

EXPLOITATION OF A MASSIVE LOW GRADE ZINC-LEAD RESOURCE AT ROSH PINAH ZINC CORPORATION, NAMIBIA

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ABSTRACT

Rosh Pinah Zinc Corporation (Pty) Ltd (RPZC) operates an underground mine at Rosh Pinah in southern Namibia producing zinc and lead sulphide concentrates. It currently mines around 0.7 Mtpa run-of-mine ore containing around 6-10% zinc and 1.5-3.5% lead. As part of past exploration and current intensified exploration, a massive continuous low grade ore body was identified which grades at around 3% zinc equivalent. This ore body is near current mining infrastructure and could be amenable to bulk mining methods. In the present paper a concept is presented on how it could be exploited.

As a precursor to exploitation of the low grade a number of enhancements are proposed for the current mining operations including:

- shortening load-and-haul distances by extending the conveyor raise further down the mine in a phased manner and back-filling of waste into mined-out stopes;
- use of mobile crushing plant at the crusher tip, and;
- installation of a system to allow scoops to load directly from stopes into ore passes close by combined with truck loops to haul from these ore passes to the crusher tip.

To exploit the low grade ore body the following concepts are proposed:

- open stope mining from two areas at a total rate of up to 2 Mtpa;
- underground pre-beneficiation of mined low-grade ore near the stopes using either dense medium separation or X-ray sorting;
- pre-beneficiated tails back-filled to mined-out stopes and;
- pre-beneficiated product transported to surface by linking into proposed run-of-mine conveying system.

INTRODUCTION

Rosh Pinah Zinc Corporation (Pty) Ltd (RPZC) operates an underground mine at Rosh Pinah in southern Namibia that produces zinc and lead sulphide concentrates containing minor amounts of copper, silver and gold. The sulphides are concentrated in a milling and flotation plant to respectively lead and zinc concentrates. Both concentrates are transported by road to the Aus rail heading. From there zinc concentrate is exported by rail to Zincor, a zinc smelter in Springs (South Africa) wholly-owned by Exxaro Resources Limited. The lead concentrate is railed to Walvis Bay (Namibia), where it is exported via the harbour and sold by metal traders on the international market.

CURRENT OPERATIONS AT ROSH PINAH

Rosh Pinah's geology and ore bodies

The Rosh Pinah ore deposit is hosted by a thick package of turbidites comprising, both hinterland and contemporaneous-volcanic, clastic provenance; which was deposited in a Neoproterozoic rift basin during the early part of the evolution of the Gariep Terrane of southern Namibia. Metals from a primary, Sedex-style, cherty/argillitic, exhalite ore were scavenged and concentrated by later hydrothermally-driven carbonatisation, providing a carbonate host to the bulk of the economic resource. Basin inversion led to oblique continental collision and complex deformation of the orebody, in two phases of disharmonic overfolding with associated faulting and shearing. The orebody is consequently presented as a series of discrete carbonate and exhalite bodies, generally in variably-plunging, second-phase fold hinges, connected by a partially attenuated exhalite-dominated ore-equivalent horizon.

Rosh Pinah orebody has not been effectively closed off by drilling due to the complexity of the structure; the orebody is presented as a series of discrete lenses, more of which may occur along the ore equivalent horizon to the north, south, east or west. The rough dimensions of the envelope containing currently defined ore pods are about 1800 m long from north to south, 700 m wide from east to west and 600 m deep at its thickest points.

Rosh Pinah's mining and concentrator operations

Rosh Pinah mine has been in continuous operation since 1969 (Alchin et al., 2005). The mine's orebodies are accessed via multiple declines. All mining is mechanised using drill rigs, loaders and dump trucks. Waste is hauled via declines to a surface waste dump. Ore is tipped into an ore pass feeding a grizzly and primary crusher and is subsequently conveyed to the surface plant. Mining is predominantly by sublevel open stoping, with a small section of the mine being stoped using a modified-room-and-pillar method due to flatter dip. Ore development level spacing for open stoping is between 15 m to 30 m depending on ore thickness with drive width dimensions of 6 m wide and 4m high. Blast holes for stoping are drilled from lower levels in a fan pattern using Atlas Copco Simba drill rigs. Slot raises for stopes are drilled using an ITH rig and are drop-raised where possible. Extraction of stopes starts on upper levels and proceeds down dip. On surface, run-of-mine ore is crushed to below 9 mm by secondary cone and tertiary gyratory crushing. Crushed ore is fed to a ball mill and three stage cyclones and milled to 80% minus 100 micron. Lead and zinc sulphide concentrates are consecutively floated using a combination of flotation bank, tank and column cells and a regrind mill circuit. Automated mill and flotation circuit controls were recently implemented. Since the first SAIMM base metals conferences RPZC has increased its production concentrate to around 120 ktpa zinc concentrate from 75 ktpa (Joubert et al., 2001; Diedericks et al., 2002), mainly due to mining of higher grade ore.

