waste**
S Linero, University of Newcastle and SRK Consulting, Australia; S Fityus, University of Newcastle, Australia; JV Simmons, Sherwood Geotechnical and Research Services, Australia; E Azéma, University of Montpellier, France; N Estrada, University of Los Andes, Colombia; J Dixon, Fortescue Metals Group Ltd, Australia

677 **Waste rock characterisation and stability assessments for feasibility level studies**
D Dwumfour, J Dixon, Fortescue Metals Group Ltd, Australia; J Mylvaganam, SRK Consulting, Australia

691 **The intact rock strength of anisotropic rocks in the Pilbara: the use of field estimations, practical limitations of calibrations and statistical bias**
A Maldonado, The University of Western Australia, Australia; PM Dight, Australian Centre for Geomechanics, The University of Western Australia, Australia; K Mercer, 3rd Rock Consulting, Australia

703 **Geotechnical data aggregation and visualisation supporting informed risk management: the one-stop geotech shop**
SDN Wessels, R Dixon, Rio Tinto Iron Ore, Australia

Assessment and implications for uncertainty in design

715 **3D limit equilibrium method for rock slope stability analysis using generalised anisotropic material model**
NS Kumar, Universiti Sains Malaysia, Malaysia & Centre of Excellence for Engineering and Technology (CREaTE) JKR, Malaysia; MAM Ismail, Universiti Sains Malaysia, Malaysia

731 **An overview of bench design for cut slopes with an example of an advanced dataset assessment technique**
S Coetsee, Reutech Mining, South Africa

749 **Toe rock mass strength in footwall failures**
A Duran, PSM, Australia; D Cardona Lopez, Prodeco, Colombia

763 **Increasing the reliability of mining plans by predicting geotechnical instabilities with structural control: case study at a BHP mine, northern Chile**
C Roa, J Calderón, Minera Escondida, Chile; R Castellón, M Vargas, TIMining, Chile

771 **Tuff bands and the stability of coal mine slopes**
K Koosmen, PSM, Australia

791 **Epistemic uncertainty propagation in slope stability analysis and implications in safety margins**
CE Valderrama, M Cofré, E Hormazábal, R Álvarez, SRK Consulting (Chile) S.A., Chile

805 **Proceedings authors index**