International Journal of Rock Mechanics & Mining Sciences 72 (2014) 173–181

Contents lists available at ScienceDirect

International Journal of
Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Stability of underground mine development intersections during the life of a mine plan

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ARTICLE INFO

Article history:
Received 25 February 2013
Received in revised form
26 August 2014
Accepted 6 September 2014

Keywords:
Mine developments
Underground mining
Deformation monitoring
Numerical modeling
Rock failure
Case study

ABSTRACT

The stability of mine developments is of utmost importance during the planned period of production or the life of a mine plan. Many Canadian underground mines use transverse stoping with delayed backfill to extract tabular ore deposits. These methods require access to the orebody through a number of sill drives and cross cuts which link the orezone to the haulage drift hence creating intersections on multiple levels. This paper presents the results of a study on the stability of mine development intersections at Garson Mine of Vale in Sudbury, ON, Canada. Multi-point borehole extensometers (MPBX) are used to monitor the rock deformations of an intersection as mining activities progress. The monitoring results are used to calibrate a multi-level FLAC3D numerical model, which has been developed to assess the stability of the intersection. It is shown that stope extraction causes a lateral shift to the intersection, accompanied by high shear stress in the roof. It is also shown that same-level mining has stronger influence on the stability of the intersection than lower-level mining.

1. Introduction

Transverse and longitudinal stoping with delayed backfill has been widely adopted by many Canadian metal mines such as Bosquet, Doyen, Laronde, and Lapa mines in Quebec and Garson, Creighton, Red lake and David bell mines in Ontario. In the transverse method, ore is accessed from upper and lower sills of the stope through cross cuts and a haulage drift; see Fig. 1a and b. Ore is broken up in a sequence of two or more blasts within a stope and the blasted ore is mucked from the lower sill or the draw point. Once mined out, the stope is backfilled. The longitudinal method uses two drifts (upper and lower) running along the strike through the orebody with fewer cross cuts, thus requiring less mine development. Stoping and backfilling are often practiced in longitudinal retreat; see Fig. 1c. Both transverse and longitudinal stoping methods are particularly suited for steeply dipping orebodies.

As the mine developments, such as haulage drifts and cross cuts, are the only access where loaders and/or trucks travel through, they must remain stable during their service life. The stability of mine developments may be influenced by many factors such as the strength and quality of the rockmass, mining depth and more importantly nearby mining activity (production blasts). Mine developments such as haulage drifts and cross cuts are more likely to be influenced by stope production blasts. As mines continue to reach deeper deposits, mine developments will experience higher pre-mining and induced stress conditions, thus suffering from more instability problems. The distance between the mine developments and the stopes is another important factor affecting their stability. It is known that there exists a trade-off between the drift stability favoring long distance and mining savings favoring short distance [1–6]. The distance between haulage drifts and nearest stopes depends on many factors such the quality of the rockmass, in situ stresses, mining depths, stope access geometry, geometry of the orebody and more importantly the hauling equipment (e.g., perhaps use material handling equipment). The quality of the rockmass in the underground mines in the Canadian Shield is moderate to strong (e.g., the Canadian Shield is composed of metamorphic and igneous Precambrian rocks). The length of mobile loading and hauling equipment used in Canadian mines can vary from 3 to 12 m depending on the thickness of the orebody and the rate of production (e.g., mucking machine 3–5 m

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http://dx.doi.org/10.1016/j.ijrmms.2014.09.002
1365-1609/

Nomenclature

c	Cohesion of the rockmass
γ	Unit weight of the rockmass
υ	Poisson's ratio
E	Modulus of of elasticity of the rockmass
ϕ	Friction angle of the rockmass
ψ	Dilation angle of the rockmass
σ_t	Tensile strength of the rockmass
K	horizontal-to-vertical stress ratio

and Scoop tram from 6 to 12 m). Zhang and Mitri [5] have reported that, the extent of yielding zones around haulage drift significantly increases as the distance to the orebody decreases.

Mining sequence is another important factor affecting the stability of haulage drifts and intersections. Different stope extraction sequences will result in different mining-induced stresses, which in turn will have varying influence on the stability of drifts and intersections. Other factors are the dip and thickness of orebody and the geometry of haulage drifts (e.g., shape and size) [2,4].

Mine development instability can result in production delays, loss of reserves, as well as damage to equipment, and injuries. High stress magnitudes which occur in hard rockmasses and soft or fractured rockmasses can lead to an unstable state of deformation (e.g., immense fracture of rockmass) around deep large excavations. It is important to properly use an efficient and timely ground support system to mitigate these instability issues due to stress redistribution and to provide safe access to mine openings. Also, it is imperative to implement the ground support systems in combination with conventional geomechanical instrumentations, e.g., microseismic monitoring systems, multi-point borehole extensometers (MPBX) and load cells [4,7,8].