The purpose of this paper is to present concepts that are being considered to improve current operations and to exploit a massive low grade resource that has been discovered which is close to existing mining infrastructure.

CONCEPTS TO ENHANCE CURRENT MINING OPERATIONS

As a precursor to exploitation of the low grade ore body a number of enhancements to Rosh Pinah's current mining operations are proposed:

- shorten load-and-haul distances by extending the conveyor raise further down the mine in a phased manner and back-filling development waste into mined-out stopes rather than hauling to surface;
- use of mobile crushing plant at the crusher tip and;
- installation of an ore pass and truck loop system to allow scoops to load from the stopes directly into ore passes close to mining areas and the trucks to load from the ore pass and haul to the crusher tip.

As Rosh Pinah's mining production levels move deeper overall mining operating cost increases due to a larger haulage fleet required, necessitated by longer haulage distances to sustain production level; it consumes more fuel and also increases maintenance and ventilation requirements. A viable solution to this challenge is to move primary crushing and conveying facilities closer to the main production areas. This could be done in a staged manner as the mine develops deeper.

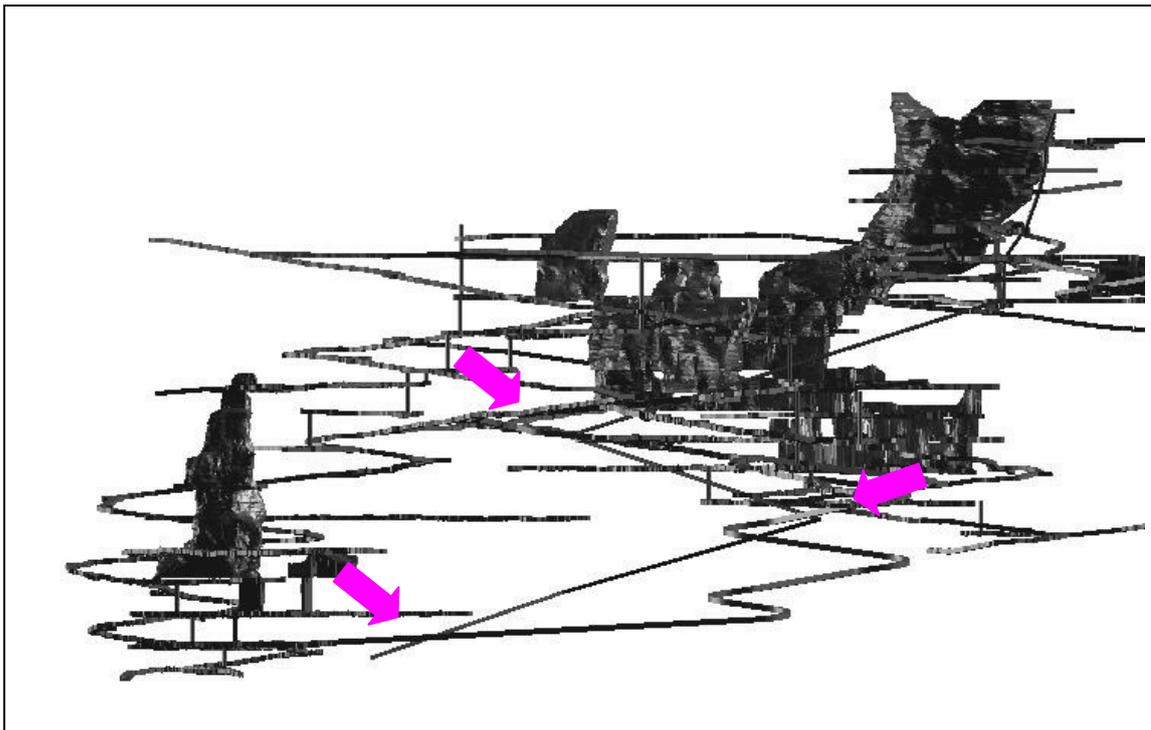


Figure 1. Decline trucking loop (indicated in blue) with three stages of conveyor raise development (indicated in red) and the mobile crusher in position (indicated by arrows) at the end of the respective stages of downward mine development.

