REPORT R105/2013

NEW TECHNOLOGICAL APPLICATIONS IN DEEP-LEVEL GOLD MINING

DIRECTORATE: MINERAL ECONOMICS

mineral resources

Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

REPORT R105/2013

NEW TECHNOLOGICAL APPLICATIONS IN DEEP - LEVEL GOLD MINING

DIRECTORATE: MINERAL ECONOMICS

Compiled by: Pieter Perold
(Pieter.perold@dmr.gov.za)

Cover picture sourced from Google Images: Gold-mining

Issued by and obtainable from
The Director: Mineral Economics, Trevenna Campus,
70 Meintjies Street, Arcadia, Pretoria 0001, Private Bag X59, Arcadia 0001
Telephone (012) 444-3743, Telefax (012) 444-3134
Website: http://www.dmr.gov.za

DEPARTMENT OF MINERAL RESOURCES

Director-General	Dr. T Ramontja

MINERAL POLICY AND PROMOTION BRANCH

Deputy Director-General	Mr. M Mabuza

MINERAL PROMOTION CHIEF DIRECTORATE

Chief Director	Ms. S Mohale

DIRECTORATE: MINERAL ECONOMICS

Director	Mr. T R Masetlana
Deputy Director: Precious Metals and Minerals and Ferrous Minerals	Ms. L Malebo

ISBN: 978-0-621-42192-7

ABSTRACT

South Africa holds the world's largest gold reserves and is host to the globe's deepest mines. However, gold production in South Africa has been on a decline, since the early 70's, despite the country's leading innovative deep-level mining for decades. While current mining methods remain relevant in deep-level mining, low grade (g/t), power supply challenges and mine accidents are increasingly placing new emphasis on alternative and complimentary ways to access gold in South Africa. In 2011, South Africa ranked as the world's 6th largest producer. South African gold mines should explore new technology and establish improved types of mining ventures to access the reserves through mechanized technology. Major innovators such as the Council for Scientific and Industrial Research (CSIR) have expanded research in underground robotic technology, to access reserves that were previously inaccessible. Underground robots are small and practical, have the potential to increase production as well as safety in mines owing to their access to deep-level narrow deposits. This report is intended to investigate current mining methods and the utilisation of this new technology in the gold mining industry in South Africa.

TABLE OF CONTENTS

TABLES

ILLUSTRATIONS

ABBREVIATIONS AND SYMBOLS

$ - US Dollar
£ - Pounds Sterling
g/t - gram per ton
Kg - kilogram
kt - kiloton
Mt - megaton (million tons)
n.a - not available
R - Rand (RSA currency)
t - Metric ton
cm - centimetres
SAMREC - South African Code for Reporting of Exploration Results

1. INTRODUCTION

Gold mining in South Africa is mainly deep-level orientated and characterised by hard-rock mining at very high temperatures, as high as 55 degrees Celsius. Although South Africa is still a world leader in a host of mining equipment and products, there is an atmosphere of great excitement about promising new technology that could make deep underground mining possible and prolong the life of South Africa' gold mines. AngloGold Ashanti's Mponeng mine extends to about 4 kilometres underground, positioning it as the worlds deepest mine. Thus, a new technology would be required to mine much deeper levels. Although traditional mining that is currently utilised, includes excellent methods for deep-level mining, current mining technology leaves much to be desired. Current technology allows only minimum face advance of around 25 metres per month at deeper levels, while usual mining obstacles such as heat, rock bursts, erratic grades and narrow stopes increase.

New technology could greatly assist in improving many hurdles faced today by the gold sector. In addition, this technology would undoubtedly increase operational advancements of major and/or hopefully smaller producers of gold in South Africa. This report is intended to investigate current mining methods in South Africa and the utilisation of new technology in order to access reserves. For the purposes of this report, an analysis of mining methods and possible future technological applications will be examined. The report is also intended to examine the impact of new technology on safety in deep-level mining. It is hoped that this report will generate interest in the capability of new technology and its application in the gold mining industry.