2. Garson Mine geology

The Garson nickel–copper (Ni–Cu sulfides) mine is located in Greater Sudbury, ON, Canada. Fig. 2 presents plan view of a typical level (e.g., level 4900) of Garson Mine with all different geological units. Garson Mine comprises two orebodies, Fig. 2, namely the #1 Shear and #4 Shear that runs 76 m to the North of #1 Shear. The two orebodies have a strike length of about 610 m, dip about 70° to south and vary in size and shape. An Olivine Diabase Dyke crosses these two orebodies near the mid-span on the 5100 level. The dyke is steeply dipping to the south west and continues with depth. The footwall typically consists of Norite (NR) and Greenstone (GS) and the hanging wall consists of Metasediments (MTSD). The mine has essentially been in operation for 100 years and has produced 57.2 million tons containing an average grade of 1.33% copper and 1.62% nickel [9]. Both transverse and longitudinal stope mining methods are employed. The typical planned stope dimensions are $15 \times 12 \times 30$ m ($L \times W \times H$). The stopes are extracted in two or 3 blasts and then tight filled with a mixture

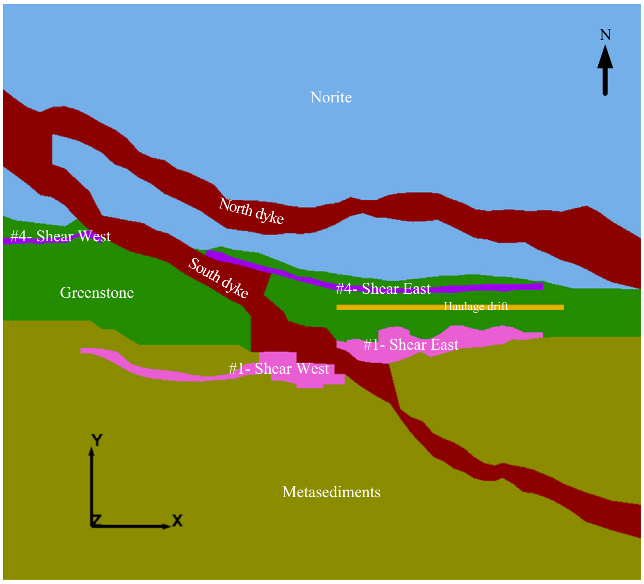

Fig. 2. Plan view of level 4900 showing the different geological units.

Table 1
Major rock types and their geomechanical classification [10].

Geological unit	Q' range	GSI range
Norite	11–33	70–80
Greenstone	5–17	65–75
South limb dyke	No observation	55–75 (estimated)
North limb dyke	20–50	90–100
Massive sulfide (ore)	30–38	65–75
Metasediment	0.4–2	20–35

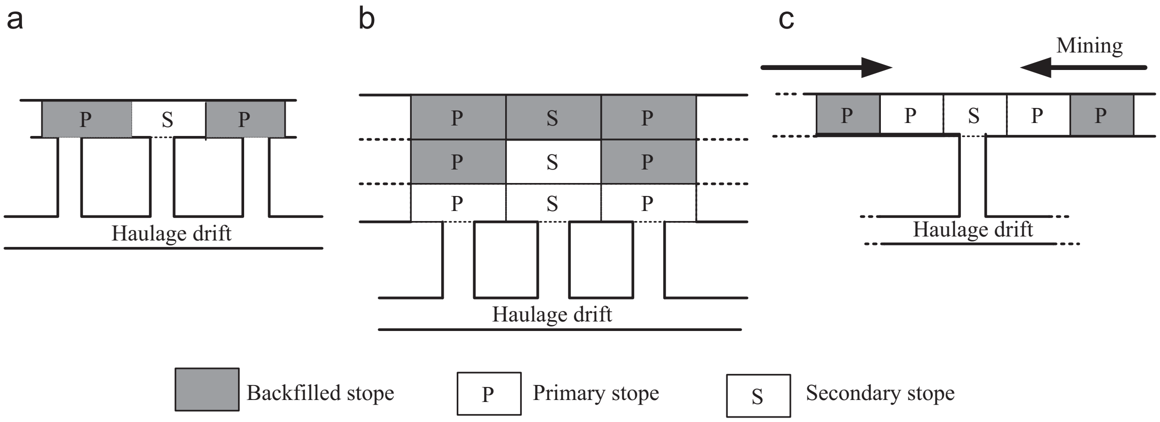

Fig. 1. Transverse and longitudinal stoping layout. (a) Transverse-tabular, (b) Transverse-wide and (c) Longitudinal.