The first stage of conveyor decline of around 400 m in length and 3 m by 3 m cross section could be developed downwards from the existing conveyor-primary crusher position towards the ore body. A further two decline stages could zigzag further down. The intermediate stage of around 250 m should be positioned to link up with a haul loop (proposed below) and the last stage of 400 m should end at a position close to the low grade ore body.

The conveyor decline could be constructed by developing from both ends. A mobile crusher can be installed at its lower level. This is shown in Figure 1. A further enhancement could be to install a suspended conveyor from the roof. These conveyors offer advantages of ease of installation and extension compared with conventional types and could even be considered to assist with removal of waste during the development of the conveyor raise.

Currently, all waste mined at Rosh Pinah (approximately 25% of total material handled) is hauled to surface and dumped onto a waste rock dump. Waste could be dumped into stoped-out areas resulting in shorter waste hauling cycles and more capacity available for ore haulage. An improvement in ore production could be as high as 15% in addition to an operating cost saving due to less waste haulage. The geology surrounding the stopes should be well defined, to ensure that the risk of resource/reserve sterilisation and the geotechnical risks associated (if any) is well quantified. Movable waste tip heads and lighting will have to be installed for stopes to be waste-filled. Both safety and cost need to be considered in the design of these tips; the tip head should be anchored to the stope sidewalls to prevent vehicles reversing into the stope void and the cab of the truck should always remain under supported ground.

The current mining method of up-hole benching is not as productive as the proposed Sub-Level Open Stopping method. This change in method will improve the economics of the stoped ore and also improve equipment productivities including charging, drill, loader and hauling fleets. The mining method will be large scale open stopping with extraction and drill levels to mine multi-lift stopes. The ore will be developed drilled, blasted then mucked with large loaders to central ore pass systems. The ore will then be loaded into the haulage fleet through chutes to be transported to the tip facility and into the crushing and conveying system to be transported to surface. A conceptual Sub-Level Open Stopping layout is shown in Figure 2. The advantages for this change include:

- Significantly less development;
- Larger diameter fan drilling production holes (higher tonnes for drilled/charged metre) resulting higher tonnage and a reduction in the number of blasts;
- Large tonnage - reduced number blasts;
- Remote mucking significantly reduced;
- Draw point loading improve truck and loader productivity;
- Concurrent mucking and charging operations;
- Ore pass stockpiling of ore;
- Chute loading of trucks (reduced loading times);
- Better truck fill factor due to no oversize material, which has been screened out by the grizzly;
- Better ability to handle oversize material and;
- Improved safety for charging and mucking operations.

Potential disadvantages for this change includes:

- The increase of planned mining dilution;
- The decrease of reserve extraction.

Some infrastructure and equipment purchases and modifications are needed for the proposed enhancements. The capital cost is estimated at around US\$ 11 million yielding operational cost savings of up to US\$ 4.5 million per year indicating an attractive return.