2. MINING METHODS IN SOUTH AFRICA

Mining methods in South Africa, although advanced, have remained largely unchanged for the past ten decades, with the same methods of blast and re-entry still being used in gold mines. Early mining methods involved mining of outcropped reef surfaces of the Wits Basin. As the Wits Basin down dips, mining has become deeper to access gold reserves. There are currently five mining methods that are being utilised in South Africa, namely cut and fill, drift and fill, shrinkage and stoping, room and pillar mining and finally bulk mining methods, such as block mining. In line with these mining methods, the normal drill and blast method is utilised. After a blast, miners still use a jack-legg drill and blast again to gain access to gold, after which the ore-containing gold is transported by means of a scaling bar to the surface. Many of the ore-containing tubular ore bodies are less than 1.5 meters thick, making access difficult. The development of the technical capacity to mine deep-level gold bearing ore bodies has seen South Africa become a world leader in deep-level mining technology until recently.

As depths increase, extensive mining methods, technology and exploration will have to be utilised to gain access to gold reserves. The new vision by many major companies is that the deep-level mines are already mining at these deep levels, so deepening these mines further will increase the life of mine and cost competitiveness. Major producers are also involved in developing new technologies and mining methods, such as increasing mechanisation (with fewer people at the rock face), which will have an application in all deep-level mining. In South Africa, ambitious new mining projects are ultra-deep mines with shafts deeper than 3.5 km, where temperatures rise beyond 55 degrees Celsius and, rock bursts are common under these strenuous circumstances. These mining conditions pose many other challenges relating to logistics to get gold and waste to the surface.

2.1 Types of Mining Methods

- *Cut and Fill*: This is a method of short-hole mining used in steeply dipping or irregular ore zones, in particular where the hanging wall limits the use of long-hole methods. The ore is mined in horizontal or slightly inclined slices, and then filled with waste rock, sand or tailings. Either fill option may be consolidated with concrete, or left unconsolidated. Cut and fill mining is an expensive but selective method, with low ore loss and dilution.

- *Drift and Fill*: The method is similar to cut and fill except, it is used in ore zones which are wider than the method of drifting will allow to be mined. In this case, the first drift is developed in the ore, and is backfilled using consolidated fill. The second drift is driven adjacent to the first drift. This carries on until the ore zone is mined out to its full width, at which time the second cut is started atop of the first cut. The drift-and-fill method is being utilised at a major producer. Production is highly mechanised, using long-hole stoping where reef widths allow this, and either cut-and-fill or long-hole stoping in narrow reef areas. Broken ore is handled using remote-controlled Sandvik load-haul-dump machines. Drift-and-fill mining is used in flat-lying reef areas. The depth of the orebodies means that all the stoping areas must first be de-stressed by developing conventional narrow-reef stopes above them and, once extracted, all stopes are backfilled using cemented mill-tailings.

- *Shrinkage and Stoping*: Shrinkage stoping is a short-hole mining method which is suitable for steeply dipping ore bodies. The method is similar to cut and fill mining with the exception that after being blasted, broken ore is left in the stope where it is used to support the surrounding rock as a platform from which to work. Only enough ore is removed from the stope to allow for drilling and blasting the next slice. The stope is emptied when all of the ore has been blasted. Although it is very selective and allows for low dilution, since most of the ore stays in the stope until mining is completed there is a delayed return on capital employed. Shrinkage and stoping is also used in AngloGold's Mponeng mine.

- *Room and Pillar mining* : Room and pillar mining is commonly done in flat or gently dipping bedded ore bodies. Pillars are left in place in a regular pattern while the rooms are mined out. In many room and pillar mines, the pillars are taken out starting at the furthest point from the stope access, allowing the roof to collapse and fill in the stope. This allows for greater recovery as less ore is left behind in the pillars.

