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Back analysis of a pillar monitoring experiment at 2.4 km depth in the Sudbury Basin, Canada

G. Walton [a,*], M. Diederichs [b], A. Punkkinen [c], J. Whitmore [c]

[a] Colorado School of Mines, Golden, USA
[b] Queen's University, Kingston, Canada
[c] Vale Ltd., Sudbury, Canada

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ABSTRACT

In November 2013, a pillar monitoring and back analysis experiment was initiated on the 7910 level of the Creighton Mine, in Sudbury, Canada. An extensometer array was installed horizontally through the pillar to allow zones of brittle spalling damage and dilatancy in the granitic rockmass to be identified. To aid in the interpretation of the in-situ data, laboratory data were analyzed and a calibrated three-dimensional finite-difference model of the mining area was developed. Based on an interpretation of the available data and models, it was determined that following the onset of yield, pillar cohesion degrades more rapidly than pillar frictional strength increases. The overall rockmass strength remains relatively unchanged, however, due to dilation-induced confining stress increases. As the primary dilatancy of the pillar begins to decay and the pillar walls expand, the confinement in the pillar drops. This is followed by an increase in the vertical load sustained by the pillar as the effects of mobilizing friction strength begins to dominate the rockmass behavior. The relationships demonstrated between dilatancy, strength evolution, and stress path, have significant implications for support design and understanding rockburst mechanisms.

1. Introduction

As part of mining operations in highly stressed ground, monitoring changes in rockmass behavior throughout the mining process provides important information to ground control personnel. In particular, the use of Multi-Point-Borehole-Extensometers (MPBXs) can allow for the estimation of depth of yield/fracturing and the assessment of the effects of mining-induced stress changes. The differences in rockmass movement throughout a pillar and over time can also be correlated with numerical modeling results to help develop and improve an understanding of stress conditions as well as rockmass strength and deformation parameters.

Over the past few decades, the global mining industry has seen a significant increase in the use of numerical modeling tools for geotechnical risk mapping and mine planning applications. One of the first uses of numerical modeling for mining applications was elastic stress analysis, a tool that remains in use today.[1–3] Plastic constitutive models (continuum) are applied in mining analysis, both to capture non-linear behavior with respect to stress redistribution and to directly model depth of yield.[4,5] Newer modeling approaches such as the synthetic rock mass (SRM) approach[6] and hybrid continuum/discontinuum [7,8] which are being developed also have potential applications in mining.

With recent advances in the modeling of brittle failure[9–12], the greatest degree of uncertainty with respect to non-linear continuum models for brittle rockmasses now lies in the post-yield domain. In particular, the relative proportions of shear and volumetric deformation post-yield (controlled by the dilation angle, ψ, for a Mohr–Coulomb constitutive model) can have a significant impact on the development of yield and ground movement patterns. Understanding and accurately modeling post-yield dilatancy can improve stress models, help predict ground displacements and support loads, and allow for a better understanding of strain burst mechanisms.

Although several different approaches exist for the treatment of post-yield dilatancy in rocks which involve a direct modification of the plastic potential function, more recently researchers have tended to define mobilized functions for ψ within a Mohr–Coulomb framework.[13–17] Of these dilation models, the method of Walton and Diederichs[17] is proposed as the most appropriate for the modeling of brittle dilatancy, given its ability to fit data for a wide range of rock types using a relatively small number of unique parameters. Also, its applicability to in-situ rockmasses has been demonstrated using several case studies.[17,18]

* Corresponding author.
E-mail address: gwalton@mines.edu (G. Walton).

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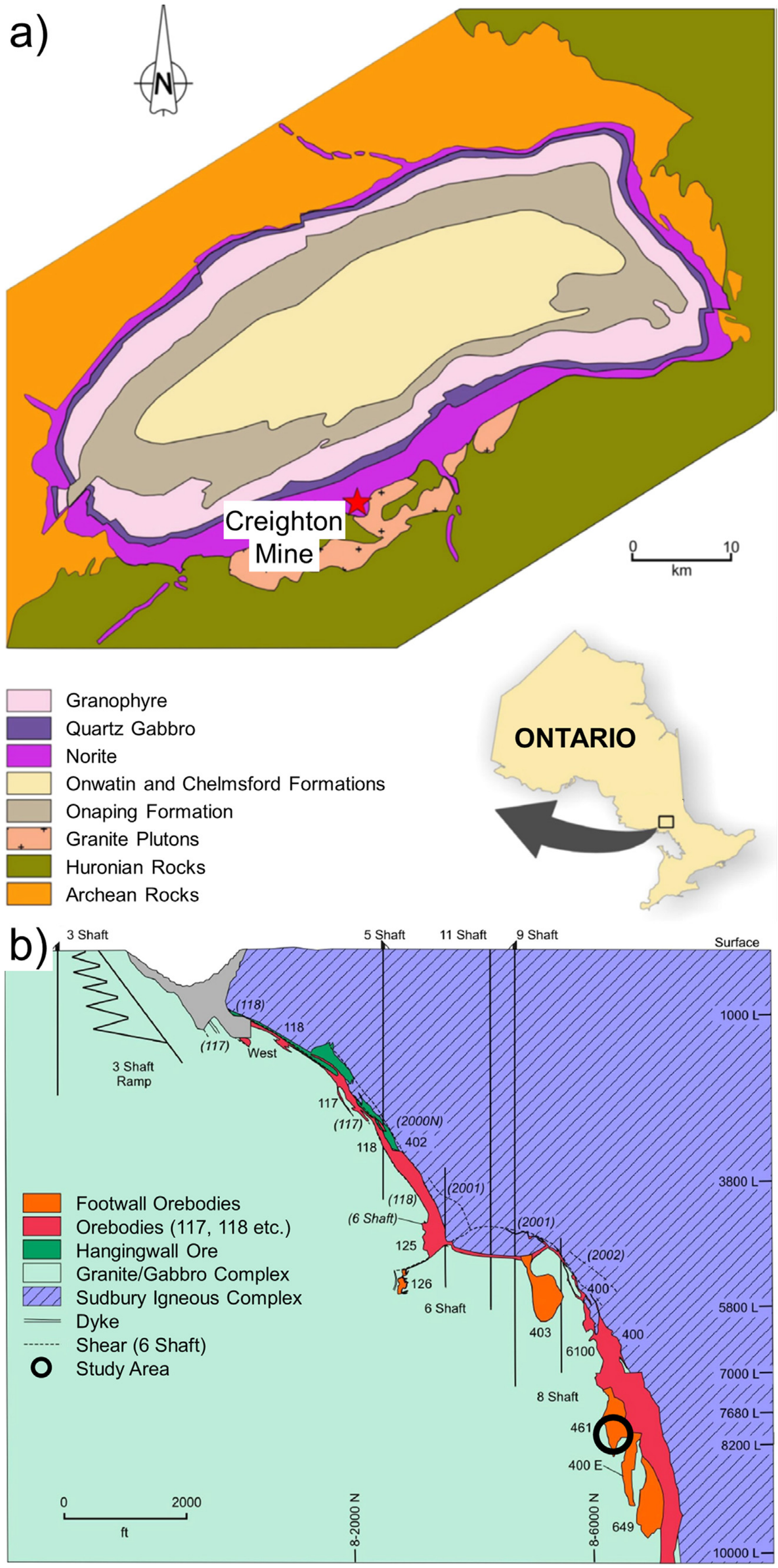

Fig. 1. (a) Geological setting of the Creighton Mine; (b) Simplified cross-section of the Creighton Mine geology (after[3]).