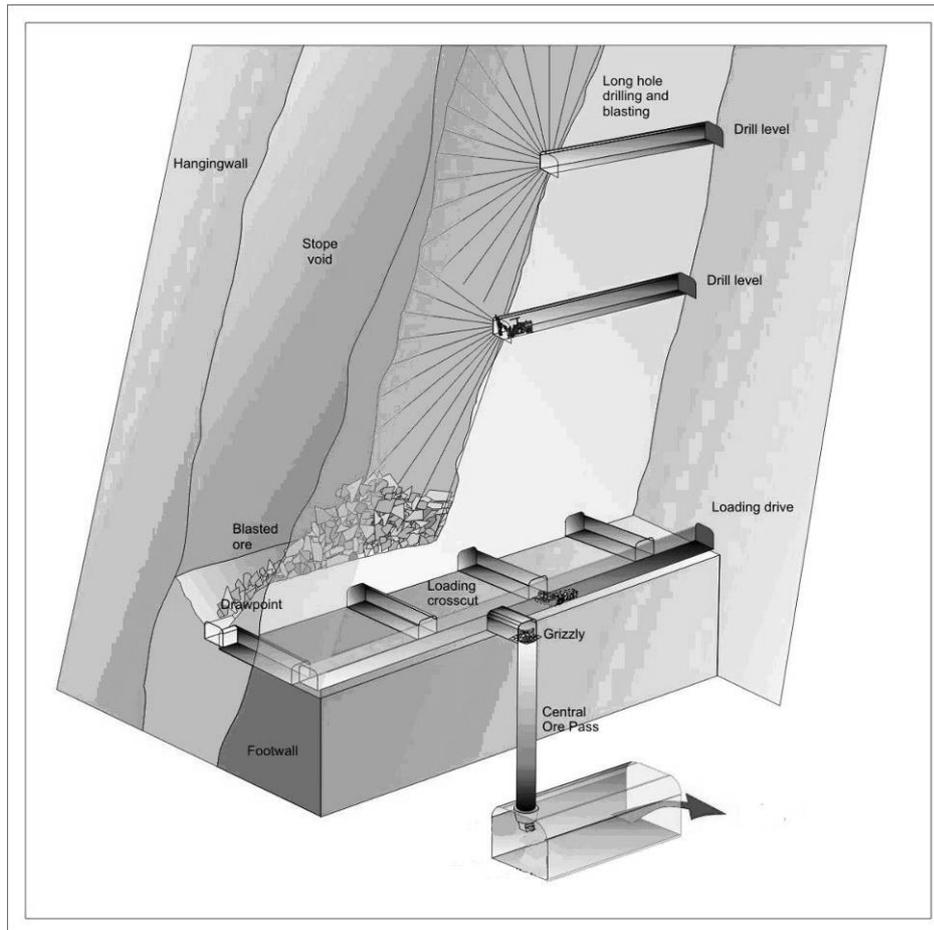


Figure 2. Schematic Sub-Level Open Stopping layout.

CONCEPTS TO EXPLOIT MASSIVE LOW GRADE ORE BODY

To exploit the low grade ore body the following concepts are proposed:

- open stope mining from two areas at a rate of up to 2 Mtpa with pre-beneficiated low grade ore tails back-filled to mined-out stopes, and;
- underground pre-beneficiation of mined low-grade ore near the stopes using either dense medium separation or X-ray sorting.

It is intended that the exploitation of the low grade ore body will occur concurrently with sustained operation for the normal mining areas at reduced rates.

Low grade orebody geology, mineralogy and preliminary mineral resource estimate

During past exploration for Rosh Pinah's Western Orefield 1 (WF1), Western Orefield 2 (WF2) and Southern Orefield 3 (SF3) sporadic mineralized footwall lithology was intersected. These intersections were of low grade and not of economic interest at that time. With recent intensified exploration to delineate Western Orefield 4 (WF4) and deeper portions of SF3 more drill holes intersected the low grade mineralised footwall arkose.

The low grade mineralization occurs in a thick package of arkose (up to 250 m) representing the footwall to the Western Ore Fields and Southern Ore Field 3. It extends over a strike length of about 750 m with a thickness varying between a few meters to up to 130 m with an average of 30 to 40 m. The inclination of the preliminary interpreted body is about 70 to 80°

SE. Sporadic mineralization occurs in brecciated and silicified portions of this arkose. Brecciation is not observed throughout the unit and the genesis of the brecciation is still not well understood. The sulphide mineralization is of remobilised nature and occurs mainly in the fractures of the breccia or as accumulation horizons of varying thickness. The thicknesses of the mineralized horizons vary between a few millimetres to several tens of centimetres, with mineralization semi-massive to massive in places and consisting mainly of brown sphalerite, galena and pyrite. Pyrrhotite and chalcopyrite occur occasionally.

Macroscopically the arkose is light coloured and has an irregularly banded texture which is produced by alternating sulphide-rich (pyrite/sphalerite) and sulphide-poor bands. In places the leucocratic bands are soft and carbonate-rich and are mainly of dolomitic composition. Arkosic interbeds occur throughout the succession. The carbonate silicate ratio varies from highly brecciated and silicified rock to softer more carbonate rich rock. Some intervals have slightly magnetic patches due to disseminated pyrrhotite.