- *Block caving*: Block caving is used to mine massive steeply dipping ore bodies, typically low grade with high friability. An undercut with haulage access is driven under the ore body, with "draw bells" excavated between the top of the haulage level and the bottom of the undercut. The draw bells serve as a point for caving rock to fall into. The ore body is drilled and blasted above the undercut and the ore is removed via the haulage access. Due to the friability of the ore body, the ore above the first blast caves and falls into the draw bells. As ore is removed from the drawbells, the ore body caves in, providing a steady stream of ore. If caving stops and removal of ore from the draw bells continues, a large void may form resulting in the potential for a sudden and massive collapse and potentially catastrophic windblast throughout the mine. Ore bodies that do not cave readily are sometimes preconditioned by hydraulic fracturing, blasting or by a combination of both. Hydraulic fracturing has been applied to preconditioning strong roof rock over coal long wall panels and to inducing caving in both coal and hard rock mines.

3. SOUTH AFRICA'S GOLD RESERVES

Deep underground mines found within the Wits Basin are engineering marvels, yet the cyclical nature of the drill and blast method is rife with inefficiencies, especially in very deep mines. The Witwatersrand Basin from which 95 percent of South Africa's gold has been produced remains a vast ore body, even to present-day. Table 1 illustrates the aggregated estimated reserves and resources of South Africa's major gold producers by analysing 2010/2011 figures. South Africa's mineable reserves total some 2 843 tons (t) with the likelihood of having a resource base of approximately 8 767.73 t (Table 1). It is evident that South Africa still has a vast amount of gold resource, especially in the Wits Basin.

TABLE 1: RESERVES AND RESOURCES OF MAJOR PRODUCERS

ANNUAL REPORT (2010)	RESERVES# (t)	RESOURCES# (t)
AngloGold Ashanti	944.81	3 044.94
DRDGold	227.19	1 866.99
Gold Fields	303.4	1 318.1
Harmony	1 368.4	2 537.7
Total	**2 843.8**	**8 767.73**

#Reserves and Resources estimation as per Annual Report (2010/2011)

According to South African Code for Reporting of Exploration Results (SAMREC 2011), it is always necessary to include reserves and resources when reporting production as a good resource base gives an indication that there is always gold available for later extraction when economic circumstances and technological conditions change. Reserves are mineable gold that can be extracted economically at current gold prices and inclusive of cost to company expenses. A resource base estimation is the estimated amount of gold that is still available, but not extracted due to technological, economic innovations and legislative constraints.

As gold mining becomes deeper and more expensive, the industry could supplement traditional mining methods (mentioned in section 2) with new technology and mining methods to access reserves and increase blast ratios. The future deep-level mining will largely depend on new technological innovations to make extraction much cheaper and safer. New mining methods and technologies could be utilised to mine deeper, extract a greater yield (g/t) and improve safety in mines. New technologies have an added advantage since they may be used in existing as well as decommissioned mines. Most mines in the Wits Basin were closed over time as a result of inability of the mine to yield sufficient operating margins, a combination of the fluctuating gold price, low yield (g/t) and the economic climate. However, these mines, although currently flooded, may be re-commissioned and further exploited by small machines (robots).

How can new technology assist in countering South Africa's production decline and improve safety? The CSIR may have the answer!

4. NEW TECHNOLOGY AND DEVELOPMENTS IN GOLD MINING

Small machines (Robots) that are currently under development by the CSIR are practical, small and measure less than 30 centimetres in diameter (Figure 1). These machines employ gas sensors, camera and scanners already in circulation, and are intrinsically safe, capable of mapping deep-level mining areas. 3D mapping is another important data-source collection used by robots. Robotic mining sensors have the ability to make a positive contribution to all spheres of deep-level gold mining. These sensors will enable autonomy, mapping, decision making and could potentially enhance current mining methods. These machines will be able to perform dangerous work and will continuously work without fail. In addition, they have the ability to increase reserves by extracting gold in narrow stopes of up to 50 centimetres in diameter, for example. Drill and blast cyclical mining will also be reduced or eliminated altogether and most importantly, fatalities will be curbed, reducing safety stoppages, saving valuable lives as well as improving production levels.

