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# TECHNICAL REVIEW OF THE NATIONAL WILDLIFE FEDERATION COMMENTS REGARDING KENNECOTT'S PROPOSED PROJECT TO CONSTRUCT AND OPERATE THE EAGLE MINE PROJECT

Prepared for:
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**Rock Mechanics, Rockburst Monitoring, Rockburst Control**

## EXECUTIVE SUMMARY

I have reviewed the reports submitted to NWF by Parker and Vitton (2006), Bjornerud (2007), and Vitton and Parker (2007). They all point out what they consider to be deficiencies with the KEMC Mining Permit Application and the backup Golder geotechnical work. And further, they conclude that a crown pillar over the Eagle Mine will not be stable. Previously, Itasca (Sainsbury, 2006a,b) had reviewed the stability of the crown pillar and reported deficiencies in the geotechnical studies, but concluded that an 87.5 m crown pillar would be stable, and that any further mining could not be carried out until a thorough underground geotechnical study were undertaken. Earlier this year I reviewed the Itasca, KEMC and Golder Reports and agreed with Itasca that an 87.5 m crown pillar would be stable, and that further underground geotechnical work was required (Blake, 2007).

The negative assessment of the stability of the crown pillar by Vitton and Parker is basically a result of the study Dr. Bjornerud carried out using the photos of the core boxes provided from a NWF request under the FOIA, and her surface inspection. In addition, the influence of the collapse to surface over the Athens Mine is also a big factor. Their concerns are real as any disruption of the surface or groundwater over the Eagle Mine would have very serious consequences. I share their concerns and I'm not pleased that the missing RMR data found in a few of the logged core holes were not all pointed out and satisfactorily explained by Golder. However, I do not agree with their conclusion that basically any crown pillar will be unstable.

I still conclude that the crown pillar is in fair to good rock and that an 87.5 m thick crown will be stable. It has not been established that the contact along the intrusive with the metasediments is a highly fractured zone, or that there are other direct water conduits to the crown pillar. The affect of the horizontal in situ stress on the stability of the crown pillar is still unknown – whether it acts to close or open joints or other structures, or has no affect.

I would also conclude that driving the access ramp will have no affect on the surface, and that the initial longitudinal mining at the bottom of the deposit will be carried out without any problems. Both Itasca and I have previously concluded that transverse longhole mining could be safely carried out up to the 327.5 m level. We also agreed that any mining above this level would require an extensive underground geotechnical investigation to delineate a stable crown pillar that took into account surface subsidence and hydrological affects. Hence, we endorsed the revised Mining Permit Application of KEMC.

I also recommend that the Phase 3 mining limit at the 327.5 m elevation remain in place, and that the previously endorsed underground geotechnical investigation, including in situ stress measurements, be carried out to establish a stable crown pillar that precludes adverse subsidence and/or hydrological affects.

This program should begin with in situ stress determinations carried out from the initial access openings at the bottom of the intrusive. The normal geologic, geotechnical and hydrological data would be collected from each of the sublevel access and panel openings as driven, and while panels were mined. Supplementary diamond drilling could also be carried out underground to fill in any gaps. This would allow a 3D physical model of the mine to be developed and maintained, as well as an accurate assessment of ground and hydrologic conditions, so that ground support requirements and the stability of the back/crown pillar were always maintained. Hence, by the time the 327.5 m elevation was reached, only a small amount of diamond drilling would be required to provide additional geologic, geotechnical and hydrologic data to supplement the 3D physical model. KEMC and their consultants would then be able to prepare and submit a thorough crown pillar stability document to the MDEQ in a timely manner. It should also be stated that any serious ground or ground water conditions encountered during mining up to the 327.5 m elevation would be a cause for great concern, would have to be reported to MDEQ. Any such stability or water problems would also have to be investigated and reviewed in order to allow mining to proceed.

While the issues and concerns raised by the NWF through Vitton, Parker and Bjornerud are legitimate, I still recommend that the revised Mining Permit Application of KEMC be approved.

