

The influence of stress and geologic structures on mining-induced seismicity in the Creighton Mine, Sudbury, Ontario

Paige Snelling*

Department of Geological Sciences and Geological Engineering, Queen's University

Paige.Snelling@gmail.com

Laurent Godin

Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Ontario

Steve McKinnon

Department of Mining Engineering, Queen's University, Kingston, Ontario

Abstract

The Creighton Mine, near Sudbury, Ontario, is a structurally complex and seismically active mining environment. The mine records numerous microseismic events each day. Larger magnitude events occur less frequently but may increase risk to mine infrastructure, operations and workers. Seismic events that locate remote to mining and excavations have long been attributed to slip along a number of mine-scale shear zones. The role of these structures in generating seismicity has been called into question as the mine plans to extract ore at greater depth. Therefore a better understanding of the behaviour of geological features influenced by mining-induced stress will allow for the improvement of existing hazard mitigation measures that permit safe production underground.

A multi-faceted approach to understanding the relationships between geologic structures and mining-induced seismicity was employed, focusing on the deepest section of the mine, known as the *Creighton Deep*, between 2011 metres (6600 feet) and 2420 metres (7940 feet) below surface. Geologic investigations were conducted both underground and in the laboratory to characterize prominent shear zones and examine their kinematic relationships. A seismological analysis examined the seismic event parameters, event fault plane solutions and the relationships between failure mechanisms and stress. Lastly, numerical modelling was used to investigate the distribution of stress and yielding as well as fault sensitivity on the 7400-foot Level (2255 m).

Four families of shear zones were identified during field investigations, including a prominent family of shear zones striking SW and steeply dipping NW. Mine-scale structures are found to reflect the geometry of regional-scale structures and to share a similar tectonic heredity, exhibiting a strong reverse component of ductile paleo-displacement. Many of the shear zones were found to be healed with little evidence of brittle reactivation.

Seismic activity from 2006 and 2007 was analyzed. Spatial and temporal trends in seismicity do not show distinct correlation to shear zones, nor do seismic event parameters reflect shear zone geometry. Instead, microseismic event parameters correlate to spatial clusters of events. A remote cluster located to the southwest of the excavation exhibits anomalously high seismic

parameter values. This area of the mine continues to be a source of elevated seismicity. Migration of stress from mining on levels below is suggested as a source for such events. Fault plane solutions for macroseismic events are randomly oriented, rather than systematically aligned with shear zones. Fault plane solutions derived for microseismic events, however, share similar pressure, tension and null axes. This suggests slip occurs along preferentially-oriented fractures, yet, the resulting microseismic fault planes do not align with mapped shear zones. A stress inversion using microseismic focal mechanism information yields a stress tensor that is comparable with the regional stress tensor. Specific stress inversion for the cluster having elevated event parameters identifies an area subject to a rotation in the stress field.

Stresses were further explored for the 7400-foot Level using Universal Distinct Element Code numerical models. These models demonstrate that a yield zone exists immediately surrounding the excavation. SW-striking shear zones modify the stress field, resulting in increased stress to the southeast of the excavation. These high-stress zones are areas of preferred seismic activity. Localized slip is induced on select SW-striking shear zones to the south of the excavation as well as localized yielding.

The integration of geological, seismic and numerical modelling information suggests large events in the Creighton Deep are weakly-correlated with mine-scale shear zones. The characteristics and distribution of microseismic events suggest that these events reflect a degradation of the rock mass that results from excavation as the rock mass relaxes to a state of equilibrium. Although the results of this study do not identify a direct link between structure and seismicity, they highlight a need for improved fault classification to help identify potential slip surfaces and define the characteristics of seismically active structures in the subsurface.

Acknowledgements

The authors would like to acknowledge Vale Inco and Creighton Mine for financially supporting this study as well as the ESG Solutions for providing the necessary software.