Figure 1: Underground Robot

Source: *Google*

The majority of fatalities in South Africa’s deep-level gold and platinum mining are a direct result of underground mining activities. Workers are mainly injured as a result of fall of ground (FOG) accidents. These types of accidents occur mainly as a result of seismic events, improper identification of unsafe areas, especially after the entry examination. In South African hard-rock mines, best practice dictates that the hanging-walls be inspected after blasting. This process is known as ‘making safe’ and although intended to save lives, it is laborious and subjective. The making safe process may be improved in various ways through improved technology and automation. Automation will not only enhance the process, but save lives by gathering data after a blast, thereby making it safer for employees to enter hazardous areas, especially at deeper levels. The automated process is not expected to hamper large scale employment levels, as it will only be utilised in very dangerous areas, exiting mines and narrow stopes. This will allow for mining operations to improve turnaround times after a blast, while improving the safety of employees after a blast.

Gold mining will immensely benefit from advanced software that has already been developed and applied in other industries, such as defense and aerospace. These systems may even be connected to companies’ intranet systems, making environmental impacts of decisions clearer. Examples of already existing 3D visualizations packages are Extreme and Smartmine. These packages offer very good solutions for medium term planning and pit design. In addition, complementary software focuses on sophisticated planning methods.

5. CONCLUSIONS

South Africa's gold industry is in dire need of technological innovations in order to slow down the continuous decline in gold production. South Africa was the world's largest gold producer, when it was overtaken by countries like China, Australia, U.S.A, Russia and Peru, positioning South Africa as the 6th producer in 2011. The turnaround-strategy and future of sustainable gold mining in SA will most likely begin with the research and funding of new technology, as well as how this technology could be combined with better working conditions and productivity. Robots have many other applications and could also create risk maps for coming shifts in a deep-level gold mine, reducing fatalities and cutting unnecessary stoppages. The benefits of other spheres of technology, such as new and improved computer technology will undoubtedly have a positive impact on South Africa's gold production outlook, especially if used in combination with other technologies. New and improved technological applications in the mining industry will improve safety and better working conditions for employees.

Small machines (robots) have applications in existing as well as decommissioned mines and, could be used as an additional tool in a "future mine" model. The new technology will ensure improved production levels and productivity in the gold mines as well as platinum mines. This technology could prove to be even more beneficial in these P.G.M mines, as grades have been proven to be more stable and evenly distributed than gold grades, which has shown to be erratic in some mines. However, it might impact on employment levels underground. Due to the deep levels associated with gold and platinum mining in SA, this type of technology is required to access the reserves. This reduces the number of workers required due to mechanisation that is necessary for the sustainability of the gold industry. The technology will also result in safer working conditions and job satisfaction of employees.

New technology is likely to help access previously inaccessible deposits, extend lifetime of mine and save jobs. However, this might impact negatively on employment in deeper levels. In contrast, general employment levels are likely to rise in downstream value addition as effects on employment is expected to be beneficial as a result of higher supplies made available to the sector. The level of contribution of the sector to the country's Gross Domestic Product (GDP) is likely to rise and help with the realisation of Government Policy objectives, including promotion of investment and further industrialisation of the economy, consistent with the New Growth Path (NGP) and National Development Plan (NDP)

6. REFERENCES

1. Anglogold Ashanti Limited 2010 Annual report
2. Central Rand Gold Limited 2010 Annual report
3. CSIR 2010, 2011
4. Data available from ten years of historical Department of Mineral and Energy (DMR).
5. DRD Gold Limited 2011 Annual report
6. Eastern Goldfields Inc 2010 Annual report
7. Fields Limited 2011 Annual report
8. Goldplat PLC 2011 Annual report
9. GSSA 2010 - 2013
10. Harmony Gold Mining Company Limited 2011 Annual report
11. Klapwijk P, Walker P, et al, 2011. Gold Survey 2009: GFMS Ltd, London, 121 pp
12. Lonmin Plc 2011 Annual report
13. Mineral Commodity Summaries, 2001 – 2010; and
14. Miningweekly, November 4 - 10
15. Miningmx, September, October 2012
16. Mintails Limited 2011 Annual report
17. Mr. J Green (CSIR), CARs & FOF 2011, 26 – 28 July, Kuala Lumpur, Malaysia
18. Pan African Resources PLC 2011 Annual report
19. South Africa's Mineral Industry, 2003 – 2011'
20. United Sates Geological Survey