## 1.0 INTRODUCTION AND BACKGROUND

In February of 2006 the Kennecott Eagle Minerals Company (KEMC) submitted an application to the Michigan Department of Environmental Quality (MDEQ) for a mining permit to construct and operate the Eagle Project Mine in Marquette County Michigan (Kennecott, 2006). This application relied on the geotechnical design study carried out by Golder Associates Ltd. (Golder, 2005). There were concerns about the stability of the crown pillar that was to be left above the mined out orebody, as well as any induced surface subsidence which could affect both the surface and ground water regimes. An additional study was carried out to address these issues (Golder, 2006a), but there were still concerns, and the MDEQ contracted the Itasca Consulting Group (Itasca) to review the stability of the crown pillar (Sainsbury, 2006a). Further geotechnical work (Golder, 2006b) concluded that an 87.5 m thick crown pillar would be stable, and further geotechnical work would be required to allow any mining above the corresponding 327.5 m level. Itasca reviewed this work and agreed with this conclusion (Sainsbury, 2006b). Apparently there were still some concern about the proposed mining of the Eagle Project Mine and the stability of the crown pillar, hence, I was contracted to review both the Golder and Itasca geotechnical studies, as well as the methodology utilized in their evaluations, and make recommendations to address any remaining questions relative to the issuance of a mining permit. I was also given photos of core boxes from 3 of the holes that intersected the crown pillar. I concluded that a Phase 3 mining limit at the 327.5 m elevation would result in an 87.5 m thick crown pillar that is stable, and further, that additional field investigations and data analysis had to be carried out to determine whether mining could take place above the Phase 3 mining limit leaving a smaller, but stable crown pillar that would preclude adverse subsidence and hydrological affects (Blake, 2007). I also recommended that the Mining Application Permit for the Eagle project be approved.

The National Wildlife Federation (NWF) still had concern regarding the stability of the crown pillar and disruption of the surface and groundwater, hence, contracted their own studies to evaluate the KEMC and MDEQ work and come to a conclusion regarding the crown pillar stability. This study was carried out by Dr. Stan Vitton and Jack Parker with the assistance of Dr. Marcia Bjornerud. They reviewed the geotechnical data available to the public in the mining permit application, and received photos of some of the core boxes from drill holes in the crown pillar, including RQD and RMR data in an EXCEL file, from a Freedom of Information Act Request. They concluded that the crown pillar would not be stable (Vitton and Parker, 2007). Previous technical reviews of the KEMC Application to Mine Permit were carried out by Jack Parker and Dr. Stan Vitton for the NWF (Parker and Vitton, 2006).

The MDEQ has contracted me to carry out a technical review of the NWF study and its conclusions.

## 2.0 REVIEW OF NWF STUDY OF MINING PERMIT APPLICATION FOR PROPOSED EAGLE PROJECT MINE

The opinion reached in the NFW study that the crown pillar would not be stable was based on a number of factors.

1) The RMR values used in the geotechnical studies to characterize the rockmass in the Eagle Project Mine were incorrect and overstated.

2) The proposed stope backfilling will not achieve a 'tight fill' status, hence not provide support to the crown pillar.

3) The permit did not take into account a "plug" type failure such as occurred at the Athens Mine some 23 miles away.

4) In situ stress measurements were not carried out in the exploration boreholes drilled at the site to determine the horizontal stress.

### 2.1 RMR Values

Rock mass classification systems, including RQD and RMR, were developed primarily to provide a means of determining ground support requirements for underground openings. Initial use of these parameters was in civil applications where little geological information was available, and expected ground conditions and support requirements had to be determined for contract excavation purposes. In general, mining companies have been slow to utilize these techniques in their operations. In recent years, lack of experienced mining or geotechnical engineers at most mining operations has led to greater use of rock mass classification systems to establish expected ground behavior and required ground support for both development and mining openings.

Cores from diamond drill holes for geological exploration of the Eagle ore body, as well as some additional holes for geotechnical purposes were logged by KEMC geologists and put into a data base. The geotechnical logging carried out by KEMC consisted of a determination of the A1-A5 parameters for each 3 m core run. These data were utilized by Golder (Golder, 2005) to develop a geotechnical data base from which charts and plots of RQD and $RMR_{76}$ parameters could be made for mine stability and design purposes. Crown pillar stability evaluations were based on the RQD and $RMR_{76}$ data from 26 boreholes that intersected the crown pillar. Eight holes were identified as containing 'major structures' Table 4 (Golder, 2006a). Photos of core boxes for these holes and their EXCEL data base were utilized by Vitton and Parker in their stability analysis of the crown pillar.

