CONCEPTUAL MINE DESIGN PROPOSALS FOR EXPLOITING LUNAR WATER ICE. Mr. A.M. Neale, B.Eng (Mining), Department of Mining Engineering, University of Pretoria in collaboration with VBKOM Consulting Engineers, Pretoria

Introduction

The results from NASA's Mini-Sar experiment on Chandrayaan-1 confirmed that there are large amounts of water ice at the lunar North Pole (NASA, 2010). If the ice can be mined, a sustainable human presence on the moon will be close within reach.

The author intends to do a master's study on the conceptual mine design of extracting lunar ice. This will be done by using the mine feasibility study techniques and processes used by VBKOM, a South African mining consulting company.

Two important aspects of the study will be discussed here: the modeling of the ice as an orebody and some possible mining layouts applicable to such an orebody.

The ice orebody

In the light of the new results from Mini-Sar (NASA, 2010 and Spudis, 2010), lunar ice formations can now be viewed and modeled as potential orebodies. The following can be used as a basis for geological block modeling, one of the first steps in mine conceptual mine designs:

Shape: Bowl shaped, one of three possibilities depending on whether a) the ice formation is heavily influenced by gravity and concentrates lower down the crater, b) the ice is stable only directly underneath permanent shadow or c) the overburden protects ice even in sunlight areas (see Figure 1).

Size: Depends on the host crater. Ice has been confirmed in craters 2-15km in diameter.

Thickness: At least 2m.

Grade: 90% water ice which may contain other volatiles.

Composition: Pure solid ice or snow-like; this will influence the geotechnical properties.

Dip: 30° on crater slope, relatively flat at crater bottom.

Overburden: Dry lunar regolith, tens of centimeters thick.

A preliminary block model has been created as is illustrated in Figure 2 and Figure 3. This block model can now be refined and used as a base for the conceptual mine design.

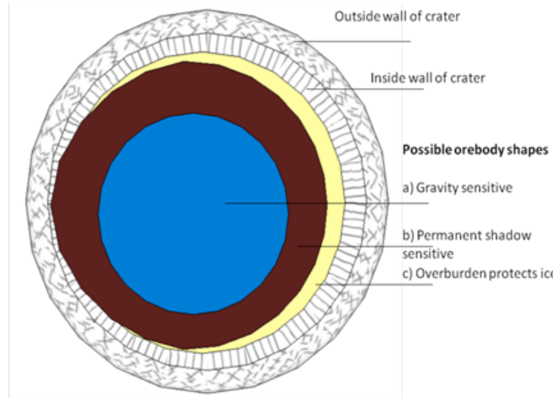

Figure 1: Possible shapes of ice orebody

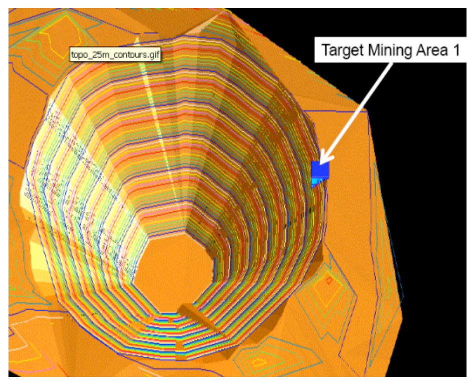

Figure 2: 3D model used for block modeling

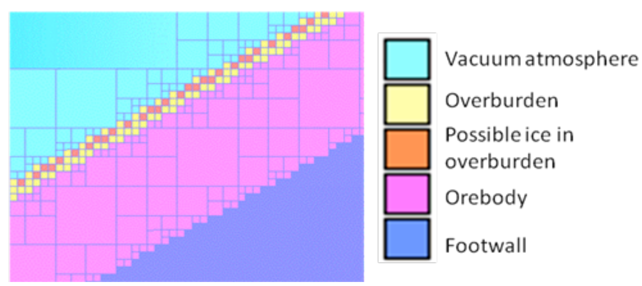

Figure 3: Example of geological block model section

Ice mining layouts

Gustafson and Rice (1999) said that at 1% ice there will be significant tradeoffs between processing ice in-situ and transporting the ore to a processor. At 90% ice, moving the ore looks more favourable than previously thought.

There are different proposals for transporting the ore, but they require equipment (Gustafson and Rice, 1999) and will have an expensive launch mass. If gravity transport can be successfully implemented in microgravity, the need for ore hauling equipment will be reduced and so will the payload launch cost.