Texturally the ore reflects the characteristics of a typical metamorphosed deposit displaying coarse grain sizes and good liberation qualities. There are however minor textural features that are detrimental to good ore recovery such as the very fine grain size of sphalerite, galena and chalcopyrite associated with chalcopyrite disease, as well as inclusions in pyrite, granulation and alteration due to fracturing and interstitial web-like distribution of galena between silicate and carbonate gangue. The total effect of these textures will have a minimal influence on overall base metal sulphide recovery but will provide zinc-lead anomalies in pyrite tails and lead anomalies in the zinc concentrates.

To assist with preliminary studies a number of samples were taken from the low grade ore body. These included:

- drill core samples taken at 1.5m intervals over the mineralized zone, and at 1.5m “waste samples” taken on either side of the mineralised zone;
- a 10 ton sample of boulder-size rock taken across the whole thickness of the low grade ore body from a well understood and explored area.
- Two samples of one ton each of boulder-size rock of respectively well mineralized carbonate ore and mineralized microquartzite ore.

The bulk samples were used for preliminary tests on crushing, screening and separation by dense medium and X-ray sorting.

A preliminary mineral resource of the low grade body was estimated as outlined below. Firstly, the low grade areas were viewed within the existing geological model and drilling data. It became obvious that low grade material was associated and in some cases encompassed by higher grade material, some of which was in the current mining reserves. With this in mind, a geological model was constructed and run incorporating all the associated material, both low and higher grade material to give the mineral resource given in Figure 3. Next the mining cut-off grade (COG) was estimated based on mining, milling and concentration costs and recoveries and a net smelter return based on zinc price, treatment charges and cost of sales. An overall COG of 3.0% zinc was determined with the incremental COG 1.5%. This gave 15.3 million ton ore at a weighted average grade of 3.0% zinc and 1.95% lead.

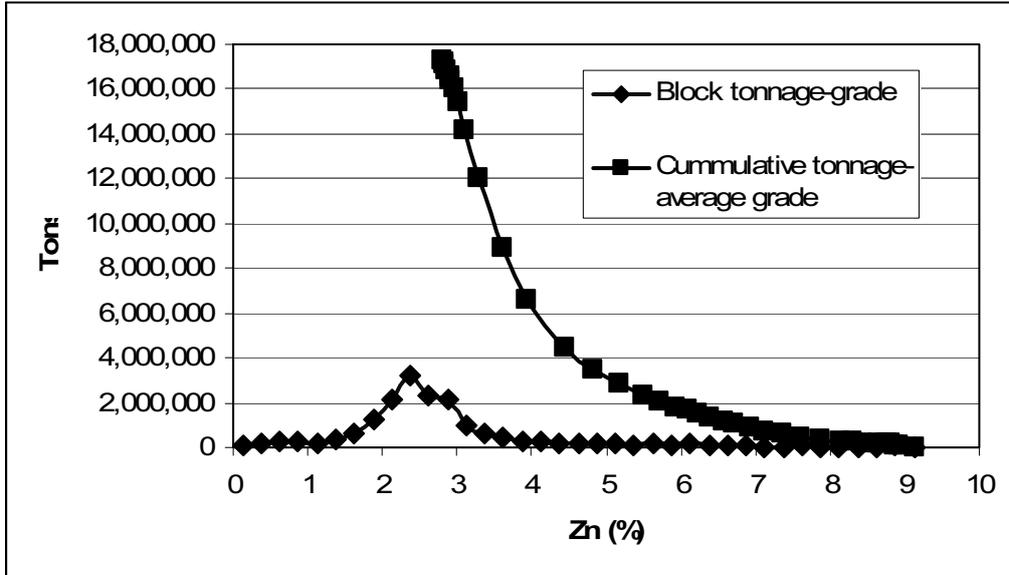


Figure 3. Low grade ore body tonnage-grade distribution and cumulative tonnage and weighted average grade curves.