Dr. Marcia Bjornerud of Lawrence University logged these 8 cores and determined $RMR_{89}$ values for them. She did a very thorough job of core logging. She determined her own values for A3, A4 and A5, and utilized the A1 and A2 values (point load or compressive strength, and RQD) determined by KEMC. The RQD values determined by KEMC geologists were not based on the 8 cm scale shown on each core box. In addition, there were a number of sections along holes 60, 62 and 64 where the $RMR_{76}$ values were missing. This was caused by the way the Golder program calculated the RMR from the KEMC data base. Apparently when the RQD values were very low an RMR was not calculated. The missing RMR data occurred at the beginning of all these holes, as well as along a 30 m section of hole 62. Dr. Bjornerud characterized these missing sections as highly fractured metasediments and gave them very low $RMR_{89}$ values. The metasediments are adjacent to the crown pillar. The missing section along hole 62 was listed in Table 4 of the Golder 2006b report.

Comparison of the $RMR_{76}$ values determined by KEMC/Golder with the $RMR_{89}$ values determined by Dr. Bjornerud showed that KEMC/Golder values were always higher than hers. She reported the weighted average of $RMR_{76}$ for the 8 boreholes to be 68, and the weighted average of the $RMR_{89}$ for these same holes to be 51. This discrepancy is due to the different values used for the A3, A4 and A5 parameters. The KEMC geologists had the advantage of being able to physically pick up and anyalze core pieces, whereas Dr. Bjornerud could only view the photos. The KEMC geologists were also more aware of the fractures caused during core extraction, as well as during the handling and shipping of the cores to Marquette. While results of the core data analyses by Dr. Bjornerud are very different from those of the KEMC geologist, it should be remembered that they do this for a living on a daily basis, whereas her experience with respect to evaluating core and geological data for mining operations is unknown. While I don't do core logging or RMR calculations, I did review photos of core boxes for holes 46, 54 and 104, as well as the core photos shown in Vitton and Parker for holes 55 and 62. I judged all the cores in the photos I inspected to be in the fair to good range.

Vitton and Parker stated that the Permit Application gives an RMR for the crown pillar of 75 or 85 indicating 'good rock' to 'very good' rock, whereas the information they received for the 8 cores led to an overall weighted average RMR of 68, which indicates only 'fair' rock in the crown pillar, which would indicate a factor of safety of about 1.0. The RMR in the Permit Application used RMR data from all the available holes in the crown pillar, not just these 8 cores. The Golder (2006a,b) reports did point out that the structures identified in the crown pillar area were a cause for concern, and stated that the 'potential presence and nature of these structures should be determined as part of the planned underground drilling program prior to establishing the upper levels of the mine and the crown pillar'.

Vitton and Parker have concluded that essentially any crown pillar will not be stable based on their review of the core data and their evaluation of the mining plan. Both Sainsbury and I agreed that an 87.5 m crown pillar will be stable based on the data presented.

In my 35 years of consulting for mining companies all over the world, I have observed that the geological model of a deposit based on widely spaced diamond drill core data seldom accurately delineates the orebody or the continuity of the ore within it. In addition, I have observed that the rock surrounding underground openings, judged to be fair to good by rock mass classification or just visual evaluation of drill core data, is almost always found to better than predicted. Further, the exploration and geotechnical holes for the proposed Eagle Mine were not ideally positioned on surface due to access and environmental restrictions.

### 2.2 Stope Backfilling

Vitton and Parker point out that the proposed panel mining results in secondary stopes being mined against backfilled stopes, and that the cemented rock backfill will not be strong enough to remain stable as the secondary panels are mined. Panel mining using cemented rock backfill was successfully carried out to mine the 1100 orebody at Mt. Isa in Australia. It is obviously an operational problem to cement the backfill sufficiently so that it stands up during mining. Regarding the compaction of the backfill, the blasted muck onto it and the vibrations from the action of the scooptrams mucking out the panels will provide compaction.

It will be difficult to achieve a 'tight backfill' for final mined out panels using a cemented rockfill. However, this is routinely done in a large number of mines using paste fill and modified scooptrams that jam the fill tightly against the back. While this was not mentioned in the permit application it should be remembered that mining plans are continually tweaked to deal with changing conditions as mining progresses.