A simple way of applying gravity transport to the lunar ice is shown in Figure 4. The ore is mined with any of the means proposed by Gustafson and Rice (1999). It then "flows" down slope to a stockpile. From the stockpile it is transported to the beneficiation plant either inside or outside the crater.

This simple method will not be effective on large areas as the broken ore will accelerate to hazardous velocities. Means to reduce the speed are required. Possible solutions can be found in the gravity transport techniques of Earth's underground mines.

One of the major ways of decelerating broken ore in underground mines is with "doglegged" ore-passes. Figure 5 shows how this principle can be applied on the ice orebody. The trenches provide means for the broken ore to flow downward into the main trench. The main trench might also have to be doglegged, but a winch type of transport system can be utilized if the processing is done outside the crater.

The sequencing will be important, since the intact ore used to reduce the speed will be removed at some stage. Two possible sequences are illustrated in Figure 5, the choice of which will depend on things like ice geotechnics, fragmentation method, and trench dimensions and angles. This method will work better if the ice is in solid form instead of snow-like.

Another form of gravity transport is caving. Here the ore is allowed to fall freely until it reaches the rest of the broken ore (Figure 6). Drawpoints are developed prior to caving to funnel the ore. Draw control is one of the most important factors in caving and this will still be the case. If the gap between in-situ and broken ore becomes too large, the high velocities will aggravate the risk of flyrock.

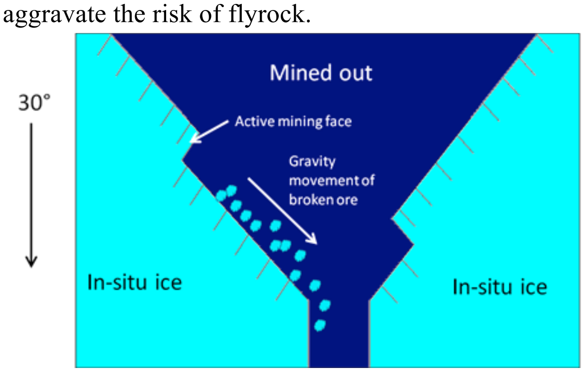

Figure 4: Simple gravity transport mining layout

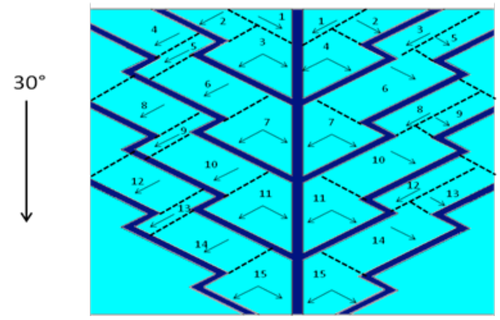

Figure 5: Mining layout applying ore-pass principles

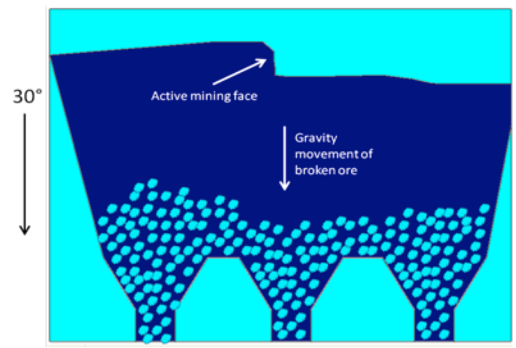

Figure 6: Mining layout applying caving principles

It must be remembered that although principles from underground mining methods are being considered, there are major differences in applying it. For example, since there is no hanging wall / roof, there is the risk of the broken ore flowing over the intact ore. There are some advantageous differences as well: men and material transport can take place on top of the reef and is not confined to tunnels.

Conclusion

The basis for geological block modeling of the lunar water ice as an orebody has been established and can now be refined. The planned mine feasibility study will compare different mining methods and layouts, three of which have been proposed in this study.

References

GUSTAFSON, R.J. and RICE, E.E. 1999. *Lunar Polar Ice: Methods for Mining this New Resource for Exploration* in Aerospace Sciences Meeting and Exhibit, 37th, Reno, NV, Jan. 11-14, 1999

NASA. 2010. *NASA Radar Finds Ice Deposits at Moon's North Pole.* Available at: http://www.nasa.gov/home/hqnews/2010/mar/HQ_10-055_moon_ice.html

SPUDIS, P. 2010. *Personal communication.*