

8th International Symposium

ROCKBURSTS AND SEISMICITY IN MINES



ALEXEY AND DMITRIY MALOVICHKO - EDITORS

RUSSIA. Saint-Petersburg - Moscow. 1-7 September 2013

Proceeding of the 8th International Symposium on

ROCKBURSTS AND SEISMICITY IN MINES

Editors

Alexey and Dmitriy Malovichko

Geophysical Survey of Russian Academy of Sciences

Mining Institute of Ural Branch of Russian Academy of Sciences

Obninsk – Perm 2013

Published by

Geophysical Survey of Russian Academy of Sciences
189, Lenin av., Obninsk, Kaluga region, 249030, Russia

Mining Institute of Ural Branch of Russian Academy of Sciences
78A, Sibirskaya str., Perm, 614007, Russia

© Geophysical Survey of Russian Academy of Sciences, 2013

© Mining Institute of Ural Branch of Russian Academy of Sciences, 2013

ISBN 978-5-903258-28-4

The papers in this volume have been for the most part prepared by the authors, with additional typesettings and formatting by Geophysical Survey of Russian Academy of Sciences and Mining Institute of Ural Branch of Russian Academy of Sciences

Cover: Evolution of the sinkhole in Berezniki-1 potash mine (Perm region, Russia) and associated seismicity

Backcover: Cross-section of fossilized Permian tree conserved in salt layer

Printed by Inter-YES ltd, Perm, Russia

CONTENTS

MECHANISM OF SEISMIC EVENTS AND MECHANICS OF ROCKBURST DAMAGE. LABORATORY STUDIES, VISUAL AND SEISMIC OBSERVATIONS

Keynote Lecture: Constraints on behavior of mining-induced earthquake inferred from laboratory rock mechanics experiments

A. McGarr, M. Johnston, M. Boettcher, V. Heesakkers and Z. Reches 3

Keynote Lecture: Forensic rock mechanics, Ortlepp shears and other mining induced structures

G. van Aswegen 11

New insight into the nature of size dependence and the lower limit of rock strength

B.G. Tarasov and M.A. Guzev 31

Fault formation in foliated rock – insights gained from a laboratory study

X. Lei, T. Funatsu and E. Villaescusa 41

In-situ monitoring and modelling of the rock mass response to mining: Japanese-South African collaborative research

H. Ogasawara, G. Hofmann, H. Kato, M. Nakatani, H. Moriya, M. Naoi, Y. Yabe, R. Durrheim, A. Cichowicz, T. Kgarume, A. Milev, O. Murakami, T. Satoh and H. Kawakata 51

Quasi-static fault growth in a gabbro sample retrieved from a South African deep gold mine revealed by multi-channel AE monitoring

T. Satoh, X. Lei, M. Nakatani, Y. Yabe, M. Naoi and G. Morema 61

Relating tilt measurements recorded at Mponeng gold mine, South Africa, to the rupture of an M 2.2 event

P. Share, A. Milev, R. Durrheim, J. Kuijpers and H. Ogasawara 67

Determining the proneness of rock to strainburst

P.M. Dight, B.G. Tarasov and A.W. O’Hare 75

Seismic dynamic influence of rock mass tremors on roadways according to the orientation of the rupture plane in the tremor source

K. Stec 83

Testing of the source processes of mine related seismic events

D. Malovichko and G. van Aswegen 93

ACQUISITION, PROCESSING AND INTERPRETATION OF SEISMIC DATA

Keynote Lecture: The use of moment tensor solutions in the analysis of mine seismicity: evaluation and interpretation

C-I. Trifu 109

Development of measuring complexes for the assessment and control of burst-hazard during mining

I.Yu. Rasskazov, V.A. Lugovoy, G.A. Kalinov, A.V. Gladyr, P.A. Anikin, M.I. Rasskazov and D.I. Tsoj 121

Accurate 3D location of mine induced seismicity in complex near-field underground conditions S. Coccia, A. Lizeur, P. Bigarré, I. Contrucci and E. Klein	125
Seismic hazard assessment using bent-ray and rectilinear passive tomography in the Polkowice-Sieroszowice copper mine J. Dubiński, A. Lurka and G. Mutke	137
Investigating the potential for locating trapped miners using a pre-existing microseismic monitoring system D. Cumming-Potvin, J. Wesseloo, Y. Potvin and M. Green	145
High accuracy measurements of seismic velocity variation in mines R.A. Lynch, G. Olivier and M.T. Green	157
Frequency range, log E, log P and magnitude A.J. Mendecki	167
Resolution of microearthquake mechanism inversions using a close-to-surface array at Ocnele Mari, Romania Z. Jechumtálová, J. Šílený and C-I. Trifu	175
Reverse time imaging of complex sources E.C. Lötter	181
Mining induced seismicity: moment tensor vs. shear-tensile/implosion model. Case study of Ridgeway, E. Australia gold mine J. Šílený, E.C. Lötter and G. Capes	189