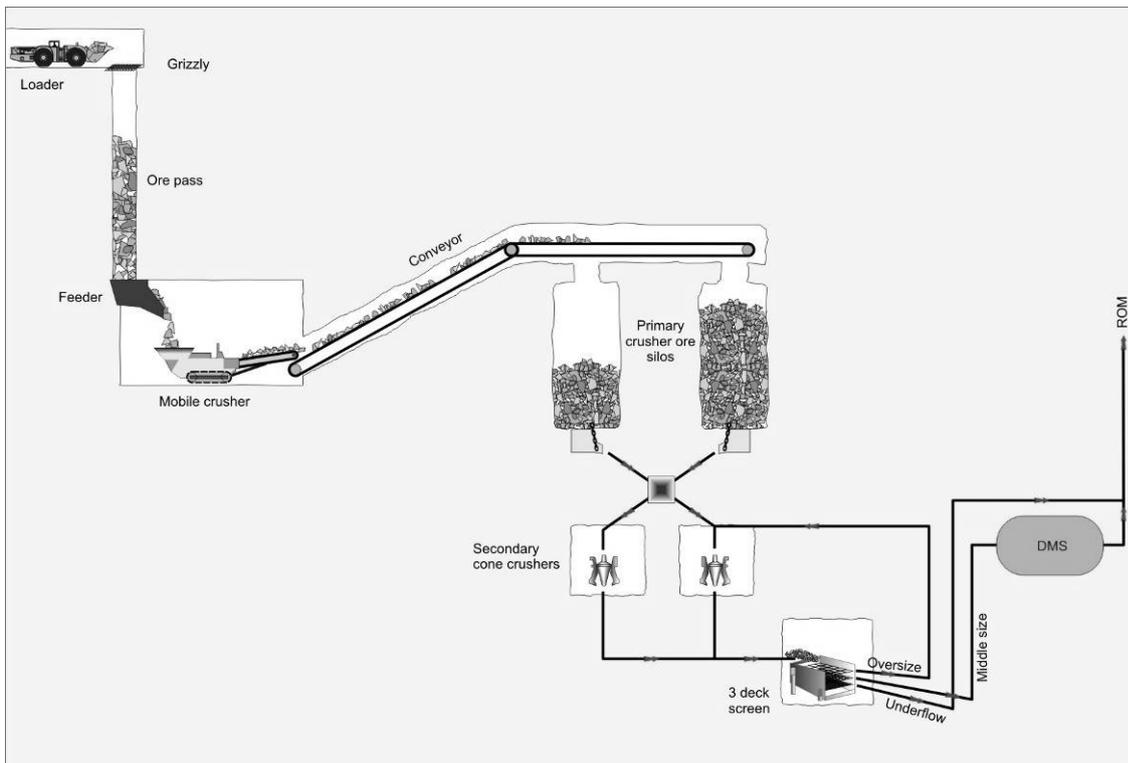


Figure 4. Conceptual layout of primary and secondary crushing

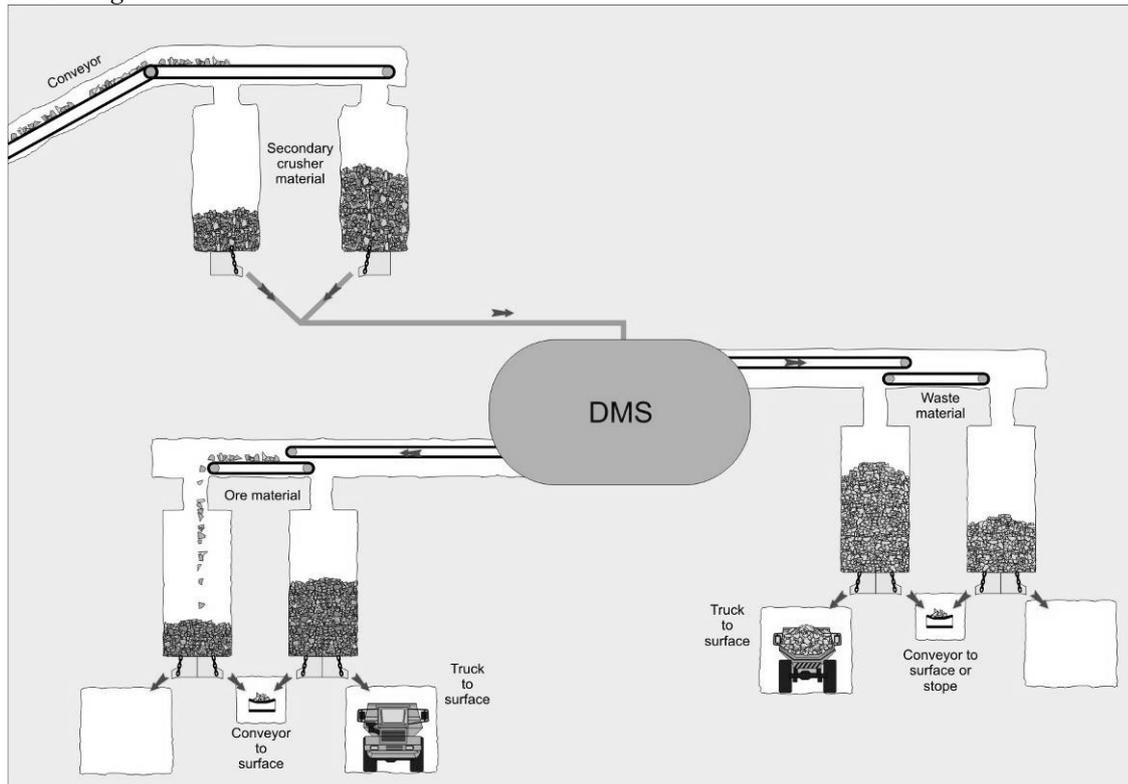


Figure 5. Conceptual layout around underground DMS plant

Mining and underground pre-beneficiation

The form of the low grade deposit is an envelope, in which higher grade ore is surrounded by the lower grade ore. Current mining operations are in its vicinity and it can be accessed with relative ease from the existing development of the high grade core. The most viable mining method is open stoping with waste rock fill, as proposed above for the current operations but at a larger scale (Figure 2). Conceptual stopes are proposed of the magnitude 100 m high, 100 m long and 50 m wide to determine the mining and economical parameters. The ore will be mucked with 18 to 20 t scoops to central ore pass systems.

The ore will then be crushed. Mobile primary and secondary crushers are proposed for the low grade ore application because they will have to be moved as the mining horizon and location change over time (Figure 4). Other advantages of mobile units include: they are compact and low profile so that large well-supported excavations are not required and they are designed for rapid setup and start up. Secondary crushing and screening can be situated with the DMS plant. The crushed and screened ore is transported to the underground DMS plant for pre-beneficiation (Figure 5). The pre-beneficiated product will be transported to surface. The pre-beneficiated waste material will be transported back into existing stoped out areas. Mining at a rate of 2 Mtpa will be on a much larger scale than currently practice, increasing economies of scale. In addition, successful pre-beneficiation with back-filling of around 1.4 Mtpa of pre-beneficiated waste should limit the handling cost of this material compared with hauling it all to surface.

Rosh Pinah investigated pre-beneficiation of its run-of-mine ore in the late 1990s. The study indicated that the ores were amenable to dense medium separation. Ore samples from the low grade ore body was tested in 2006. These results replicated the previous run-of-mine ore test work thereby confirming the potential to apply dense medium separation (DMS) technology.