### 2.3 'Plug' Type Failures

Because of failure to the surface over the Athens Mine in Negaunee, Michigan, a great deal of concern has been expressed regarding a similar type failure occurring over the proposed Eagle Mine, located only 23 miles away. Vitton and Parker mention this in their report and point out similarities to the proposed Eagle Mine. While there may be some similarities there are also substantial differences.

The soft iron orebody at the Athens Mine was almost flatlying, some 500 ft wide by 1500 ft long and 250ft thick. Part of the orebody was intersected by two well defined and near vertical dikes that extended to the surface. Initial mining took place at the top of the lowest part of the orebody at the western end of the mine using a top-slice caving method. As mining slices continue downward the ground over it caves. Production mining started in 1918 and some 3,100,000 tons had been mined up until 1932. The surface cave over the orebody suddenly appeared on the morning of June 19, 1932 (Allen, 1933). This cave did not occur soon after mining, but took some 14 years to reach surface. The proposed sublevel longhole mining at Eagle is not a caving method.

The geology of the Marquette Iron Range is quite different from the geology at the Eagle Mine site. The Eagle Mine deposit is a massive sulfide type orebody that occurs more or less conformably in a vertically oriented intrusive oriented about east-west. The intrusive is up to 100m wide at the surface and narrows to some 10 m wide at the depth of the deepest drilling, some 340 m below surface. The strike length of the intrusive is some 480 m. The eastern part of the orebody is only mineralized up to the 250 m elevation, whereas the western portion is mineralized up to the 400 m elevation.

Major continuous structures were not identified during surface mapping and have not been identified from diamond drilling. While a lineament from Resolve EM studies projects a structure crossing the deposit at about a 45º degree angle, such a structure has not been identified by diamond drilling. Dr. Bjornerud observed a surface depression or lineament which she concluded would transmit water underground.

Based on a review of the photos for the 8 cores, Vitton and Parker reported that there were fracture zones along intrusive boundaries which could possibly act as a failure plane for the crown pillar. There is insufficient hard data to suggest that a "plug" type failure at the Eagle Mine is likely to occur.

## 2.4 In Situ Stresses

Vitton and Parker criticized the assumptions made regarding the in situ stresses for crown pillar stability analyses, and inferred such stress measurements could have been made from any of the available surface boreholes. In situ stress measurements utilizing existing surface boreholes are not routinely carried out by the mining industry. There have been a few such stress measurements carried out using hydrofracturing, but the results are generally neither reliable nor repeatable. In situ stress measurements were carried out at the nearby Mather B Mine in Ishpeming (Bickel, 1993) at a depth of 3200 ft. The maximum principal stress was determined to be some 3820 psi oriented at N 82º W, while the minimum principal stress was determined to be 2940 psi. These data would indicate that the horizontal stress is only 1.2 times the overburden stress and is oriented about parallel to the orebody at the Eagle Mine site. It is not likely that the in situ stress at the Mather B Mine can be related to the in situ stress at the Eagle Mine site.

It is agreed by everyone that in situ stress measurements need to be carried out at the Eagle Mine site for input into both mine and crown pillar stability analyses.

## 3.0 CONCLUSIONS AND RECOMMENDATIONS

I have reviewed the reports submitted to NWF by Parker and Vitton (2006), Bjornerud (2007), and Vitton and Parker (2007). They all point out what they consider to be deficiencies with the KEMC Mining Permit Application and the backup Golder geotechnical work. And further, they conclude that a crown pillar over the Eagle Mine will not be stable. Previously, Itasca (Sainsbury, 2006a,b) had reviewed the stability of the crown pillar and reported deficiencies in the geotechnical studies, but concluded that an 87.5 m crown pillar would be stable, and that any further mining could not be carried out until a thorough underground geotechnical study were undertaken. Earlier this year I reviewed the Itasca, KEMC and Golder Reports and agreed with Itasca that an 87.5 m crown pillar would be stable, and that further underground geotechnical work was required (Blake, 2007).

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While the issues and concerns raised by the NWF through Vitton, Parker and Bjornerud are legitimate, I still recommend that the revised Mining Permit Application of KEMC be approved.

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