INTEGRATION OF NUMERICAL MODELLING AND SEISMIC MONITORING

Keynote Lecture: Numerical modeling of seismicity: theory and applications A.M. Linkov	197
Surface stress modelling of some shear slip seismic events that occurred in AngloGold Ashanti's tabular mines G. Hofmann, S. Murphy, L. Scheepers and G. van Aswegen	219
Improvement of numerical stress models using the source mechanisms of seismic events D. Malovichko	233
Evaluation of stresses in strongly inhomogeneous rock with multiple cracks, openings and pillars L. Rybarska-Rusinek, E. Rejwer and D. Jaworski	249
Numerical simulation of the released energy in strain-softening rock materials and its application in estimating seismic hazards in mines V. Levkovitch, D. Beck and F. Reusch	259
Forecasting mining induced seismicity from modelled energy release in high stress stope extraction S. Arndt, V. Louchnikov, S. Weller and A. O'Hare	267

SEISMIC HAZARD

Keynote Lecture: Characteristics of seismic hazard in mines A.J. Mendecki	275
Inter-event volume mined outperforms recurrence time as a hazard indicator C. du Toit	293
Some aspects of quantitative version of rockburst Hazard Evaluation Method J. Kurzeja	299
Towards real-time probabilistic hazard assessment of the current hazard state for mines J. Wesseloo	307
Some results on mining-induced seismicity prediction in the Khibiny Apatite mines A.A. Kozyrev, Iu.V. Fedotova and O.G. Zhuravleva	313
Methods and results of burst-hazard assessment in the underground mines of Russian far East I.Yu. Rasskazov, B.G. Saksin, P.A. Anikin, M.I. Potapchuk, A.V. Gladyr, A.V. Sidlyar, E.E. Damaskinskaya, B.A. Prosekin and S.P. Osadchiy	319
Short term seismic hazard assessment in S.A. gold mines D.B. Rebuli and G. van Aswegen	323
Collapses forecasting based on seismic monitoring data analysis V.I. German	333
Microseismicity of coal mine goafing A.V.Z. Brink, S. Spottiswoode, S.Z. Pethö and C. Selai	337

GROUND CONTROL AND SEISMIC RISK MANAGEMENT

Keynote Lecture: Rockburst damage mechanisms and support design principles P.K. Kaiser and M. Cai	349
Keynote Lecture: Improving seismic risk management in hardrock mines Y. Potvin and J. Wesseloo	371
Mapping seismic vulnerability in stopes in deep South African gold mines R.J. Durrheim, J. Kuijpers, G. Henry, A.V.Z. Brink, B. Kagezi, G. Ferreira, R. Teleka, A. Milev, H. Ogasawara, A. Ward and J. Wienand	387
Application of seismic information in the mining design and monitoring of the KDC-East main shaft pillar N. Naicker	395
A modified sequential grid layout to increase production rates in deep level hard rock mines Y. Jooste	413
Rockburst and seismic hazard management at the New Mine Level project, Codelco VP, Chile J. Jarufe, P. Vasquez, J. Pereira and W. Rodriguez	429

Sesimic hazard assessment and abatement geotechnology for safe iron ore mining in West Siberia A.A. Eremenko, V.N. Koltyshev, V.A. Eremenko and V.A. Shtirtz	439
Development of seismic heading re-entry and exclusion zones at the Tasmania Mine A.R. Penney and P.B. Hills	447
 CASE STUDIES	
Keynote Lecture: Multi-scale seismicity at potash mines. Fifteen years of the seismic monitoring at Verkhnekamskoye deposit A.A. Malovichko, D.A. Malovichko, R.A. Dyagilev and D.Y. Shulakov	463
Converting to sub-level caving at over 1000 mbs – Seismicity at Eloise Copper Mine M.H. Turner	475
Micro-seismic monitoring at the Tasmania Mine, Beaconsfield, Tasmania P.B. Hills, D.B. Rebuli and R.A. Lynch	485
Kola Peninsula mines induced seismicity and secure development of rockburst-prone deposits A.A. Kozyrev, V.I. Panin, Iu.V. Fedotova, S.S. Pugachev and P.A. Korchak	495
Results related to pitwall microseismic monitoring (“Zhelezny” mine, Kovdorsky GOK, JSC) M.M. Kagan, A.A. Kozyrev and D.S. Chernobrov	501
Relation between microseismic activity and parameters of mining in the Verkhnekamskoye potash deposit D.Y. Shulakov and T.V. Verkholantseva	505
Seismicity associated with karst in flooded salt mines in Perm region, Russia R.A. Dyagilev, D.Y. Shulakov and P.G. Butyrin	511
Characteristics of rockbursts in the flooded mines of Kolar Gold Fields C. Srinivasan, Y.A. Willy and R.M. Carter	517
 TERMINOLOGY	
Mine seismology: Glossary of selected terms A.J. Mendecki	527
 AUTHOR’S INDEX	555