DMS of the low grade ore could potentially upgrade ore crushed to within the range of 32 to 16 mm from a feed grade of 3% zinc to a pre-beneficiated product grade of 9% zinc (which is similar to Rosh Pinah's normal run-of-mine ore grade) at a density of 2.85 at a zinc recovery of around 90% and mass yield of 30%.

X-ray sorting is also being considered for underground pre-beneficiation as an alternative to DMS. X-ray sorting has matured with the information age and it potentially could sort high volumes of ore in the particle size range considered so far for DMS in the present study. It has the advantage over DMS that it does not require water or any medium make-up and medium recovery circuits. Preliminary X-ray sorting test work was undertaken and gave promising results. Further work is currently underway.

The exploitation of the low grade ore body was evaluated at scoping level and found attractive. A pre-feasibility study is currently underway.

CONCLUSION

A number of concepts have been developed for the enhancement of Rosh Pinah's current mining operations and the exploitation of its massive low grade ore body. These concepts are being developed further for potential future implementation.

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REFERENCES

Alchin, D.J. and Moore, J.M., 2005. A review of the Pan-African, Neoproterozoic Rosh Pinah Zn-Pb deposit, southwestern Namibia. *South African Journal of Geology*, Volume 108, Number 1, p71-86.

Diedericks, A.W., Fouche, P.A.P. and Badenhorst, S.N., 2002. A systems approach in implementing Minerals Resource Management at a base metal mine (Rosh Pinah Zinc Corporation, Namibia). In: *SAIMM Conference: Recovery of base metals in Southern Africa – "mine to metal"*, 16-18 Jul, Sun City (South Africa).

Joubert, J., Plaskitt, M., du Plessis, M., van Wyngaard, J. and van Wyngaard, H., 2001. Zinc and lead mineral processing improvements at the Rosh Pinah concentrator. In: *SAIMM Copper, cobalt, nickel and zinc recovery conference*, 16-18 Jul, Victoria Falls (Zimbabwe).

